Development of Learning Media "Solar System" Multiplayer Virtual Reality Using Samsung Gear VR

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Abstract—**The lack of student participation in the learning process results in the decrease of their learning interest and comprehension. In addition, in the interactive learning process, two-way communication takes place between instructors and learners. Teachers deliver learning material and learners provide responses to the learning material they receive. This can be realized by using a Multiplayer Virtual Reality to display the visualization of learning material. Virtual reality can be used to increase the effectiveness of delivering material with an immersive environment so students can develop intuition to perceive the abstract knowledge that is difficult for teachers to describe. The multiplayer system allows teacher-student interaction, which supports the ongoing learning activities in the virtual world. The test results show the mechanism of object interaction in a virtual environment is easy to use with 50% of respondents agreeing and 50% of respondents saying the interaction feels natural. Furthermore, solar system multiplayer virtual reality can be an interesting learning media with 50% of respondents strongly agree and this learning media is effective to be used in the delivery of solar and eclipse material in sixth-grade of elementary school with 67% of respondents expressing their agreement strongly.**

Keywords—**Virtual Reality, Multiplayer, Android, Samsung Gear VR, Education.**

I. INTRODUCTION

STUDENT participation during the learning process tends to only consists of taking notes and listening to the teacher's explanation, students are very rarely to ask questions or argue, and even incline towards being quiet. As a result, the interaction between teachers and students only takes place in one direction which causes the learning atmosphere becomes dull. This condition becomes the factor behind the weariness in learning which students experience and this causes their learning activity in grasping the material remains low and adversely affects their comprehension of the learning material. [1]

It is also known that students need more attention in learning science. Science learning in elementary schools should be carried out in an interesting and fun way. Students of primary school age which are still in the concrete operational stage, require concrete examples in order to understand what they learn. Learning using conventional methods such as lectures is less suitable for science learning in elementary schools because many of the material objects are difficult to observe directly or not in the student's environment. Textbooks that guide students in learning science are also insufficient as a reference source because there are only pictures and illustrations.[2]

In the interactive learning process, two-way communication takes place between the instructor and the learner. Teachers deliver learning material and learners provide responses to the learning material they receive. In interactive learning, lecturers do not only act as deliverers of material but also receive feedback from students and provide reinforcement of the learning outcomes they have taken. [3] That is why the right learning media are needed to increase interaction, interest in learning and understanding of students. The right media in accordance with the objectives will be able to improve the learning experience and support learning outcomes.

This can be realized by an interesting and interactive learning media of a Multiplayer Virtual Reality using Samsung Gear VR Head-mounted Display to display the visualization of learning material and remote control to interact with the objects presented. Virtual reality can be used to increase the effectiveness of delivering material with an immersive environment so that students can develop intuition to perceive abstract knowledge that is difficult for teachers to describe. [4] The multiplayer system allows the teacher and student interaction, which supports the ongoing learning activities in the virtual world. In addition, the multiplayer system keeps the teacher in control of the material and can equate the experience and perception of all students towards the content of the lesson. Students are expected to get more understanding because their learning activities will not only consist of listening to the teacher's description, but also other activities such as observing, doing, and interacting directly with 3D objects in real-time. With the existence of this learning media, it is hoped that it can facilitate students to think and analyze, provide variations in learning, and students can understand the subject matter systematically.

II. LITERATURE REVIEW

A. Learning Media

Learning media are all things related to software and hardware that can be used to convey the contents of teaching material from learning sources to students (individuals or groups), which can stimulate the learner's thoughts, feelings, attention, and interests in such a way that the learning process (inside / outside the classroom) becomes more effective. [3]

B. Virtual Reality

There are four important elements in virtual reality. The four elements are as follows:
1. Virtual world, a content that creates a virtual world in the form of screenplay and script

2. Immersion, a sensation that brings users of virtual reality technology to feel as if they are in a real environment which actually fictitious. Immersion is divided into 3 types, namely:
   a) Mental immersion, making the users' mental feel like they are in a real environment
   b) Physical immersion, making the physical of the user feel the atmosphere around the environment created by the virtual reality
   c) Mentally immersed, giving sensation to users to sink in a virtual reality-generated environment
3. Sensory feedback functions to convey information from the virtual world to the senses of its users. This element includes visual, audio (hearing) and touch
4. Interactivity is incharge of responding to the actions of users, so that users can interact directly in a fictitious or virtual world field.

