Development of virtual reality-based learning media on electromagnetic wave radiation material

M J Shepa*, V Serevina and I M Astra

Department of Physics, Faculty of Mathematics and Natural Science, State University of Jakarta, Pemuda Street No. 10, Rawamangun – Jakarta Timur, 13220

*jennishepa94@gmail.com

Abstract. The aim of this study to develop virtual reality-based learning media on electromagnetic wave radiation material. The research method used the research and development (R & D) with the ADDIE models (Analysis, Design, Development, Implement, Evaluation). Data collection techniques used through observation and questionnaires. The development of virtual reality-based learning media was done in School of St. Yoseph Bekasi. This development research was conducted on science subject teachers. This virtual reality-based learning media has been validated by experts, that is content experts and media experts by providing validation instruments. Virtual reality-based learning media can be used to simulate a learning process that does not allow direct involvement because it will be dangerous for learning participants in this covid19 pandemic era. So, the virtual reality-based learning media just tried to the teachers and experts. The conclusion of this research was the development of virtual reality-based learning media on electromagnetic wave radiation material can be used as a learning resource for students.

1. Introduction
The world has entered the era of the industrial revolution 4.0 and requires human resources who do not only rely on technical abilities. This fourth-generation industrial revolution is marked by the emergence of super-computer and artificial intelligence [1]. The challenge for education in the future is how to prepare human resources that cannot be replaced with machines. To face this challenge, there are several competencies needed, including the ability to solve problems (problem solving), adaptability, collaboration, and creativity and innovation. Therefore, the role of education is very influential in order to be able to create students who will become long life learner.

From the results of questionnaires through google form to 53 (fifty-three) respondents spread across several schools in Jakarta and Bekasi, 83% of them stated that their teachers had been using online learning media, but 17% of them stated had not. 79% of the online learning media are generally in the form of websites, but the files uploaded in the websites are still in the form of pdf and ppt files. There only a small amount of schools who have provided websites in the form of video, animation, and simulation lessons. 83% of respondents stated that they have not used virtual reality as the technology that supports the learning process, but 17% of them stated that they have. 70% of respondents stated that virtual reality needs to be developed to support learning process.

To answer the problems faced in the world of education nowadays, it is necessary to develop media that helps learning process. Three-dimension virtual world or virtual reality (VR) is a technology that...
can be used to help and enrich media and learning effectiveness. The ability of this media visualization to mimic the real world into the virtual world makes the imitation of reality animation imitation closer to this virtual world.

In a study on learning and application for education solar system based on virtual reality technology, it is stated that virtual reality technology applied in the planetarium application is proven to be a planetary learning simulation, which is able to create a new and interesting atmosphere for users, so that users can learn and play in this application. Users can see planetary objects and celestial bodies in the solar system, in which this application is almost the same as the real situation in the outer space environment [2].

Moreover, like any advancement in technology, virtual reality is a tool that must be used properly in order to be effective. Despite the great promise of virtual reality use, over the years the cost and computational power required to produce a realistic environment are major barriers in the use of virtual reality media in education (Merchant et al., 2014; [3]). In addition, some virtual reality systems are difficult to use and the equipment that the user needs is a rather complicated process. Fortunately, technological advances for mobile devices have reduced the size of virtual reality devices and for some deterioration in quality, inexpensive audience mobile devices such as Google Cardboard have made virtual reality devices very affordable and easy to use [4].

Based on the analysis of previous studies by concerning on various advantages and disadvantages, as well as the results of filling out questionnaires that were distributed to several schools, a synthesis was obtained that could provide research opportunities, namely the development of virtual reality-based learning media with Electromagnetic Wave Radiation material studied in high school classes, grade XII (twelve). The results of the synthesis show that the use of virtual reality media in the classroom can increase engagement in learning, provide constructive experiences, create new points of view, and the ability to visualize models that are difficult to learn. The creation and development of virtual reality-based learning media will be validated by media experts and material experts so that an attractive design presentation is obtained, the content of the material is in accordance with the learning objectives, and the right physical concept.

