The design of sound wave and optic marker for physics learning based-on augmented reality technology

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Abstract. This research aims to design and develop the augmented reality marker of sound wave and optic topics for physics learning. Augmented reality is a technology that can provide visualization and integration a perspective. The develop stages consist of determine the instructional needs and goals, develop the markers, and evaluate the design from peers. This research generated eleven markers: (1) how sound wave made a stress and strain in a percussion phenomenon, (2) the Doppler Effect, (3) the application of organ pipe, (4) the diffraction of the light, (5) the interference of the light, (6) the polarization of the light, (7) how the eyes make object, (8) how the camera make object, (9) how the magnifying glass work, (10) how the microscope work, and (11) how the telescope work. The markers expected to assist in the achievement of the instructional objectives. The peer assessment results indicate that the marker design on sound wave and optic topics supports the physics learning through technology rich environment.

1. Introduction
Sound waves and optics are a major topic of the developing competence in physics. For example, in optics student will discuss about the concept of single or double slit, this concept is a prerequisite for understanding the quantum mechanics [1]. Some research shows that students have difficulties in developing a conceptual understanding of optics [2-4]. The other research shows similar case in sound waves topics. Many students are unable to interpret common interpretations of sound waves, are unable to account for the underlying wave model of sound [5].

One of the most important reasoning for lack interpretations in physics is a textbook [3]. The one of the cases is textbook only show a figure about how an object seen, as the result is students generally cannot demonstrate a link between the eye and viewed object [6]. Figure in textbook cannot show the process. But with using the Augmented Reality (AR) technology, figure in textbook we can showing this process.

AR is a technology that develop by combination of virtual and real world and made by computer [7-9]. AR become famous in many fields, including industry and military, travel and tourism, medicine and health care, retail and marketing [7], and training and education [4,7,10,11]. AR for educational users offers several special pedagogical opportunities, including mobility, visualization, alternative perspectives, comparison/contrast of multiple perspectives, and integration of multiple perspectives [7]. Specially AR-based learning with the formative assessment mechanism significantly enhances the learners’ learning achievements and motivation and reduces their cognitive load [7,12]. Based on the
benefit of AR specially visualization and integration a perspective, that is possible to combine a figure (example in a textbook) and AR technology where the AR technology can display the videos [13]. The videos help students to developing a conceptual understanding and the term for scanned figure is a marker. For display the videos, students must scan the figure by using application on smartphone.

After considering the problems, this research finally made a design of a sound waves and optics marker for physics learning based-on AR technology. The develop stages for made a design consist of determine the instructional needs and goals, develop the markers, and evaluate the design from peers. AR that when triggered played a short video about sound waves and optics. This video will help students for developing a conceptual understanding of sound waves and optics. Outputs of this research are eleven markers and AR application for android platform.

2. Materials and method

The materials of eleven markers are eleven pictures uploaded on Vuforia. Before uploading, make sure that the marker uploaded on Vuforia has a good rating because a good rating will make AR applications easy in displaying videos. Other terms and conditions are that the smallest marker rating is three out of five stars and the size of the bit depth allowed by Vuforia is only 8 bits of gray scale or 24 bits of RGB with a JPG or PNG file type. To change the bit depth markers, in this study we use Adobe Photoshop CS6.

The materials of AR application are:

2.1. Vuforia software

Vuforia is an augmented reality software development kit (SDK) for mobile devices that enables the creation of augmented reality applications [14]. Vuforia platform supports all smartphones and tablets include android platform [8].

2.2. Unity

Unity is platform for created the AR. Most AR experiences around the world were created with Unity [15]. Unity can build the final project as an iOS, Android, Windows, OS X, Web Plugin, Flash, Xbox 360, PlayStation 3, Wii U [8].

2.3. Videos

A short video about sound waves and optics triggered played by using AR application [13]. The videos used is sourced from YouTube.

2.4. Videos editor

Videos used from YouTube must be edited. The editing process including, trim the video, merger the video, insert a text, dubbing, and add an original URL of video. Recommended video duration is less than one minute because the longer video will increase the size of AR application.

The research and development method consist of determine the instructional needs and goals, develop the markers, and evaluate the design from peers. The stage of determine the instructional needs and goals is analyze the instructional needs and goals such as the purpose of a marker, several concept physics materials, the instructional to determine the learning indicators and analyze the smartphone devices that support AR technology. The stage of develop we made a eleven markers about: (1) how sound wave made a stress and strain in a percussion phenomenon, (2) the Doppler Effect, (3) the application of organ pipe, (4) the diffraction of the light, (5) the interference of the light, (6) the polarization of the light, (7) how the eyes make object, (8) how the camera make object, (9) how the magnifying glass work, (10) how the microscope work, and (11) how the telescope work. The last stage is evaluating the design from peers; we test a legibility for check that any problem with the marker or not. Then, evaluate the design.
3. Results
The result of physics materials, the instructional to determine the learning indicators, and analyze the smartphone devices that support AR technology shown in Table 1.

