Virtual reality app on Milky Way solar system, case study: Kebraon II Public Elementary School, Surabaya, East Java, Indonesia

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Abstract. 6th grade students of Kebraon II Public Elementary School at Surabaya, Indonesia, learn the introduction to astronomy about the solar system. However, they don't understand some basic concepts, such as the differences of rotation and revolution, shape and size of planets and other celestial bodies. In addition, they are not interested in studying astronomy, because of the books consisting of large amount of text and black-and-white still images. To spark the students' interest on astronomy, we create an interactive application which features virtual reality (VR) to introduce astronomy. It features the solar system and other celestial bodies with their information (orbital time, rotation time, revolution time, etc.), as well as solar and lunar eclipse animation and information, in accordance with Indonesia's Ministry of Education 2006 curriculum, KTSP (Kurikulum Tingkat Satuan Pendidikan, School-Based Curriculum). The application is developed for Samsung Gear VR using Unity 5. Users will be able to see the whole solar system and navigate using a Bluetooth-enabled, Android-compatible gamepad, and interact with celestial bodies to see their information. The application is black-box tested to teacher and 10 students. All students are more interested in astronomy, concluding that this app can be used as an alternative medium to introduce astronomy.

1. Introduction

Astronomy is a very broad topic which consists of Solar System [1]. The components of our solar system are the eight planets, Sun, Moon, comets, meteoroids, asteroids, and other celestial bodies. There are also natural phenomena in our solar system, such as solar and lunar eclipse. These celestial bodies form a galaxy, such as our galaxy Milky Way.

The curriculum for 6th grade elementary school in Indonesia includes astronomy as one topic to study for natural science class. The selected topics for astronomy are Solar System, planets (along with their characteristics such as orbital time, rotation time, revolution time, mass, diameter, distance from Sun, temperature, number of natural satellites), asteroids, meteoroids, comets, and solar/lunar eclipse. However, the books [1] and [2] do not provide figures for individual planets and celestial bodies. There are only Solar System figures within the books. They are even presented in black/white, although the books are in full color, as seen on Figure 1. This results in confusion among students because they cannot figure out what the planets look like in real life.

Lack of appropriate figures and tools to represent planets and celestial bodies results in less interest from students to learn and understand astronomy. Therefore, in this research, we aim to spark their interest in astronomy by developing an interactive application by mean of virtual reality. This application will comply with Indonesia's Ministry of Education 2006 curriculum for 6th grade.

