Application of Mobile-Based Augmented Reality Technology Concepts in Interactive Learning Systems for Liquefaction Phenomena for the Deaf

Bonifacius Vicky Indriyono[1*], Natalinda Pamungkas[2], Iqlima Zahari[3], Yuni Lestari[4], Imelda Dimentieva[5]

[1,2,3,4,5]*Information Systems, Dian Nuswantoro University, Indonesia*

[1]bonifacius.vicky.indriyono@dsn.dinus.ac.id (*)

[2,3][natalinda.pamungkas, iqlima.zahari]@dsn.dinus.ac.id

[4,5][612202200074, 612202200069]@mhs.dinus.ac.id

Abstract— One of the natural disasters currently happening in Indonesia is an earthquake. An earthquake is a condition where the earth shakes due to volcanic activity and collisions due to the movement of the earth's plates. Earthquake activity causes many problems. One of them is liquefaction. Liquefaction is an event that indicates a loss of soil shear strength due to an increase in pore water pressure. This occurs because the earthquake load occurs so quickly and briefly. Liquefaction is an illustration of the effect of an earthquake so that the soil layer loses its strength. The public rarely knows the phenomenon of earthquakes and liquefaction. Not many people know how the process of the movement of the earth is the forerunner of earthquakes, especially people with hearing impairments. They could only feel an earthquake. Therefore, there is a need for education that can be conveyed to the public. Educational techniques in the virtual form will be a special attraction for people, especially people who are deaf or hard of hearing. Augmented Reality (AR) technology is a technology where virtual objects and real objects are combined. The AR is used to create virtual and interactive learning media. This study produced an application as a learning media that utilizes AR technology with the Marker Based Tracking method. The technology was developed using the MDLC (Multimedia Development Life Cycle) method for the learning media to be more interactive. The results of the tests concluded that the application could be used as an interactive learning medium to increase knowledge about earthquakes and the effects of liquefaction on the community.

Keywords— Earthquake, Liquefaction, Augmented Reality, Marker Based Tracking, Multimedia Development Life Cycle.

I. INTRODUCTION

Recently, Indonesia has experienced many natural disasters. One of the frequent natural disasters is an earthquake. An earthquake is a condition where the earth vibrates due to volcanic activity and collisions due to the movement of the earth's plates. The phenomenon of earthquakes is related to the movement of slow waves, which eventually make the rocks that make up the layers of the earth penetrate [1]. Earthquakes are original vibrations that originate from within the earth and then move to the earth's surface. An earthquake is an event that releases a certain amount of energy in the rocks of the earth's crust. One of the energies released is wave energy, known as seismic waves [2].

Earthquake activity causes many problems. One of them is liquefaction. Liquefaction events generally occur in granular soil layers where this soil has a large volume of water. The increase in water pressure in the pores is triggered by the effects of earthquake vibrations which cause soil particles to contract very quickly and are not drained [3]. Liquefaction is changing soil from a solid form filled with water in an undrained state to the soil in a liquid form due to cyclic loading [4]. This cyclic load is caused by the propagation of earthquake shear waves so that the pore water pressure increases. This liquefaction will occur if the pore water pressure has the same level as the effective soil pressure. Liquidification can be measured in a region by analyzing the correlation between soil depth and soil effective stress [5]. The phenomenon of earthquakes and their impact in the form of liquefaction is still rarely known by the public. The movement of the earth due to volcanic activity and the movement of the earth's plates which are the forerunners of earthquakes is not widely known by the wider community, especially people with hearing loss. They can only feel earthquakes without having extensive knowledge of how earthquakes occur. One of the reasons for their limited knowledge is the lack of learning about earthquake phenomena and their consequences.

For this reason, education needs to be conveyed to the community. The current trend in society is virtual learning. This virtual learning will also make hearing-impaired people feel helped. Educational techniques in the virtual form will be a special attraction for people, especially deaf people. One technology that is now widely used to create virtual and interactive learning media is Augmented Reality (AR). AR is defined as a technology where the real and virtual worlds are combined into one, interactive from the real world side, and designed in a three-dimensional animation model [6]. According to [7], AR is a technology that merges the virtual and real worlds. This merger aims to provide information about whose data is taken from a system on real objects. AR technology can correlate between the real world and the virtual world. Any information can be added so that the information is real-time, as if the information is interactive and real. AR technology has been widely developed in various fields, especially education. One of the uses of AR is to create interactive learning media to convey and socialize certain information.