III. METHODOLOGY

Methodology is a system of broad principles or rules from which specific methods or procedures may be derived to interpret or solve different problems within the scope of a particular discipline. There are six main step to design and implement the application system design so it can produce the main output. The six elements are as follows:

A. Literary Research

Collect the reference especially curriculum about the solar system materials for sixth-grade of elementary school students which later will be the fundamental information for learning inside gameplay.

B. Making Game Design

In this process the author design the Game Design Document that include the main aspects about the game such as the rules, scoring, visual design, and leveling.

C. Collect the Assets

Collect and make the assets that used in the game likes sound assets and 2D or 3D models. Assets collected from the Unity Assets Store or another resources.

D. Making the VR Environment

Process of making scene in Unity according to the storyboard that already made with arrange all of the 3D assets, text, music, and adding visual effect. Avatar also added to represents the presence of the teacher and the students in virtual world.

E. Configure the Controller

Adding the control function to the player such as pointer interaction, select, and grab object with processing the input value from controller device.

F. Adding the Multiplayer

Connecting one device to another so they can interact inside the virtual world. Implement object spawn and also player's movement synchronization using Photon Unity Networking.
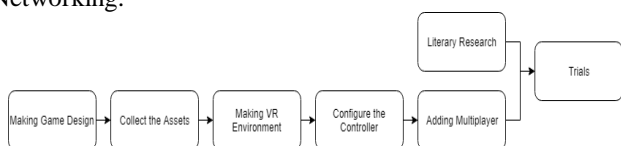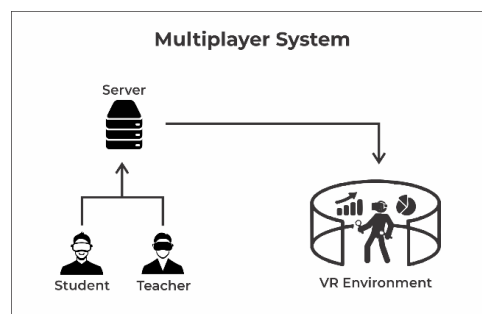
Figure 1. Methodology.

IV. SYSTEM DESIGN

Figure 2. System Design.

This study aims to design a multiplayer-based learning media applications by utilizing a HMD device and device controller as an input and output device and a server to process data that can be used in multiplayer. Data input received will be displayed in the form of an avatar and interaction with virtual environments which will then be processed by the server so that it can be received and observed by all players. In order to realize this final project, a system design that describes the concept and work of the system is made.
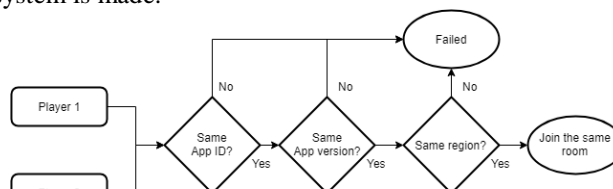
Figure 3. Matchmaking scheme.

A. Storyboard Design

1) Menu Display

In this main menu, there are two choices of material that can be chosen by the user, the material of the solar system and eclipse material.

2) Solar System Material

In the material of the solar system, students will be confronted with spawner where later on this spawner will appear a planet randomly from the eight planets in the solar system. Students are asked to place the eight planets in the appropriate order, then observe the eight planets in the solar system revolving around the sun.
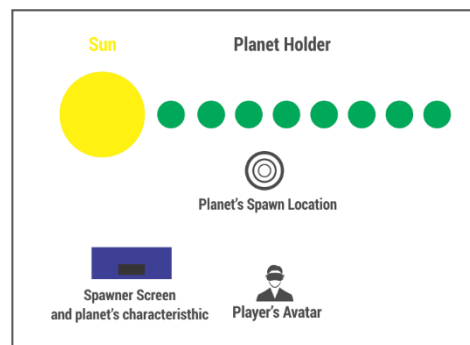
Figure 4. Solar System Scene Plan.

