Physics learning media based Augmented Reality (AR) for electricity concepts

A Ismail1,*, S Gumilar1, I F Amalia1, D D Bhakti2 and I Nugraha3

1 Department of physics education, Institut Pendidikan Indonesia, Jl. Pahlawan No.32, Garut 44151, Indonesia
2 Department of Information System, Institut Pendidikan Indonesia, Jl. Pahlawan No.32, Garut 44151, Indonesia
3 Department of English education, Institut Pendidikan Indonesia, Jl. Pahlawan No.32, Garut 44151, Indonesia

*aliismail7@institutpendidikan.ac.id

Abstract. Physics concepts are unique because some of them are the abstract concepts so they need to be visualized so as easier to be understood. However, it is rarely the learning media that can combine the real and virtual visualization of abstract physics concepts in the same time. This present study aims to create the application that is used as the physics learning media to aid the virtual visualization of the abstract concept of physics combined with real visualization using augmented reality. The abstract concepts of physics that are visualized are electricity concepts. The waterfall method is the method utilized to test the application on the android system. There are four standards to analyze data, namely functional suitability, performance efficiency, portability, and usability. The findings reveal that two standards (i.e., performance efficiency, and portability) lead the application is valid and good to be used while the usability standard achieves high value based students’ questionnaire that means the application is valid. The implication of this present study indeed can be widened to implement the application on the physics learning in the classroom.

1. Introduction

In the education context, the development of information technology has begun to have a positive impact because the development of information technology in the education world has begun to show significant changes [1]. Many things are perceived to be different and change compared with the way that developed before. The development of information, communication, and technology (ICT) enables the creation of various multimedia in learning that can facilitate and arouse students' learning motivation in learning the concepts of Physics.

Physics material itself is consisted of concrete and abstract concepts. Abstract physical material such as electricity, magnetism and modern physics are difficult to visualize, causing students to have difficulty in examining abstract physical concepts. This is what makes students think that physics becomes difficult and boring. Therefore, to be able to develop students' conceptual understanding of physics learning, especially in abstraction physics concepts, it needs information technology assistance. Information technology in education is applied in the form of multimedia in the form of software which provides facilities for students to learn a learning material.
One of the learning media that is considered to be able to help and facilitate students in learning abstract material physics is augmented reality (AR). AR is an attempt to combine the real and virtual world made through computers so that the boundary between the two of them becomes very thin [2]. In simple definition, AR can be defined as a real environment that is added to virtual objects. Some previous studies have examined how the application of AR was developed in various forms such as in the form of games [3] and in book [4,5]. In addition, the making of AR seen from the marker can be divided into two marker forms that were image and location based [6]. If viewed from the hardware used, AR can use desktop or mobile [7]. In addition, several studies have also tried to apply AR applications to learning. Some studies depict that the application of AR in learning can have a positive impact on learning such as increasing understanding of concepts on the subject of electricity [8]. The application of AR technology can improve laboratory skills and students’ attitudes towards physics laboratories [9], and also can increase learning motivation in computer learning [10] and facilitate learning of abstract concepts [11].

According to the rationale of explanation, this present study aims to create the learning multimedia based AR that can be used as one of learning medias in the classroom. Indeed, this present study gives the implication in the development of physics education research.

2. Method
The method used in this study was the waterfall method. The reason for using this method is because the waterfall method approaches systematically and sequentially in building a system. The process of the waterfall method that is on the execution of a system is done sequentially. The products produced will be a good quality due to their gradual implementation so that they are not focused on certain stages. There are four stages of the waterfall method [12] analysis, design, code, and test. The waterfall method stage can be seen in figure 1.

![Figure 1. Waterfall method.](image)

3. Results and discussion

3.1. Analysis stage
Analysis is carried out by making of literature studies on several books and journals related to the results of research on physics learning in electricity. The analysis that has been done starts with reading books and journals, understanding the contents, analyzing and describing them, and giving conclusions. The results of the analysis are obtained:

- Physics material related to electricity is composed of concrete and abstract concepts
- Abstract physical materials such as electricity, magnetism and modern physics are difficult to visualize, causing students to have difficulty in analyzing abstract physics concepts. This is what makes students think that physics becomes difficult and boring.

The conclusion from the results of the analysis is that an alternative learning media is needed to visualize abstraction physics concepts. One of the learning media that is considered to be able to help and facilitate students in learning abstract material physics is AR.
3.2. Design stage

Design of User Experience is an application design about how interactions on applications can run. Making this User Experience is carried out by using the Visual Paradigm application. There are three diagrams used, namely use case, activity, and sequence diagram.

3.2.1. Use case. The use case is an explanation of the functions that exist in the application system. The Use case scenario is a process of how the actor process runs certain functions contained in the application system. This scenario is described in detail in the table 1.