The research conducted this time aims to build an interactive learning media software application based on AR

technology about the phenomenon of liquefaction specifically for the deaf. The main reason is that deaf people cannot receive information properly through the sense of hearing, so the process of liquefaction phenomena needs to be presented through an interesting visual display. This application is made using the Marker Based Tracking technique. The application is developed using the Multimedia Development Life Cycle (MDLC) technique for this learning media to be more interactive.

The basic idea of using AR technology in this study is because AR has interesting characteristics, including can combine the virtual world with the virtual world, being more interactive in real-time, and allowing it to be displayed in 3D. AR technology can simulate abstract things in 3D or 2D so that they look real so that learning using learning media can be more effective. In addition, AR technology can enter certain information into the virtual world and display this information in the real world with the help of equipment such as webcams, computers, Android smartphones, and special glasses. This learning media application contains animated 3-dimensional objects that describe and tell about the occurrence of earthquakes which cause liquefaction phenomena. The application is designed to be more interactive to provide understanding and knowledge for people, especially the deaf, about earthquakes and their impacts.

Previous studies have widely discussed the development of learning media by utilizing AR technology. A journal entitled AR as Learning Media for Recognizing ASEAN Landmarks Based on Android Using the Marker-Based Tracking Method explains using AR with 3D animation effects to introduce landmarks for ASEAN countries. The results of the test conclude that media that presents information in the form of 3D objects using the AR concept can be more interactive and fun [8]. The AR concept can also be applied in the application of interactive learning media for human excretion systems for school students so that students can understand and apply the application properly [9]. AR technology can also be applied in the cultural field. In research on the use of AR to visualize cultural heritage objects, it was explained that through the characteristics of AR, which include objects in 3D, interactive and real-time, AR could be used as a means of developing interactive technology to serve as a medium for introducing cultural heritage objects to society [10].

AR technology can be built using Vuforia and Unity 3D software to produce interactive, fun, easy-to-use learning media. Other research discussing the use of Unity 3D and Vuforia to build interactive learning media explained that image-shaped patterns in Unity 3D and Vuforia software can be implemented properly in AR applications [12]. AR technology can be utilized for various fields of activity, from social, educational, and other fields. The maximum use of AR can help humans in various fields of activity [13].

II. RESEARCH METHODOLOGY

According to [14], the research methodology is a technique that can be studied scientifically to obtain data to support research activities or other purposes.

A. Research Methods

The process of implementing this research is described in the flowchart of research activities. The research activity flowchart describes the stages that are passed, from carrying out the research to the process of developing research results. The stages of implementing research activities are in Fig.1.
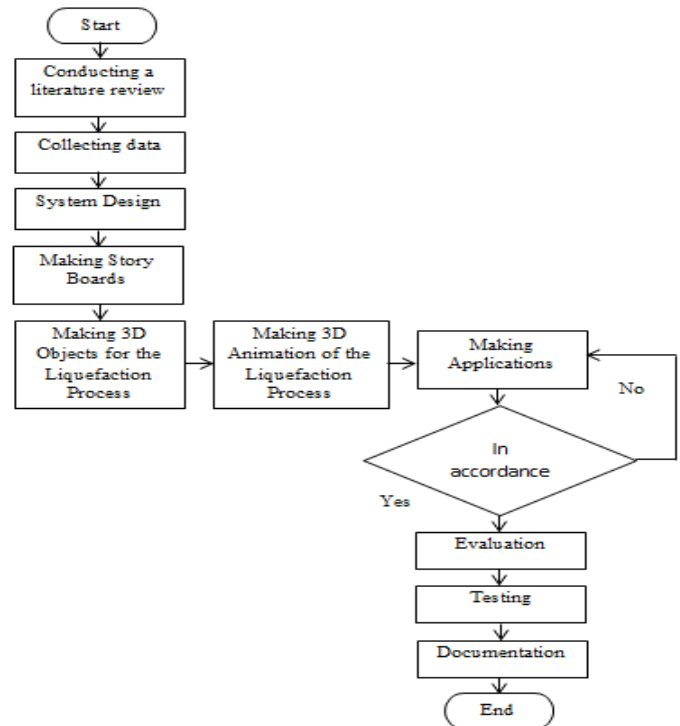

Figure 1. Research Method

From Figure 1, it can be explained the stages of the research as follows:

1) *Conducting a literature review:* At this early stage, the research team collected several references in the form of journals, proceedings, books, and other articles that support the writing of the research topics being carried out.