3) Eclipse Material

In the eclipse material menu, students are also faced with the object of the sun, earth, and moon. Then, students are asked to move the position of the moon into the right position such as when the solar eclipse or lunar eclipse occurs. If students can place the sun, earth and moon in the right position, students and teachers can observe the process of eclipse above them and as if they were observing an eclipse from the surface of the earth.
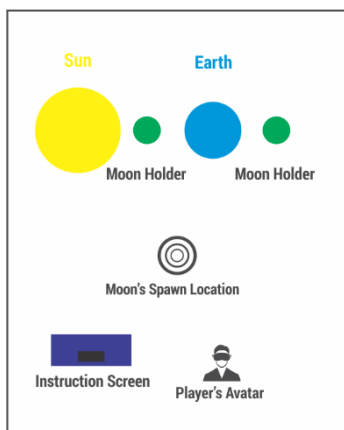
Figure 5. Eclipse Scene Plan.

B. Student Worksheet

A Student Worksheet is created to guide students to do various activities. It contains guidelines for the two materials in this application, the material of the solar system and eclipse material.

1) Solar System Student Worksheets

This Student Worksheet will be used as a guide to the solar system scenario with basic competency guidelines as shown in the following table 1.

Table 1.
Basic competency for Solar System materials

Standard Competency	Basic Competency	Indicator
Understanding the sun as the center of the solar system and the interaction of the earth in the solar system.	Describe the solar system and the position of the solar system.	1. Defines the notion of the solar system 2. Mention the constituent members of the solar system. 3. Mention the names of planets in sequence and their size. 4. Explain the rotation of planets in the solar system

In accordance with the basic curriculum above, a guideline is made as follows figure 6.
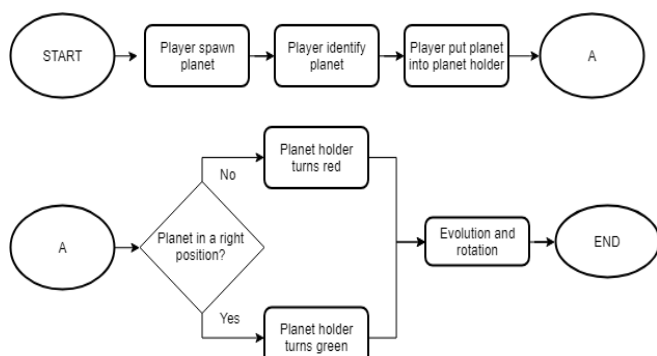

Figure 6. Solar System Scene scheme.

1. Students press the spawn button and planets will appear randomly
2. The teacher describes the characteristics of the planet
3. Students answer the name of the planet then put the planet in the order of its position.
4. Students observe the phenomenon that occurs with an explanation from the teacher.

2) Eclipse Student Worksheet

This Worksheet will be used as a guideline on eclipse scenarios with basic competency guidelines as shown in table 2.

Table 2.
Basic competency for Eclipse materials

Standard Competency	Basic Competency	Indicator
Understanding the sun as the center of the solar system and the interaction of the earth in the solar system.	Explain the occurrence of lunar eclipses and solar eclipses.	1. Explain the process of lunar eclipses and solar eclipses. 2. Explain the total lunar eclipse and partial lunar eclipse. 3. Explain total solar eclipses and partial solar eclipsesproses terjadinya gerhana bulan dan gerhana matahari.

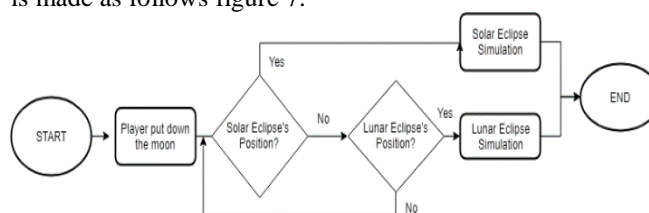In accordance with the basic curriculum above, a guideline is made as follows figure 7.