1.1. Study literature

1.1.1. Learning Media. According to Rusman, et al., media is a presentation technology using text, audio and visual at the same time. The advantage of media is that it combines all elements, such as text, video, animation, images, graphics, and audio into a single presentation so that it accommodates students who have visual, auditive, and kinesthetic types [5]. Furthermore, Purwanto said that media in learning is a combination of various media consisting of text, graphics, still images, animation, sound, and video. Examples of interactive media are interactive learning media, game applications, and others [6]. In general, the benefits that can be obtained from learning media are that the learning process becomes more interesting, more interactive, the amount of teaching time can be reduced, the quality of student learning can be improved, and the teaching and learning process can be done anywhere and anytime, and student learning attitudes can be improved.

1.1.2. Virtual Reality. Virtual reality, abbreviated as VR, can create a three-dimensional world simulation by bringing up a three-dimensional image created by means of a computer with the help of certain equipment and applications.

The most important characteristic is that people who feel the virtual world are deceived and believe that what they experience is reality, even though it is only a picture that resembles reality. Virtual reality generally presents a visual experience, displayed on a computer screen or via a stereoscopic device, but some simulations include additional sensory information, such as sound through speakers or headphones.
In general, VR is an interactive and participatory experience based on three-dimensional graphics (3D) through a head mounted display (HMD) that is connected and simulated by a computer directly (real time) [7]. According to the virtual reality society on the page https://www.vrs.org.uk/, VR is the creation of a virtual environment that is presented to our senses in such a way that we experience them as if we were actually there. Virtual reality (VR) is the use of computer technology to create a simulated environment [8]. Reporting from the Wikipedia page, virtual reality is a simulation experience that can be similar to the real world or completely different. Then, VR is a set of hardware and software components that make it possible to realize a virtual reality environment [9].

With the consideration of using cellular technology such as smartphones / smartphones and tables, the use of virtual technology is more feasible and affordable for educational institutions and students, so it is very relevant to understand the advantages and disadvantages of using technology in an educational environment [10]. Google cardboard is a wireless HMD made of cardboard and consists of two optical lenses. This tool uses a smartphone as a provider of virtual nature through the Google Cardboard application which is available on iOS or Android. The requirement for a smartphone to be used as virtual reality media is to have an accelerometer and gyroscope sensor.

![Google Cardboard](image1.png)

**Figure 1.** Google Cardboard

In his article entitled 'The Most Important Virtual Reality Sensors and Why They Matter', on the appreal-vr.com site, Yariv Levski states that the accelerometer actually has a number of different functions, but is mainly used to tell a device which direction it is facing. For example, on your smartphone or tablet, the accelerometer will tell a device whether it should be in portrait or landscape mode depending on the way in which the device is being held.

![Accelerometer](image2.png)

**Figure 2.** Illustration of the accelerometer function on a smartphone

According to the site www.elprocus.com, a gyroscope sensor is a device that can measure and maintain the orientation and angular velocity of an object. This sensor is more advanced than the accelerometer. A gyroscope can measure the inclination and lateral orientation of an object whereas an accelerometer can only measure linear motion. Apart from sensing angular velocity, the gyroscope sensor can also measure object motion. For a more powerful and accurate motion sensor, the gyroscope is combined with an accelerometer sensor.
The software used in making this virtual reality-based learning media are as follows:
a) Unity for Windows version 2018.4.17f1
   Software used to create Virtual Reality applications.
b) Visual Studio Code version 1.4
   This software is for creating scripts in Virtual Reality. The software workflow used to create Virtual Reality with Unity is as follows:

![Software Workflow Diagram]

**Figure 3.** Illustration of the gyroscope function on a smartphone

**Figure 4.** Software Workflow

2. Research methods

The research method used in this research is research and development (R & D), by following the ADDIE model stages. The first stage is analyze, which is a stage where the researcher collects information related to the existing problem. The Analyze stage was carried out by analyzing the needs of teachers in the form of distributing questionnaires and literature studies. Furthermore, the design stage, is concerned with developing ideas that can be the answers to the problems faced in the analysis stage. Ideas related to learning objectives, assessment instruments, learning content, analysis of subject matter, lesson planning and selection of appropriate media. Furthermore, the development stage, in which virtual reality-based learning media has been realized. There is a validation instrument for media and material experts. Product revisions are carried out based on feedback from experts. Revisions are deemed unnecessary when the experts agree that the product is fit for testing. Furthermore, the implementation stage, due to the Covid-19 pandemic conditions, the implementation of this media cannot be done to students, but will be implemented to the validator. The main objective
of this implementation stage is to ensure that the media developed is suitable for use so that it can support the learning process and achieve learning objectives. The last stage is evaluation, which is a process carried out to determine the value, price and benefits of an object. In this case the object being assessed is a product or learning program.