2) *Collecting data:* The next step is to collect data after the literature review stage. The data used for the implementation of the research are several examples of building drawings, the earthquake process, and the effects that occur.

3) *System Design:* The system design stage is the stage that is carried out to transform the data that has been collected into a system design before being implemented into the application. The design of this system is structured to describe how to build learning media applications that show the process of earthquakes and liquefaction.

4) *Making Story Boards:* The next stage is to create scenarios for running applications which will later be used as a benchmark in building learning media applications.

5) *Making 3D Objects for the Liquefaction Process:* At this stage, the research team began to create 3D objects for the liquefaction process. The 3D model is designed to achieve the

goal of making interactive learning media. The manufacturing process starts from the initial symptoms of liquefaction until the process takes place.

6) Making 3D Animation of the Liquefaction Process: The use of animation is required to make the use of this learning media more exciting. At this point, the 3D objects of the liquefaction process that have been created are integrated into animation effects to make the process of liquefaction a more engaging experience overall.

7) Making Applications: At this stage, the research team began making applications in learning media. The application contains a series of 3D objects and their animations from each process of the liquefaction phenomenon.

8) Evaluation: Evaluating is done so that flaws in the system or program being constructed can be discovered and quick adjustments can be implemented to accomplish the desired aims.

9) Testing: This testing phase is testing part-by-section in the learning media that has been made. The test also aims to discover deficiencies in each learning media part.

10) Documentation: This stage is the final stage, where the entire series of research activities is documented in the form of a research report.

B. Collecting Data Method

The data collection method is defined as a method used by researchers to obtain useful data for the research being conducted. This data collection method is more directed at the primary data in the form of interviews or observations and secondary in the form of literature studies through books, journals, and proceedings [15]. In this study, the research data collection method was obtained by the following procedure:

1) Literature Study: Done by reading and studying books and articles related to the concept of AR and its application.

2) Discussion: At this stage, discussions were held by the research team and parties who understood the topic of discussion to obtain supporting materials for conducting this research.

3) Collect supporting data. This supporting data is in the form of examples of 3D images of liquefaction objects, houses, poles, and examples of making object animations.

C. Definition of Multimedia

Multimedia is often associated with computer-based learning activities (CBL). This is because the multimedia application is closely related to using other computer devices that can display various forms, such as animation, audio video, text, images, and other forms [16]. According to [17], multimedia is a learning tool that combines many media elements presented via a computer. In education, the solution to making the learning atmosphere comforTable, not monotonous, and for students to easily learn the material presented is to use interactive multimedia. Multimedia is defined as a combination of many media in the form of files in the form of text, images, graphics, audio video, animation, and so on, which have been packaged in such a way as to become computerized files [18]. According to [19], multimedia has a combined meaning between two input or output media. This media's form can be audio, video, animation, graphics, text, or images. Multimedia is a medium that can create dynamic and interactive presentations with a combination of text, graphics, animation, audio, and video [20].

Based on several definitions of multimedia, it can be concluded that interactive multimedia combines some media in file formats in text, images, graphics, audio, video, animation, and so on. Some of the benefits or advantages of using interactive multimedia in the learning process, among others [21] :

- The learning system becomes more innovative and interactive.
- Teaching staff are required to be more creative
- Capable of combining many types of media, including images, text, music, animation, audio, and video, into a single entity in which the different components complement one another and help achieve interactive learning objectives.
- Increase students' interest in learning to achieve comfortable and enjoyable learning objectives.
- Material seen as highly challenging to comprehend can be represented pictorially to facilitate better comprehension of the information sent to students.