Figure 7. Eclipse Scene Scheme.

1. The teacher asks students to put the moon in a lunar eclipse position
2. Students are asked to observe the Sun, Earth, and Moon models then explain what happened.
3. Students observe shadows formed on the models of the Sun, Earth, and Moon.
4. Students observe the process of lunar eclipses in the sky.
5. Students exchange the position of the earth with the position of the moon then explain what events will occur.
6. Students observe shadows formed on the models of the Sun, Earth, and Moon.
7. Students observe the process of the solar eclipse in the sky.

C. Controller Configuration

In the Event System Unity, there is a Stand Alone Input Module component which is useful for following up data input from the mouse. In this application Virtual Reality Toolkit (VRTK) is used to get input values from the controller. With input from the controller, the player can, teleport, interact with 3D objects, and interact with the user interface. To interact using the Samsung gear VR controller, you can follow these steps:

1. Create an empty object with the name "RightController".
2. Add the VRTK Controller Event component.
3. Add the VRTK Pointer component and set the "activation button" to "Touchpad Press" and fill in the "Attach to" column with "RightHandAnchor" which is on OVRCameraRig.
4. Add the VRTK Straight Pointer Renderer component to add a pointer to the controller.
5. Activate "enable teleport" in the VRTK Pointer component in the RightController object.
6. Add the VRTKInteractGrab component and then set the "grab button" to "Trigger Press" and fill in the "Controllerattach point" column with "RightHandAnchor" located on OVRCameraRig.

By using VRTK, after configuring the controller, several components can be added for interaction with the user interface:
1. Add the VRTK UI Pointer component to the RightController object.
2. Set the "activation button" to "Touchpad Press" and "selection button" to "Trigger Press".
3. Add VRTK UI Canvas and Raycaster Graphic components to the canvas object.

With this configuration, the UI Pointer will be active when the player presses the touchpad to enable teleportation when directed to an area that can be explored and will trigger UI elements such as buttons, sliders, and checkboxes using the trigger button when directed to the canvas object.

D. Object Interaction

The object must be able to detect the controller and need to be configured on what will happen if the grab button is pressed. With VRTK configuration objects can be done in the following ways:
1. Add collider components and rigid bodies to objects.
2. Add the VRTK Interactable Object component to the object.
3. Activate the "is Grabbable" option and Stay Grabbed on Teleport on the VRTK Interactable Object component.
4. Add the VRTK Track Object Grab Attach component to the object and fill in the Grab Attach Mechanic column in the VRTK Interactable Object with that component.
5. Fill in the Right Snap Handle column on the VRTK Track Object Grab Attach with the Transform component from the object itself.

This configuration allows objects to be able to detect the presence of a controller and can be grabbed by the player. By using the VRTK Track Object Grab Attach mechanic, Right Snap Handle on the object which in this case is the transform component of the object itself, will follow the value of the controller's transform so that the interaction feels natural.

V. TESTING AND DISCUSSION

There are two stages of testing, System Performance Testing, which includes testing the framerate in each scene with the device used and Usability Testing which consists of effectiveness testing and questionnaire testing.

A. System Performance Testing

In testing the performance of the system, the system is tested on both scenes in the application to determine system performance based on the obtained framerate. The devices used in performance testing are Samsung Galaxy Note 5 and Samsung Galaxy A8 + which have the following technical specifications.

Table 3.
Specifications for Samsung Galaxy Note 5

Samsung Galaxy Note 5 Specification	
Processor	Octa-core (4×2.1 GHz Cortex-A57 & 4×1.5 GHz Cortex-A53)
RAM	4 GB
GPU	Mali-T760MP8
HDD	32 GB
Operation System	Android N 7.0 (Nougat)

1) Framerate Testing

Framerate is the replacing frequency of images displayed on the screen. The minimum framerate of an application to be comfortable to use is 30 FPS, and the recommended framerate is 60 FPS [5]. The framerate test is carried out in two scenes, the solar system simulation scene and eclipse simulation scene. The framerate test results from the application are as follows table 4.