| Table 1. The result of determine the instructional needs and goals. |
|---------------------------------------------------------------|
| **Result** |
| **Physics materials** | The physics materials including introduction sound waves, The Doppler Effect, the organ pipe, the light waves (diffraction, interference, and polarization), and the optical device (the eyes, camera, magnifying glass, microscope, and telescope) |
| **Indicators** | Student can describe about how sound waves made, the characteristics of light, and how an object is seen using an optical device. Student also can show the phenomena of Doppler Effect and application of organ pipe in real life. |
| **Smartphone devices** | Smartphone for android platform with minimum version is 4.4.1 (Kitkat), and maximum version is 8.1 (Oreo). |

The results of the marker purpose and develop stage shown in Figure 1-11. For scanning the marker, the design of marker can be use in softcopy and hardcopy. Use in softcopy it means markers not printed, so marker display in computer or phone. Use in hardcopy it means the marker printed in a paper.

**Figure 1.** Display video and explain how sound wave made a stress and strain in a percussion phenomenon.

**Figure 2.** Display video and explain The Doppler Effect.

**Figure 3.** Display video and explain the application of organ pipe.

**Figure 4.** Display video and explain the interference of light.
Figure 5. Display video and explain the polarization of light.

Figure 6. Display video and explain how the camera work.

Figure 7. Display video and explain how the eyes make object.

Figure 8. Display video and explain how the telescope work.

Figure 9. Display video and explain the diffraction of light.

Figure 10. Display video and explain how the microscope work.

Figure 11. Display video and explain how the magnifying glass work.
Beside developing markers, at this stage also produces an AR application. This application is used to display the video. The result of test a legibility for check that any problem with the marker or not, shown in Figure 12.

![Image](image_url)

Figure 12. Test a legibility the marker printed using android smartphone.

The aspects of evaluate from peers are the user interface AR and Content AR. The user interface AR has two indicators, the suitability of interface and marker consistency. Content AR has three indicators, the suitability of video with concept physics materials, the quality of video, and completeness of video source. The result of evaluate the design from peers shown in Table 2.

| Indicator                                      | Value    |
|------------------------------------------------|----------|
| User interface AR                              |          |
| The suitability of usability interface         | 80%      |
| Marker consistency                             |          |
| Content AR                                     |          |
| The suitability of video with concept physics materials | 87.50%   |
| The quality of video and Font size in video   |          |
| Completeness of video source                   |          |

4. Discussion

The problem in determine the instructional needs and goals lies in smartphone devices. Not all students use smartphone with android platform, and moreover, the android version also changed. The first optional to overcome the limitations of not all students use smartphone with android platform is students who have android smartphone can lend it to other students. The other optional is students use android smartphone together. Both are ways to overcome these limitations. Then, the solution to overcome the limitations of android version changes is the developer must set up the minimum API Level and Target API Level in Unity and next build the AR application shown on Figure 13.
Process uploading images to Vuforia has a problem. The problem is the picture has a low augmentable value. The problem can be overcome by edit the images. One of the process editing images is adding a shape on image to increasing the augmentable values. Figure 14 show the picture with bad augmentable values before adding a shape on image. Figure 15 show the picture with good augmentable values after adding a shape on image.

Researchers also changes some marker after test a legibility. The image was changed with the reason for consistency between the maker and the video displayed. The final images used was taken from the displayed video. The pictures shown in Table 3.

Table 3. Image changes after test a legibility.
The user interface AR has two indicators and four assessments. First indicator is the suitability of interface. This indicator has two assessments, include interface colour theme and menu layout. The value of interface colour theme is average because of the dark color composition. Therefore, we made revision theme colour in AR application (Table 4). But the value of menu layout is very good because position of menus is friendly. The menu can be found easily. Second indicator is marker consistency. This indicator also has two assessments, include consistency of size marker and consistency between the maker and the video displayed. The value of both are good; it means the marker consistency were good.

| Table 4. Revision theme colour in AR application. |
|--------------------------------------------------|
| **Before**                                      | **After**                                      |
| ![Before](image1.png)                           | ![After](image2.png)                          |

Content AR has three indicators and eight assessments. First indicator is a suitability of video with concept physics materials. This indicator has one assessment, a suitability of video displayed with physics concept materials. The value of suitability of video displayed with physics concept materials is good because the video displayed already leads to indicator. Second indicator is the quality of video and typography in video. This indicator has six assessments include the resolution videos, colour theme, font style, font size, back sound, and sound quality. But the value of the resolution videos, colour theme, and sound quality are good. The value of font style, font size, and back sound are very good because by using explanation in audio-visual (sound, video, and text) concept was delivered easily. Third indicator is a completeness of video source. This indicator has one assessment, a video source in every displayed video. The value of source displayed video is good it means not very good because the source video display shortly so it hasn't read.

5. Conclusion
The sound wave and optic augmented reality marker for physics learning have been developed. The evaluate results (peer review) of sound waves and optic marker for physics learning based-on augmented reality technology is the design of marker on sound waves, and optic topics can support the physics learning. Future research is the integration of evaluation based on augmented reality technology and its implementation of students' understanding of sound wave and optic subject.

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