D. Definition of Augmented Reality(AR)

AR is a media often used to build fun interactive learning systems. Many people consider AR technology to be able to increase students' motivation and enthusiasm for learning. Setyawan [22] argues that AR is a technology in which the real and virtual worlds are combined and interactive according to the real world and in the form of three-dimensional animation. According to [23] AR means a technological advance in which AR can combine virtual world objects into the real world environment in two and three dimensions.

AR combines virtual world objects and the real world created by a computer system. These virtual objects can be in text, animation, 3D models, or videos combined with real-world objects so that users feel virtual objects in their environment. AR is a fun new method because users can interact with computer systems. AR technology can bring objects in the virtual world into the real world to provide a real visualization experience to its users [24].

This AR technology can insert certain information through cyberspace and present that information back into the real world using hardware intermediaries such as computers, cell phones, cameras, and special glasses. In the real world, people cannot detect and identify virtual world objects with the naked eye, so a computer and camera set are needed to insert virtual objects into the real-world environment. Some of the techniques available in AR include:

1) Marker-Based Tracking: This technique was originally developed around the 1980s, while development for AR began

around the early 1990s. The image of this technique is in the form of a black-and-white rectangle with a white background and a thick black border. The computer will detect a marker at coordinates (0,0,0) and recognize the three coordinate axes (X, Y, and Z).

2) Markless AR: This method is one of several methods in AR that are starting to feel its development. The advantage of this method is to display digital elements so that a marker is no longer needed. Users can use the equipment to create mobile device-based AR provided by Qualcomm.

E. 3D Animation Theory

Animation creates a motion effect, or shape change effect that lasts for some time. Animation can also be defined as a way of displaying sequential images so that the viewer can feel an illustration of movement in the displayed image [25].

3D animation is animation in the form of a 3-dimensional object even though it can be said that it is not in the original 3D form or is not a 3D object that can be felt and touched by its physical form. 3D objects here are 3D in 2D screen media such as television, computers, and other media. In addition to having 2-dimensional and 3-dimensional properties, 3D animation also has depth. The difference with 2D is that 2D animation is flat, while 3D animation has volume. It can be concluded that 3D animation can be seen from several points of view [26].

Several steps that can be taken to create a 3D animation effect include determining the concept of the story and making storyboards, and taking pictures divided into several parts, including rigging, modeling, and animation. In order for 3D animation to work properly, all parts of the work process must be interconnected. This work process is known as the pipeline in Figure 2.
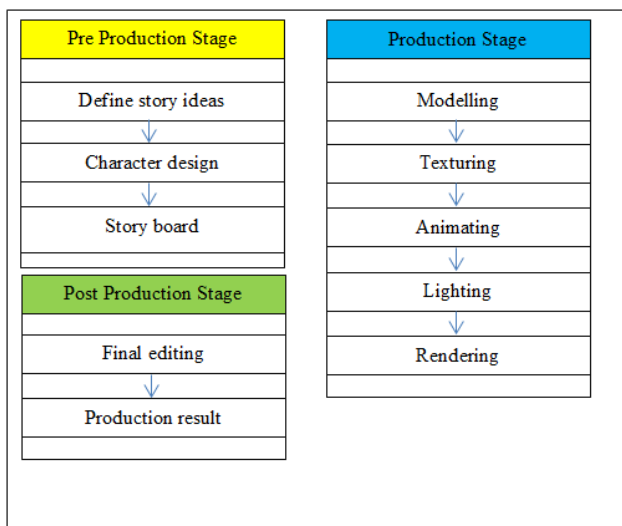

Figure 2. Stage In The Pipeline

The pipeline is divided into three stages including:

1) Pre-production: This stage consists of several activities, including planning, designing, and analyzing all 3D animation projects.

2) Production: In this production stage, all activities in the pre-production stage begin to run. All materials designed at the pre-production stage are collected to be worked on. The time required in this production stage is very long and carries a big risk. This is because sometimes finished assets must be remade to suit the design better.

3) Post-production: It is the final stage in a 3D animation project, where in this stage, the project must be really interesting through effects and color selection.

F. Definition of Deaf

Deaf is a term for people with special needs with hearing limitations. When communicating with the surrounding environment, deaf people use sign language more. The environment around the deaf people is residents who understand more spoken language than sign language, so the deaf have difficulty understanding their spoken expressions. Someone with a hearing impairment has permanent or non-permanent hearing impairments, so they can also have speech impairments or are commonly called speech impaired. [27].