Table 4.
Specifications for Samsung Galaxy A8+

Samsung Galaxy A8+ Specification	
Processor	Octa-core (2x2.2 GHz Cortex-A73 & 6x1.6 GHz Cortex-A53)
RAM	6 GB
GPU	Mali-G71
HDD	64 GB
Operation System	Android N 8.0 (Oreo)

Table 5.
Samsung Galaxy Note 5 Framerate

No	Solar System Scene		
	Min	Max	Mean
1	2.004057	51.74615	32.7612
2	2.049182	47.61628	29.71036
3	2.04542	47.54623	33.8075
4	2.029641	44.54967	29.96256
5	2.021838	41.02639	30.73237

Table 6.
Samsung Galaxy A8+ Framerate

No	Solar System Scene		
	Min	Max	Mean
1	17.49343	46.4762	29.52125
2	19.69811	60.36008	40.95329
3	19.46365	48.36022	32.31986
4	18.03979	60.61546	37.50393
5	20.43755	56.64315	35.2943

In Table 5-6 the results of these tests are shown and the average framerate obtained in each test ranges from the minimum framerate, which is 30 FPS. Thus users can comfortably explore in this scene.

Table 7.
Samsung Galaxy Note 5 Framerate

No	Eclipse Scene		
	Min	Max	Mean
1	11.26001	32.5229	18.18719
2	12.88053	41.57805	23.12559
3	14.20081	42.35335	22.37372
4	12.68654	39.39499	22.16584
5	13.39963	39.50207	23.27645

Table 8.
Samsung Galaxy A8+ Framerate

No	Eclipse Scene		
	Min	Max	Mean
1	0.465936	34.74028	19.82203
2	1.089903	37.06665	23.1408
3	15.1315	39.60955	24.05574
4	11.95754	42.43775	25.78294
5	14.64996	40.18592	21.34706

In Tables 7-8, the results of these tests are shown and the average framerate obtained at each test is less than the minimum framerate, 30 FPS. This is because when the solar eclipse simulation runs the exposure setting on the skybox is changed to darker to get the appropriate display. Moreover, the addition of the number of stellar particles in the simulation of the system particle which originally the max particle variable was 100, now is increased to 600. Both of these causes fps decrease in the solar eclipse scene because it requires heavy computing.

B. Usability Testing

Usability is the extent to which a product can be used by a particular user in achieving a goal with effectiveness, efficiency, and satisfaction in the specified context [6]. In this test two main scenes were prepared, the solar system scene,

and the eclipse scene. In each scene there are several different tasks. The measured parameter is the time spent by participants in completing each task. In addition, questionnaire data were given to participants at the end of the experiment.

Table 9.
Participant's Task

No	Task	Description
1	Spawn Planet	Generating planet randomly into the scene
2	Sequencing Planets	Placing planets in the right order.
3	Placing the Moon	Placing the moon in a predetermined eclipse scenario.
4	Observing Eclipse	Observing the eclipse process.

2) Effectiveness Testing

This effectiveness test can be done by taking into account the completion rate measurement by asking participants to complete a set of tasks that have been provided. In addition, participants will be timed to measure how long they take in completing tasks and simulations. The goal is to be able to measure how effectively the player can complete the task in the simulation.

Table 10.
Completion Rate

Task	Participant	Success	Completion Rate
1	15	13	87%
2	15	13	87%
3	15	14	93%
4	15	14	93%

In the task of placing the planet, there are two failed attempts because the planetary object does not appear when called into the scene. Whereas in the task of placing the moon and observing the eclipse there was a failed experiment. In this experiment, the moon object disappeared from the scene so that the eclipse event cannot be triggered.