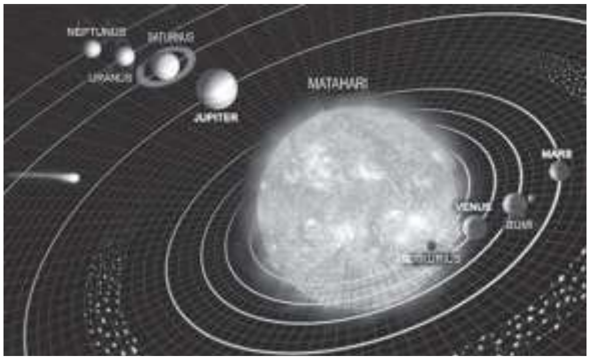

Figure 1. Example of figure showing the formation of Solar System

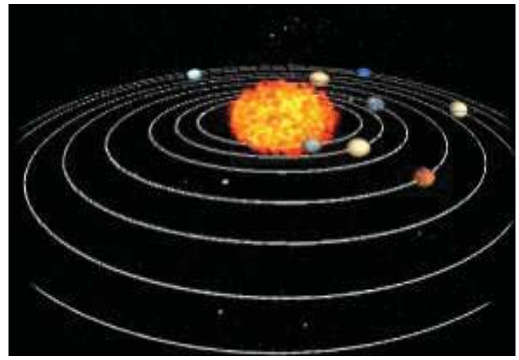

Figure 2. Screenshot of solar system app used for comparison

2. Methodology

We will use a case study of 6th grade students from Kebraon II Public Elementary School (Sekolah Dasar Negeri Kebraon II) at Surabaya, East Java, Indonesia. While developing the application, we conform with the software development life cycle, which are planning, analysis, design, implementation, and testing. Before development, we collect specific data related to the application we are developing, such as astronomy topics for the 6th grade students, VR, and similar or related works. During the analysis phase, we interview a 6th grade teacher as well as 6th grade students of Kebraon II Public Elementary School to discover issues we want to solve with the application. Because of the broad nature of astronomy, we carefully select celestial bodies which conforms with KTSP (Kurikulum Tingkat Satuan Pendidikan, or School-Based Curriculum, also known as 2006 curriculum) as required by Indonesia's Ministry of Education. We do this by selecting two books used by the teacher to teach astronomy to her students. These books will be used as basis of material. We also do research on VR and what medium to implement. After analysis, we design the application by designing the flow of material presented within our app, as well as the interface flow. We develop prototypes to quickly evaluate our design before implementing the app in the next step. Results from the final prototype are then implemented using the help of Unity3D, Samsung Gear VR SDK, and T2S (text-to-speech) for the voiceover. Finally, we perform a black-box testing with teacher and 6th grade students of Kebraon II Public Elementary School. We test our application by randomly sample 10 students, use our app, and fill in a questionnaire about aspects of the app. We end the research by summarizing the results and writing documentation for future use and research for those interested in this topic.

3. Literature Review

Although there are many forms of educational apps, we decided to use VR for this topic, as VR can be used to enhance core curriculum subjects [3]. VR enables students to be engaged with the topic using their multiple senses, as VR provides immersiveness to the virtual world. Students can interact with various aspects of the virtual world, enabling them to retain the material.

When we began this research, there were some completed researches on the same subject. One research [4] was conducted on a different sample domain and yielded fair result. The VR app was developed for Android smartphones with help of Google Cardboard. Figure 2 shows the Solar System from a top-down camera. The app was deemed quite difficult to use since users had to target the UI button with their head and moved the magnet on the side of Google Cardboard to click the button. This mean of navigation was not comfortable, especially when answering the quiz provided in-app. The planet models were too small from the user's point of view; however, users must interact with them to be able to see information about specific planet. Another similar VR app in solar system was developed with good result [5], however there were too many bodies of text, as if they were copied from the textbooks. We argue that a very long body of text is not appropriate for a VR application, as it will reduce the immersiveness and is not different than reading books. A research developed VR of mathematics for elementary school [6], which had 80.84% satisfactory rate, claimed that VR development, especially in education, was not abundant in Indonesia and still dominated by VR games.

4. Result and Discussion

Based on literature review, we decided to perform a similar research on VR app on Solar system but with different approach. Aside of the different sample domain, we use a different platform, Samsung Gear VR (SM-R323), as shown in Figure 3. Although this severely limits the range of our market by only allowing Samsung Galaxy S6 (and above) and Galaxy Note 5 (and above) [7], we believe the smartphone capability of performing VR with more power will compensate our limited market. To make the interaction easier, we opted to use a Bluetooth-enabled, Android-compatible gamepad for UI navigation as well as some of user navigation in-app. The joystick we use is Steelseries Stratus XL as can be seen on Figure 5. Users will still be able to look around with the headgear, but they only need to press a button in the gamepad to click a button.

Figure 3. Samsung Galaxy VR (SM-R323)

Figure 4. Steelseries Stratus XL Bluetooth joystick

After we decided on the platform, we started our own research by searching for current issues with the students. We interviewed a teacher of Kebraon II Public Elementary School. She uses book as the main medium of education in the school. The main disadvantage of book is the blurry or unclear figures (as discussed previously). Therefore, she has hard times to attract students when studying astronomy. Students easily get bored by just sitting and listening to the teacher, reading, and looking at still figures from the book. From the interview, it is revealed that students struggle to grasp the idea of rotation, revolution, shape and size of eight planets and other celestial bodies. She did not use any tools to represent rotation and revolution, thus the students' confusion. Furthermore, this resulted in students disinterest of astronomy. Interviews to 10 students revealed similar results. Therefore, we want to help students better understand and get interested in astronomy by developing an interactive educational app, with help of VR.