Deaf people are constrained by their hearing, so they cannot hear sounds perfectly or even hear any sounds. Deafness is a term that indicates a condition where a person loses hearing which results in being unable to perceive various sound stimuli through his sense of hearing. [28].

Genetic factors, infections in the mother such as chickenpox during pregnancy, complications during childbirth, or early childhood diseases such as mumps or chickenpox can generally cause deficiencies in terms of hearing. The initial feature of hearing loss is directing one ear to the person who is speaking, communicating only using one ear, or not understanding a conversation when the face of the person speaking cannot be seen, often asking people to repeat what they say. Some factors that cause this hearing disorder include factors before the child is born (prenatal), such as measles and lack of oxygen. The following factors are factors when the child is born (natal), Rhesus (Rh), the mother and child are of the same sex, and factors after the child is born (postnatal) [29].

In general, people who are deaf have differences from individuals who can hear. The striking difference is in the physical condition, emotions, and characteristics. Deaf people have barriers that can affect their relationships with other people, communication processes, reading, and language in developmental stages [30].

G. Deaf Sign Language

In carrying out daily communication, language is the most important tool and means. Everyone needs language in the process of communicating. The deaf is no exception. Deaf people need appropriate and appropriate language to use in conveying and understanding everyday messages. In general, deaf people communicate or interact through certain movements, sign language, and use writing [31].

Sign language is a common language and is commonly used by deaf people. This language does not emphasize sounds. Sign language is a means of communication for deaf

people with the world of reality or its surroundings. The Indonesian dictionary explains that sign language is a tool that can help deaf people communicate in the wider community. This form of sign language is a systematic arrangement of a set of fingers, hands, and gestures to describe Indonesian vocabulary. Based on its formation, these signals are divided into four groups. The first group is the main sign, which reflects a word or a sign formed by the meaning component. The second group is additional signs, namely signs that represent prefixes, suffixes, and particles. The third group is the formed sign, which combines the main sign with the additional sign. The fourth group is the finger alphabet, a sign made with the fingers [32].
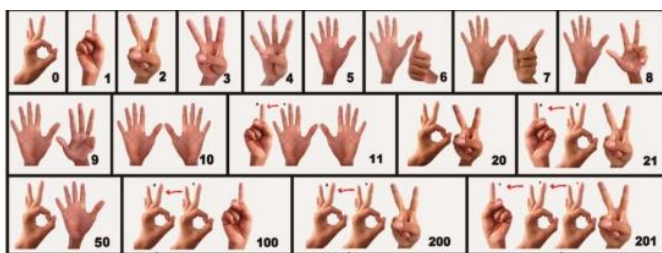

Figure 3. BISINDO Alphabetic Signs

Figure 4. BISINDO Number Cues

In Indonesia, there are two sign language groups for the deaf: SIBI (Indonesian Sign System) and BISINDO (Indonesian Sign Language). Most deaf people prefer using BISINDO compared to SIBI. SIBI is too convoluted and complicated to use [33]. BISINDO is a sign language for the deaf people of Indonesia that the deaf people of established. BISINDO is used to communicate between individuals, as with Indonesian in general. An example of the BISINDO alphabet is in Figure 3, and the number sign language according to the BISINDO dictionary is in Figure 4.

H. Liquefaction Phenomena

Liquefaction is said to be an event of loss of strength in the soil layers due to severe vibrations caused by earthquakes and vibrations due to other soil loadings. This condition is described when the ground experiences a great vibration, and the soil layer turns into a liquid so it cannot withstand the heavy weight above it. According to [34], liquefaction is changing the contours of water-saturated sandy soil to liquid due to increased pore water pressure, whose value equals the total pressure value. This is due to the dynamic load, which causes the effective soil stress to be zero. Liquefaction is where the soil's strength and stiffness are lost quickly.

Liquefaction generally occurs in soils saturated with water, where all voids on the soil's surface are filled with water. When the soil experiences vibration, the water will have a density effect on the soil [37]. Soil that experiences liquefaction symptoms has a higher compressive strength on the retaining wall, causing the soil structure to tilt or slide. This movement can cause land subsidence (settlement) and structural damage on the ground surface.