The validation instrument carried out by media and material experts is determined using a Likert scale, where scale 5 = strongly agree, scale 4 = agree, scale 3 = disagree, scale 2 = disagree and scale 1 = strongly disagree. Furthermore, the results of validation carried out by media and material experts are calculated using the following equation:

\[ \bar{X} = \frac{\sum x}{N} \]  

Information:
\[ \bar{X} \] = the mean score of each component
\[ \Sigma x \] = total score
\[ N \] = number of indicators assessed

Changing the average score into a qualitative value according to the literature [11, p. 238] is as follows:

| Score range | Average score | Category          |
|-------------|---------------|-------------------|
| \( X > \bar{X}_t + 1,8 \) | \( X > 4,2 \) | Very good         |
| \( \bar{X}_t + 0,6 sbi < X \leq \bar{X}_t + 1,8 sbi \) | \( 3,4 < X \leq 4,2 \) | Good             |
| \( \bar{X}_t - 0,6 sbi < X \leq \bar{X}_t + 0,6 sbi \) | \( 2,6 < X \leq 3,4 \) | Enough           |
| \( \bar{X}_t - 1,8 sbi < X \leq \bar{X}_t - 0,6 sbi \) | \( 1,8 < X \leq 2,6 \) | Less             |
| \( X \leq \bar{X}_t - 1,8 sbi \) | \( X \leq 1,8 \) | Very less         |

In accordance with these criteria, the media can be determined to be good if the minimum value is Good. So, if the mean value of media experts, material experts and teacher questionnaires get a good value, then the media is declared worthy of use.

3. Results and Discussion

3.1. Product developed “virtual reality-based learning media”

The development which was carried out resulted in a product in the form of virtual reality-based learning media with electromagnetic wave radiation material. This virtual reality-based learning media is presented in the form of an android application which can be installed and opened on an Android-based smartphone equipped with a gyroscope and accelerometer sensor. This media presents electromagnetic wave radiation material in accordance with the basic competencies 3.6 and 4.6 in Physics learning materials in class XII. This material is packaged in the form of virtual reality which can give the impression that the users of this media can see the material object directly. Material objects can be seen using the help of virtual reality glasses. Virtual reality-based learning media is equipped with a media usage manual, which will be described and explained as follows:
Figure 5. Smartphone VR app media display

Figure 6. Main display of VR media

Figure 7. Simulation manual menu display

Figure 8. Display of several sub menus in the simulation menu

Figure 9. Electromagnetic wave sub menu display

Figure 10. Sub Menu Display Types of Electromagnetic Waves

Figure 11. Sub menu display of one type of electromagnetic wave

Figure 12. Display of Practice Questions in Evaluation Sub Menu
Figure 13 Final View of the Exercise Problem

Figure 5 is a VR media app display on a smartphone. Figure 6 is the main display of VR media when we open the VR application. There are 4 menus in this main display. They are Simulation Guide, Simulation, Developer Profile and Exit menu.

Figure 7 is a simulation manual menu display, which serves as a guide for the use of instructional media, in order to use VR media optimally and prevent errors in the use of the media.

Figure 8 is a sub menu display on the simulation menu. There are four sub menus. They are electromagnetic waves, types of electromagnetic waves, evaluation and return. Figure 9 is a sub menu display of electromagnetic waves. There are several sub menus. They are material, history, spectrum, video and back. Sub sub-menu material and history is a brief explanation of electromagnetic waves. The spectrum sub menu provides an image of the wave spectrum, the video sub menu contains short videos of electromagnetic waves in general. The sub sub-menu returns is provided to return to the initial VR media display. Figure 10 is a sub menu display of the types of electromagnetic waves. There are seven sub menus which are types of electromagnetic waves, namely radio waves, microwaves, infrared rays, visible light, ultraviolet rays, X rays, and gamma rays. The explanation of the sub menu for each type of electromagnetic wave is shown in Figure 11. In each type of electromagnetic wave, there are sub sub-menus consisting of materials, benefits of radiation, radiation effects and returns.

Figure 12 is a display of the evaluation sub menu. There are 20 number practice questions presented in this VR media, and Figure 13 is a display at the end of the work on the practice questions. There is a simulation list menu and return to exit the sub sub-menu evaluation.