In design phase, we select the materials to be included in our app. By using two textbooks as sources, we decided to select all eight planets, meteoroids, asteroids, comets, Sun, and Moon as celestial bodies to be modeled and explained in our app. For historical reason, we also include Pluto as the "ninth planet", although in the information later it will be classified as a dwarf planet, to adhere to IAU definition of a planet [8] and NASA's classification of Pluto as a dwarf planet [9]. To help students understand the shapes of each planet, we use high definition maps from James Hastings-Trew which are derived from NASA and other reliable sources. The planets will also be modeled in proportional scale according to their real size. Information about each planet includes orbital time, rotation time, revolution time, mass, diameter, atmosphere condition, distance from Sun, temperature, and number of natural satellites. We also include common-but-rare natural phenomena, which are solar and lunar eclipse. Sun, Moon, and Earth will be positioned accordingly and move until eclipse happens. When it does, users will be notified to press a button to view more information, such as why and how eclipse happens. As VR app is still scarce in Indonesia, we feel the urge to have a dedicated tutorial section within our app, so users will have minimal difficulty of using our app. Ambient sounds will be added in all scenes to help users relax while exploring the Solar System. In this stage, an interface flow diagram helps us determine how many screens we need and how to transition between screens, as illustrated in Figure 5. Each celestial body has its own information screen, but their screens are compacted in Figure 5 to simplify the diagram, as we have numerous celestial bodies and they in fact follow the same flow.

When all design is complete, the app is then implemented in Unity 5 with help of Oculus Gear VR SDK. All planet textures are imported to Unity, then materials are created for each texture. Planets are formed by simply using Unity's primitive sphere and applying their respective materials. A rotation script is then attached to each planet with respect to its rotational speed. Revolution script is also attached to each planet so that they will revolve around the Sun. To help students easily find all planets when they start the simulation, all planets are aligned within a straight line from the Sun. All other celestial bodies are created in a similar manner but without the rotation script. For comets, we add a trail renderer component to simulate its tail. Solar and lunar eclipse screen are created in a similar manner, but the system will detect when the Sun, Moon, and Earth are within one straight line to yield an eclipse. Instruction screen is simply a collection of a gamepad image to show button layouts (as someone may never use a gamepad before), Gear VR layout, and some text explaining how to navigate and use our app. Samsung Gear VR has a Back button to exit application, nevertheless we decide not to use it and implement an Exit menu, so users never need to take their hands off the gamepad. This is to create consistency on how to interact with our app, which is solely using a gamepad. Figure 6 shows the Solar System in-app.