Some of the factors that influence the occurrence of liquefaction include:

- Earthquake intensity
- Epicenter distance. Based on past events, liquefaction does not occur if the epicenter distance is more than
  $$R = 0,82 \times 10^{0,862(M-5)} km \quad (1)$$
  however, liquefaction will likely occur if the epicenter distance is less than Equation (1).
- Depth of water level
- Type of soil.

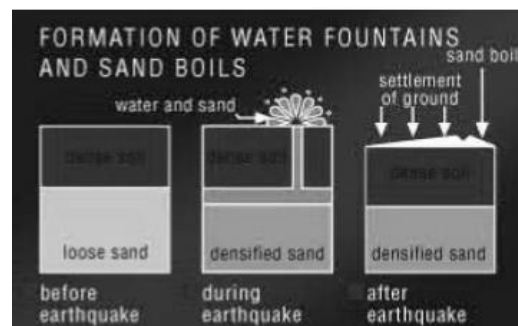An illustration of the liquefaction process can be seen in Figure 5.

Figure 5. Description Of Liquefaction

III. RESULT AND DISCUSSION

This research aims to build an interactive learning media application about the phenomenon of liquefaction due to earthquakes.
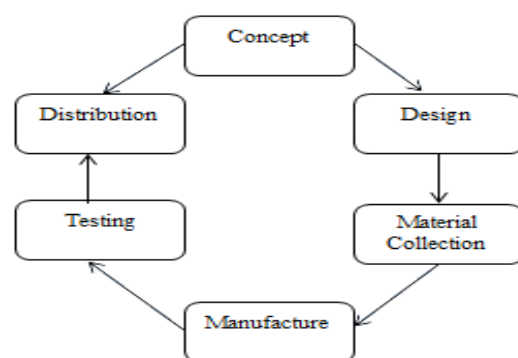

Figure 6. MDLC phases

Several stages are carried out to make the application truly interactive for users, especially for the deaf. In particular, this application was developed using the Multimedia Development Life Cycle (MDLC) method, where 6 phases must be passed, as shown in Figure 6. From the MDLC phase above, an explanation can be given as follows:

1) Concept: The concept stage is the initial stage in the MDLC cycle. At the concept stage, the research team held discussions on the purpose of making the application and determining the users of the application. The application aims to help provide virtual socialization and knowledge about post-earthquake phenomena and the occurrence of liquefaction. This application is intended for people, especially the deaf.

2) Design: The design is carried out at this stage as the basis for the application. The design plan is realized as a storyboard describing the system's running and the application's features.

3) Material Collection: This is an important stage where the data needed for application development begins to be collected. These materials include 3D objects, which are gradually made one by one using Blender. Furthermore, each 3D object that has been made is then put together so that it becomes a single unit. After the 3D object is formed as desired, then an animation is created for the object. The next stage is making markers using Vuforia and videos accompanied by text.

4) Manufacture. At this stage, all the materials that have been collected begin to be arranged one by one according to the application needs. One example is making 3D objects with Blender software. Then, use the Unity Engine software to make this application appear.

5) Testing: Testing is carried out to ensure that the results of making the application follow the plan. At this stage, the testing carried out is testing the user directly and then asking for input or feedback on the application used.
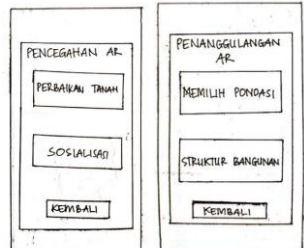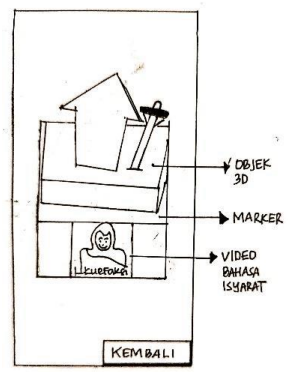
6) Distribution: In the distribution stage, products that have been built are distributed to users.

I. Making Stroy Board

Story Board is defined as a sequential application page display design. The storyboard in this interactive learning media application is in Table I.

TABLE I
INTERACTIVE LEARNING MEDIA STORYBOARD

StoryBoard	Information
	Main menu display of the application.