Table 1. Start function scenario.

| Actor Action                      | System reaction                                           |
|----------------------------------|-----------------------------------------------------------|
| 1. Press the start menu          | 2. Open the main page and activate the AR feature         |
| 3. Direct the camera at the marker| 4. Analyze markers, bring up objects arranged and menus to interact with objects |
| 5. Select the simulation menu    | 6. Run 3D object simulation                               |

3.2.2. Activity diagram. Activity diagram is a description of the activity of a system or process that exists in software. The activities contained in the AR application can be seen in figure 2.

3.2.3. Sequence diagram. Sequence diagram describes the behavior of objects in the use case by describing the life time of objects and messages sent and received among objects. The description of a sequence diagram based on the use case that has been made can be seen in figure 3.

Figure 2. Start activities.
3.3. Test stage

The next stage is the application testing stage with using 3 criteria: performance efficiency, portability, and usability. This test we will acquire the results to what extent the application is feasible to use.

3.3.1. Test results of performance efficiency. This test is conducted using an application on the cloudy site. Testing is carried out by using 10 samples of devices with different specifications. The results of the tests are as follows:

- Time behavior: Time Behavior is the aspect of how much time it takes to run an application. An average of 20-30 seconds the device can run the application.
- Resource utilization on the CPU: Resource Utilization on the CPU is the activity of the device by using CPU resources when running the application. Based on the data obtained, it can be seen that the average device can use CPU resources to be able to access the application is 14.4% with the use of a minimum of 5% and a maximum of 26%.
- Resource utilization on memory: Resource Utilization on Memory is a device activity using Memory resources when running applications. Based on the data acquired, it can be obtained that on average devices can use Memory resources to be able to access applications at 66.3MB with a minimum of 24MB and a maximum of 100MB.

3.3.2. Test results of portability. In testing this portability, the aspects tested are adaptability, install-ability, and replace-ability. Adaptability and install-ability aspects are tested by installing, running and uninstalling applications on various devices and OS versions. Results of testing adaptability and install-ability on various devices in the OS version show a success to install and uninstall. The following are the results of testing on 10 different devices with different brands and Android OS versions.
Table 2. Testing adaptability and installability.

| No | Device                | Android versions | Install | Uninstall |
|----|-----------------------|------------------|---------|-----------|
| 1  | Samsung Galaxy Grand 2| 4.3.0            | Success | Success   |
| 2  | Samsung Galaxy Core Prime | 4.4.4        | Success | Success   |
| 3  | Samsung Galaxy Grand Prime | 5.0.2        | Success | Success   |
| 4  | ZTE Blade S6        | 5.0.2            | Success | Success   |
| 5  | HTC Desire 826      | 5.0.2            | Success | Success   |
| 6  | Samsung Galaxy E5   | 5.1.1            | Success | Success   |
| 7  | ASUS Zenfone Go     | 5.1.1            | Success | Success   |
| 8  | Samsung Galaxy Grand Max | 5.1.1        | Success | Success   |
| 9  | OPLUSM               | 6.0.0            | Success | Success   |
| 10 | SONY X-peria XZ      | 6.0.1            | Success | Success   |

Based on the table-2 can be concluded that the AR application was successfully installed and uninstalled on a sample of 10 different devices. It can be concluded that the application meets the adaptability and install-ability standards with a percentage of 100% or "Valid".

Table 3. Analysis of test results of usability.

| No | Indicators     | Total score | Average | Classification |
|----|----------------|-------------|---------|----------------|
| 1  | Usefulness     | 945         | 3.93    | Feasible       |
| 2  | Ease of Use    | 1305        | 3.95    | Feasible       |
| 3  | Ease of Learning | 458         | 3.81    | Feasible       |
| 4  | Satisfaction   | 827         | 3.94    | Feasible       |
|    | Total          | 3535        | 3.9     | Feasible       |

3.3.3. Test results of usability. Usability testing was conducted by the method of directly testing the application to the user. This test is an additional test to support the results of the functional suitability test by conducting a test to see whether the application can meet the expected target or no. This testing is carried out by taking 30 participants (i.e. students in department of technology and information of one private college). The method for applying usability testing is to distribute markers in the form of cards to students and download AR applications that share via Bluetooth. Based on the results in the table-3, it can be concluded that the application meets the usability standard and a classification of "feasible". Usability testing is the end of the testing process for developing AR electricity applications.

The progress and development of Science and Technology (Science and Technology) especially Information and Communication Technology today is growing rapidly. The development of information and communication technology has brought great changes in various fields of life, not least in the world of education. Technology needs to be applied in learning to facilitate the teaching and learning process. one of the studies shows that the integration of technology in learning can improve students' critical thinking skills [13].

The importance of technology in classroom learning requires us to make various technological applications to be used in learning. One of the technologies that can be developed is augmented reality. Based on the results of the analysis above, the augmented reality media developed has been feasible to be used especially to be applied in physics learning at school

4. Conclusion

There are three conclusions obtained from this study. First, from the aspect of portability, the AR application developed has fulfilled the portability aspect because it was successfully installed and uninstalled on 10 different devices. Second, a review of performance efficiency aspects shows that the
application has met the standards to be able to run the application. Finally, from the aspect of usability, this application is easy to use by participants—in the other words this application fulfills aspects of usability.

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