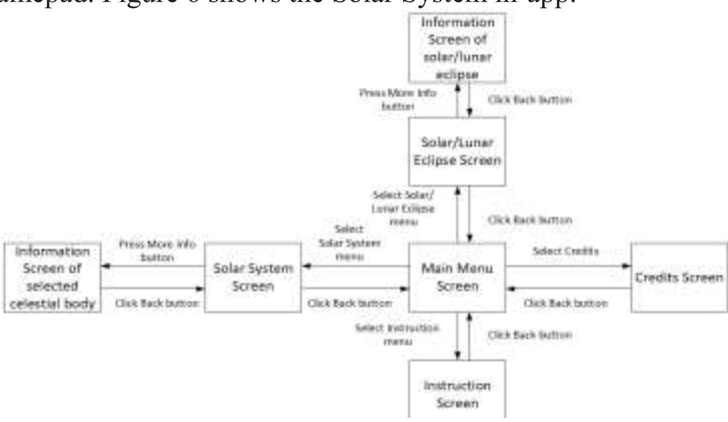

Figure 5. Simplified interface flow diagram

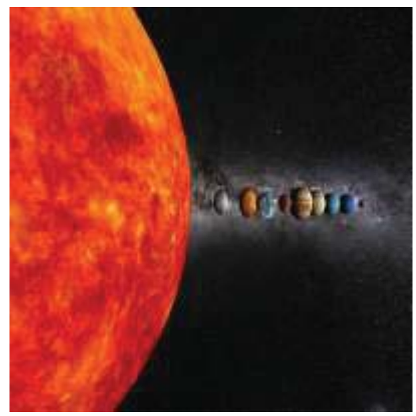

Figure 6. The Solar System screen

When the implementation is complete, it's time to evaluate the app. As the application is intended for Indonesian student, the following figures will be presented in Bahasa Indonesia, with explanations and translation for English readers. Both the teacher and randomly-selected 10 students try our app. They begin by navigating through the main menu as presented in Figure 7. When they choose Solar System formation, they will be presented with the Solar System screen. They may move the camera by using their head to rotate the camera and directional pad or left analog stick to pan the camera. To move forward, they press A button; to move backward, they press X button. This scheme is chosen as directional pad and left analog stick is already used to pan the camera. However, this schema has a drawback. As A button is already used, we cannot use A button as a confirm button, which most game uses. We finally resolve to use Y button as confirm button, with B button still acts as cancel button. When they are within range with a celestial body, they can press Y to enter information screen about the selected celestial body, as shown in Figure 8. The information is also read with the appropriate pre-recorded voiceover, which is just a result from a text-to-speech app.

When they choose Lunar Eclipse, they will be taken to the lunar eclipse screen as can be seen on Figure 9. The camera is above Sun, Earth, and Moon and looks down toward them. When Moon is between Sun and Earth, a text will occur and the animation will stop for a determined time, prompting user to press LT button for more information (Figure 10). After being satisfied with the information, user can press Y button when Back button is highlighted to go back to the previous screen.

There is a substantial problem we are unable to solve. Initially, the custom shader enables us to simulate the real lighting of Sun. All planet faces facing away from the Sun is rendered dark. However, when exported to Android, all planet faces are lit bright, even if they are facing away from the Sun. We suspect that the custom shader is created with DirectX (Windows), therefore it is not compatible with Android (which uses OpenGL ES [10]) and disabled when our app is exported to Android.

Figure 7. Main menu. From top to bottom: (title) *Solar System*, (menu) *Solar System formation, solar eclipse, lunar eclipse, instruction, credits, exit*.

Figure 8. Planet information screen. In this screen, Mercury is displayed.

Figure 9. Lunar eclipse screen. *Matahari* is the Indonesian word for the Sun.

Figure 10. On-screen prompt when lunar eclipse occurs. The prompt reads: (top) *A lunar eclipse occurs.* (bottom) *Press [LT] button to see more information about lunar eclipse.*

After trying the app, we conduct an interview with the teacher. According to the teacher, the app is easy to understand with the help of instruction screen, although she never uses a gamepad and VR app beforehand. The topics presented already conform with KTSP. She thinks that this app can be used as an alternative medium aside from books when explaining about astronomy, to gain students' interest on the subject. However, she has concern about the cost of additional tools required for this app. As per May 10, 2019 (prices are taken from various Indonesian online shops, such as Lazada and Tokopedia), a Samsung Galaxy S6 costs approximately 2.6 million Indonesian rupiahs (USD 180, using the currency rate of IDR 1 = USD 6.9×10^{-5}), a Samsung Gear VR costs approximately 1.5 million rupiahs (USD 104), and a Bluetooth-enabled, Android-compatible gamepad costs around 750 thousand rupiahs (USD 52). She hopes the Indonesian government is willing to provide the cost for our VR app. She also suggests creating another VR app for various topic; however, it is beyond the scope of our research.

The validation is also conducted to students. We randomly select 10 students to use our app and let them fill in a simple questionnaire to find out whether they find our app useful. The questionnaire consists of five statements. For each statement, student must choose if they strongly disagree, disagree, agree, strongly agree, or have neutral thought about. Table 1 summarizes the findings. Overall, we conclude that students like our app. To our surprise, one student dislikes VR and rather chooses books. The reason is simply because she feels that using a VR headset is not practical at all, compared to directly reading a book, which needs no additional tool. Two students stand in a neutral position over VR because they have motion sickness when using the app. In subject of information clarity, two students feel that the information presented in-app is less rich than the book counterpart, so they still don't understand about the subject.

Table 1. Student questionnaire result. Ten students participate in this questionnaire.