StoryBoard	Information
	Liquefaction sub menu: Definition of liquefaction, Liquefaction Process, Liquefaction Impact and Liquefaction Countermeasures
	Liquidation prevention and countermeasures sub-menu. After selecting, the camera will immediately appear, then point the camera directly at the marker book that has been provided. Then the object will appear.
	Suppose you choose the AR menu from process, impact, prevention, and liquefaction countermeasures. In that case, the camera will immediately appear, then point the camera directly at the marker book that has been provided. Then 3D objects in processes, impacts, prevention, countermeasures, and sign language videos will appear.

J. Process of Making 3D Objects Liquefaction Process

At this stage, 3D objects will be created as house objects, house poles, electricity poles, soil, mud, earthquake text, liquefaction text, and examples of liquefaction events.

1) House: The house object was the first to be made after the first creation of objects. The following representation procedures are required to construct a house object in three dimensions:

- Add a cube-shaped mesh.
- Set the scale section on the x, y, and z axes used to draw the floor of the house.
- Add a vertex line on the y and x axes using the CTRL + R keys so that it can be used to select from the corners. The result of step 3 is to make the mesh contain many boxes.
- Create the side walls of the house by blocking boxes only on the sides by pressing the keyboard shift, then pressing the keyboard keys F + E.
- Make additional floor two by adding a new mesh, then do the same as steps 2,3 and 4.

- To make the roof of the house, add a mesh plane, then set the scale on the x and y axis according to the width of the building.
- Then to give the building color, first, the object is changed in edit mode on the timeline.
- Then click face select, then click on the wall you want to color by pressing shift.
- After the wall art to be colored is selected, click mesh, edges, and mark seam. This section marks the boundaries of the faces that have been colored differently.
- To add a new color file, click material on the right and click the (+) icon.
- Click new. In the color option box, activate the image texture, then specify the desired file.
- When finished, move to the screen layout and change from default to composting.
- Open the image file that has been selected in the material section.
- The selected image is changed to the edit mode position by pressing the letter U and then selecting unwrap on the lower right side of the screen.
- Select the node tree type, then drag the BSDF line to the displacement.
- To see the results, please return to the screen layout, and change it to default again.

2) Land object: After the house object has been created, the next step is to create a 3D object for a plot of land. The following steps are required to create a 3D object for a plot of land.

- Add a cube-shaped mesh.
- Set the scale section on the x, y, and z axes used to draw the ground plane template.
- After that, add the mesh plane used as grass and scale according to the ground width in Step 2.
- Add another mesh cube, then set the scale on the x, y, and z-axes. The scale on the x and y-axis must be larger than the width of the soil in step 2, and the scale on the z-axis is also smaller. This object will be used as the second soil layer. Place it in a slightly higher position on the object created in Step 2.
- The procedure of establishing the building's texture and coloring Change the object's position to edit mode on the timeline.
- Then click face select, then click on the wall you want to color by pressing shift.
- After the wall art to be colored is selected, click mesh, edges, and mark seam. This section marks the boundaries of faces that have been colored differently.
- To add a new color file, click material on the right and click the (+) icon.
- Click new. In the color option box, activate the image texture, then specify the desired file.
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- Select the node tree type, then drag the BSDF line to the displacement.
- To see the results, please return to the screen layout, and change it to default again.

K. Production of Liquefaction 3D Animation

In the liquefaction process, several objects move simultaneously in the depiction stage of 3D objects. Single bone armature and location and size animations can create this effect. This setting is used to animate some of these objects so that they can run simultaneously.

In order for objects to run simultaneously, layout animation can be used. The smaller the distance between frames, the faster the movement of objects will be. Animation for ground movement can be used as a benchmark for making other object animations.

If all objects have been made animated clips, then the storage process is then carried out for one object with one animation it has. Then we need to export in *FBX* format by clicking the file menu, export, and selecting **.FBX*.

L. Making Markers

The marker function in this study is used to create 3D objects that can be displayed when the cell phone camera is pointed at the material book. Here is a picture of the marker and how to make it. Prepare an image object that will be conditioned as a marker. An example is shown in Figure 7.