3.2. Validation

The development of learning media based on virtual reality in this research is carried out until the expert validation stage. Validation result of learning media based on virtual reality to be evaluated before product trial run. Expert assessment result are presented in tables 3.1, 3.2 and 3.3 as follows:

| Table 3.1. Validation of Media Experts |
|----------------------------------------|
| Aspect       | Indicator                        | Average score |
|--------------|----------------------------------|---------------|
| Easy to see  | Text clarity                     | 4.5           |
|              | Clarity of 3 animation size      | 4             |
|              | Video Quality                    | 4             |
|              | Sound quality                    | 4             |
| Interesting  | The charm of virtual reality media | 4             |
| Simple       | Ease of using virtual reality media | 5             |
Useful
Right and can be accounted for
Arrangement
Design

Usefulness of virtual reality media
3D animation supports understanding the concept of electromagnetic wave radiation material
Video clarity in explaining electromagnetic wave radiation material
Clarity of instructions for use
Compatibility of application icon with electromagnetic wave radiation material
The triumph of color in the media
Feasibility of virtual reality media layouts
Clarity of menu choices in virtual reality media

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Guided by the result of the media expert's validation on this VR-based learning media, getting a score of 86.12%. The result of the media expert's validation can be stated that VR-based learning media can be used. The revision of the media is to provide examples of current electromagnetic wave radiation to attract the attention of media users.

**Table 3.2 Validation of Material Experts**

| Aspect          | Indicator                                                                 | Average Score |
|-----------------|---------------------------------------------------------------------------|---------------|
| Contents        | Suitability of the media with the core competencies of electromagnetic wave radiation material | 4,5           |
|                 | Compatibility between animation, video and audio in the media with electromagnetic wave radiation material | 4,5           |
|                 | Cluster of electromagnetic wave radiation material in virtual reality media | 5             |
| Conformity of concepts | The accuracy of the narrative (explanation) of the matter of electromagnetic wave radiation | 4,3           |
|                 | Accurate video about the benefits and effects of electromagnetic wave radiation | 4,5           |

Guided by the result of the material expert's validation on this VR-based learning media, obtaining a score of 89%. The result of the material expert's validation can be stated that VR-based learning media can be used. The material revision provides an initial simulation of the electromagnetic wave radiation material to better attract the user's attention.
| Aspect               | Indicator                                          | Average Score |
|---------------------|----------------------------------------------------|---------------|
| Media design        | Media display quality                             | 4             |
|                     | proportionality of assets in the media             | 4             |
| Language and Voice  | readability of the writing                         | 4,3           |
|                     | sound quality                                      | 4,1           |
|                     | use of language                                    | 4             |
| Features in Media   | functionality of features                          | 4             |
|                     | interactivity of features                          | 4             |
|                     | features support understanding                     | 3,8           |
| Media Use           | ease of use of media                               | 4             |
| Content of the      | suitability of the material                        | 4             |
| Material            | delivery of material                               | 4,6           |
| Media in Learning   | media worthy of use in learning                    | 4             |
|                     | quality of learning media                          | 4             |
|                     | media motivates educators to develop VR media      | 4             |

Guided by the results of the questionnaire distributed to teachers on this VR-based learning media, obtaining a score of 87.82%. The results of the questionnaire can be stated that VR-based learning media can be used. No revisions were made because all comments were included on suggestions that cannot be used as material for revising the product. For example, replacing the media background with an image of the electromagnetic wave spectrum, and discussing all the practice questions that must be included in the media.

4. Conclusion

Based on the results of the research above, the conclusion of this research was the development of virtual reality-based learning media on electromagnetic wave radiation material can be used as a learning resource for students. Virtual reality-based learning media can be used to simulate a learning process that does not allow direct involvement because it will be dangerous for learning participants in this covid19 pandemic era. This virtual reality media application can be downloaded and opened on an android-based smartphone that supports gyroscope and accelerometer sensors. The use of virtual reality-based learning media is assisted by the virtual glasses of Google Cardboard.

The size of the application is too large because it discusses the whole topic of electromagnetic wave radiation to be one of the issues that must be rethought for further research. In addition, the availability of hardware, such as google cardboard and android smartphone with gyroscope and accelerometer sensors is also a common problem to find solutions so that the learning process using virtual reality media can be run and become a solution for effective learning for students and teachers.

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