Table 11.
Solar System Completion Time

Total Participant	Solar System Completion Time		
	Fastest	Mean	Slowest
15	268 s	493.2 s	798 s

Table 12.
Eclipse Completion Time

Total Participant	Eclipse Completion Time		
	Fastest	Mean	Slowest
15	311 s	366.8 s	570 s

Based on the results of completion time testing in tables 4.9 and 4.10, it can be seen that there are some participants who need a longer time than the other participants, this is because in some experiments the controller devices connected to smartphones have improper orientation, making it difficult for participants to do the task. Another thing that affects the participants' time is an internet connection that is sometimes interrupted which caused participants to be disconnected from the room.

3) Questionnaire Testing

The testing of this questionnaire is done by giving questionnaires to participants who have tried the application. This test was conducted on 15 participants who were students of the Institut Teknologi Sepuluh Nopember aged 17-23 years. In testing this questionnaire, participants were given a number of statements and five options regarding the level of approval and are asked to choose one of these options. A list of statements can be seen below:

1. I can easily control the navigation / movement of player characters in the virtual environment.
2. The navigation / movement player control mechanism in the virtual environment feels natural.
3. I can easily control objects in the virtual environment.
4. The mechanism of interacting objects in a virtual environment feels natural.
5. I can control User Interface (buttons, menu options) easily.
6. The virtual environment feels responsive and there is no delay with the actions I take.
7. The sensation of exploration in the virtual world is interesting.
8. The description of the virtual environment is quite representative of real life.
9. The objects presented are quite representative and accurate with the real world.
10. I can complete the task of sorting planets easily.
11. I can complete the eclipse arranging task easily.
12. I am proficient in moving and interacting with the virtual environment.
13. The quality of the visual display does not interfere and does not distract me from doing the assigned task.
14. The control device (hardware) does not interfere with the assigned task performance.
15. Me and other players like being in the same environment.
16. I can communicate and interact with other players smoothly.
17. The objects presented can be well received by all players.
18. This learning media can improve my understanding of 6th grade elementary school solar material.
19. This learning media is quite effective and interesting for delivering solar and eclipse subject matter.
20. Compared to before the simulation, my understanding of the solar system, planets and eclipses increased.

Table 13.
Questionnaire

No	Scale				
	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
1	0%	13%	13%	47%	27%
2	0%	20%	20%	53%	7%
3	0%	13%	20%	60%	7%
4	0%	0%	27%	53%	20%
5	0%	7%	27%	40%	27%
6	0%	0%	20%	60%	20%
7	0%	0%	7%	33%	60%
8	0%	0%	20%	33%	47%
9	0%	0%	7%	53%	40%
10	0%	13%	7%	53%	27%
11	0%	7%	13%	33%	47%
12	0%	13%	20%	40%	27%
13	0%	0%	0%	67%	33%
14	0%	7%	20%	40%	33%
15	0%	0%	7%	40%	53%
16	0%	0%	33%	47%	20%
17	0%	13%	7%	47%	33%
18	0%	0%	7%	40%	53%
19	0%	0%	0%	33%	67%
20	0%	0%	0%	60%	40%

Statements number 1 to 5 are intended to know how the user experience the control system, interaction and navigation in the virtual world. Statements number 6 to 14 are intended to measure the user's comfort towards the virtual environment and the user's control over the tasks assigned. Statements number 15 to 17 are intended to determine the extent to which the multiplayer functions in this application can work well. Statements number 18 to 10 are to measure the function of this application as a learning media for the solar system and

eclipse. The following are the results of testing the questionnaire.

VI. CONCLUSION

The application can be used with a convenient framerate even though during the solar eclipse simulation the framerate can drop up to below 30 fps.

In questionnaire testing, the mechanism of object interaction in a virtual environment is easy to use with 50% of respondents agreeing and 50% of respondents saying the interaction feels natural.

Solar System Multiplayer Virtual Reality can be an interesting learning media with 50% of respondents strongly agree and this learning media is effective to be used in the delivery of solar and eclipse material in sixth-grade of elementary school with 67% of respondents agreeing strongly.

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