Figure 7. Example of Markers

In order for the markers that have been designed to be used, the marker images need to be uploaded to Vuforia, which will be used as a database in Unity. So Vuforia will convert the database into a file with the extension .unity, which Unity can read. The process of uploading markers to Vuforia requires the following steps:

- Enter the site https://developer.vuforia.com/. If you already have an account, log in immediately. If you don't have one, the process begins by registering to get an account.
- After the initial Vuforia window appears, then create a License Manager.

- The next process is to fill in the license manager to determine the application's name.
- Next is the creation of the target manager and determining the database type. For example, the database device was chosen in this study because it can be used offline.
- After making the target manager, carry out the process of adding marker images. When adding this marker, you can choose the single image type because the marker is a sheet of paper.
- Next, download the database created and import it into the Unity project.

M. Making Application

After all the stages have been passed, starting from making 3D image objects, making animations, and making markers, the final stage is making learning media applications. This application contains 3D image objects, 3D text objects, animations, and markers. At the application development stage, Unity 2017.3.lf1 software is used as a tool. The initial stage is to make an AR video first. Next, create a new project. One thing to note is because the object to be created is 3D, the type of choice must be 3D. The final step is to click Create the Project.

After the Unity window appears, application development begins with creating an asset provided free by Unity, namely Vuforia Core Samples. Then proceed with adding the AR Camera, and if the AR Camera has been added, you can also add an image that will be used as the target image. If all stages of making 3D objects and animations are complete, the next step is to add 3D objects and their animations to the target image. In this section, objects need to be arranged sequentially and given an animation effect. The final process is to choose which scenes will be built to become the .apk file. The final result is in Figure 8.

Figure 8. The Final Results Of The Application

N. System Testing

Testing of Device Specifications. An application performance analysis related to the devices provided is carried out at this testing stage. The results of this test are in Table II.

TABLE II
DEVICE TESTING

Device Name	RAM (GB)	Android Version	Performance	Information
Oppo F5	4	Nougat	Good	No errors
Xiaomi Redmi Note 5	3	Oreo	Good	No errors
Samsung Galaxy A6+	4	Pie	Good	No errors
Samsung Galaxy J5	1,5	Lollipop	Good	No errors

Functional testing is conducted to test whether all the features available in the application can run according to their functions or whether malfunctions are still found. Based on the tests carried out, Table III shows the final results.

TABLE III
FUNCTIONAL TESTING RESULTS

Fitur	Hasil
Liquefaction process AR menu button	Runs well
Process AR menu button	Runs well
Impact AR menu button	Runs well
Prevention AR menu button	Runs well
Ground repair button	Runs well
Countermeasures AR menu button	Runs well
The button selects the foundation	Runs well
Building structure button	Runs well
Liquefaction process button	Runs well
Liquefaction impact button	Runs well
Liquidation prevention button	Runs well
Liquefaction control button	Runs well

Markers Detection Testing. In this section, testing of the markers made is carried out. Some of the results that can occur from this test are: objects do not appear, objects appear but are unstable, and objects appear in Table IV.

TABLE IV
MARKER DETECTION TEST RESULTS

Mark	Result
10 %	Do not appear
20 %	Do not appear
30 %	Do not appear
40 %	Appears unstable
50 %	Appears unstable
60 %	Appears unstable
70 %	Appears unstable
80 %	Appears unstable
90 %	Appears unstable
100 %	Appears sTable

Testing the Marker Distance with the Camera. The test at this stage is to test the shape of the appearance of the marker object based on the distance from the camera. The test results are in Table V.

TABLE V
MARKER DISTANCE TESTING RESULTS

Mark (cm)	Result
10	The object appears, too big
20	Objects appear and fit the size
30	The object appears, unsTable

IV. CONCLUSION

Based on the results obtained in the manufacture and trial use of the application. The resulting application of learning media can make deaf people able to see visually how the

liquefaction phenomenon occurs. The concept of AR in applying the resulting learning media is that deaf people seem to see and feel the process of the liquefaction phenomenon directly. By adding text explaining each event that is seen, this learning media becomes more interactive for the deaf.

Suggestions can be given to improve the process and the research results. Images of 3D objects and their animations can be made even more interactive to make them even more fun. The animation is clarified to describe the natural phenomenon of liquefaction better. To make the application of this learning media even better and more interesting, then in the future, you can add sound visualization effects for every incident of the liquefaction process.

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