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
This app is easy to understand and use	0%	0%	0%	30%	70%
It's easier to recognize celestial bodies using this app than other printed media (book)	0%	0%	0%	10%	90%
You are more interested in astronomy after using this app	0%	0%	0%	60%	40%
With VR, you don't get bored using this app	0%	10%	20%	50%	20%
Information about celestial bodies is clear enough	0%	0%	20%	20%	60%

5. Conclusion

As the research ends, we conclude that our VR app is useful and may be used as alternative medium of teaching astronomy. The information presented in our app conforms with KTSP so 6th grade students may use it alongside the textbook. Although the cost of acquiring the required tools is expensive, the teacher of Kebraon II Public Elementary School feels that this app can spark students' interest on astronomy, broadening their knowledge.

For future improvements, we suggest implementing the correct shader that is compatible with Android to fully simulate Sun's lighting. The instruction screen may be reworked to use less text and more image explaining the navigation. If necessary, the instruction screen may be replaced with an interactive tutorial that may be disabled for advanced users. A more conventional gamepad button mapping may be adjusted to better accommodate more users. The voiceover may also be replaced with real human actors to avoid discomfort of hearing robotic voiceover. Lastly, information may be represented in a more interesting way, rather than in a wall of text.

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It is a great pleasure to welcome all of you to Bali and to the International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand. The first InCITE has been successfully held in Bali, Indonesia in 2017. We are very delighted to host the second InCITE here in Bali, Indonesia again.

There are more than 75 presentations in this conference. We welcome leading experts not only from Indonesia, but also from different parts of the world. The experts will share the knowledge and experiences in the fields of informatics, technology, science, and engineering. The main theme of this conference is **Enhancing Engineering Innovation Towards A Greener Future** in response to several world challenges including sustainable development, global convergence of information and communications technologies, climate change and global warming as well as the depletion of unrenewable natural resources. We hope this conference will provide you a good opportunity to get to know each other better and consolidate bonds of friendship and mutual trust.

We would like to express our sincere gratitude to the Keynote and Plenary speakers, International Scientific Committee, Steering Committee, and Organising Committee for their huge efforts to make this conference successful.

Thank you all for your support and attendance at InCITE 2019. Please enjoy the conference and Bali !

Asst. Prof. Djuwari, Ph.D.

Preface

Welcome Remarks, Chair of The Organizing Committee

Welcome to Bali, Indonesia to all delegates and presenters. It is my pleasure and privilege to welcome all of you to the 2nd (second) International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand.

InCITE 2019 has received more than 75 papers to be presented in this conference. All papers represent four following parallel clusters: Green Design and Innovation, Green Manufacturing and Green Processes, Power System and Green Energy Management, and The Role of IT in Innovation Enhancement. Each cluster supports the main theme of the conference, which is **Enhancing Engineering Innovation Towards A Greener Future.** The engineering innovation is the key to increase our awareness in maintaining the sustainable growth and development in the world.

The Organising Committee of InCITE 2019 would like to express our sincere gratitude for the tremendous supports and contributions from many parties. The supports from The Faculty of Engineering of UBAYA, keynote and plenary speakers, our International Scientific Committee, the Steering and Organising Committees are really acknowledged.

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Nomor ISSN yang telah diterbitkan :

» Kata kunci : tahun permohonan 2019 CARI BATAL

Pisahkan kata kunci dengan spasi. Untuk melihat daftar ISSN lengkap, klik tombol CARI tanpa menuliskan kata kunci apapun...

halaman sebelumnya »

Nomor ID	:	1567408525
Tanggal permohonan	:	Senin, 2 September 2019
Nama terbitan	:	Proceeding Book International Conference on Informatics, Technology, and Engineering (InCITE)
Sinopsis	:	International Conference on Informatics, Technology, and Engineering
Pengelola	:	Fakultas Teknik, Universitas Surabaya
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Penerbit	:	Universitas Surabaya/Fakultak Teknik, Universitas Surabaya » http://conference.ubaya.ac.id/incite2019
Frekwensi terbitan	:	2 tahunan
Nomor ISSN	:	2686-5955 (media online)
Keterangan	:	» Kategori teknik » SK no. 0005.26865955/JI.3.1/SK.ISSN/2019.10 - 21 Oktober 2019 (mulai edisi Vol. 2, 2019)

9 772686 595002

» Sampul depan [bita]

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