Development of augmented reality in the basic physics practicum module

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Abstract. This research aims to design and develop a media lab in the form of Augmented Reality applications that are used in basic physics lab module. AR applications work with a tracking system and the reconstruction of the 2D marker contained in the experimental module to display 3D video animation. The method used in this research is the development of software includes the stages of collecting and analyzing the needs, do the design and manufacturing applications, validation and testing by the user, and revision. Results of the assessment by the AR application validator media and materials are respectively 80\% and 85\% in the predicate is valid and may be used after minor revisions. The results of trials by students as the user indicates that the 2D marker on lab module was initially less obvious and less sensitive at the time of scanning. However, after the revision of the 2D marker on lab module, 2D AR marker was sufficiently clear and sensitive at the time of scanning so that AR can help the general practical implementation and the AR content to support the practical implementation. The results showed that the development of AR applications had been successfully carried out and the AR application can function well with the scan time 1-1.5 second at a distance of 10-20 cm and successfully used in the experimental module at an angle of \(<90^\circ\), with the result that, AR applications in basic physics practicum module as the media are supporting practicum implementation

1. Introduction
Laboratory activities are an integral part of the physics classroom learning activities that can serve as advice for finding and reinforcing the concept, develop skills, motivation to learn, and build attitudes towards physics [1-3]. Practical activities carried out by following the steps in the pilot or experimental module that is tailored to the theme of the lab. Modules are teaching materials arranged in a systematic, contains a set of learning experiences are planned and designed to master the specific goals of learning [3]. The module as one of the teaching materials characterized by student self-learning principle [4].

The quality of basic physics practicum modules can be found from the assessment of practicum modules. Needs analysis study conducted to determine the state of implementation of the basic physics lab at the two universities. Data was collected by documentary studies on lab module and the RPS to determine the practical outcomes to be achieved in a practical implementation. Needs analysis study results to show that the practical implementation using only conventional lab modules [5] and not
involve ICT technology in it. Students are having difficulty in understanding the basic concepts of practical matters because the lab module is only a summary of the material of the concept. Another difficulty experienced by students is to understand the shape of the electrical circuit and the direction of motion of electric current in an electrical circuit on the topic of the dynamic lab. Findings were similar in practical topics such as fluid topics, thermodynamics.

Based on the findings of the study needs analysis, to help students understand the material lab, and it is necessary to develop an AR application that is integrated into the lab module. AR application provides the opportunity for students to engage actively and interactively in real time in practical activities and gain real experience. Advantage adds AR in the lab module is of practical value in accessing the material basis of concept lab back in the object animation or video to ensure some basic concepts were forgotten during the practicum takes place. Another advantage is the AR display visualization phases of laboratory work in abstract topics such as electricity, heat, thermodynamics, and fluid.

Augmented Reality (AR) technology is a combination of real objects and virtual objects. Real objects such as pictures or objects as AR marker while the virtual object can be text, animation, 3D models, or video combined with the actual environment so that users feel virtual objects in the environment [5]. Adding AR technology in modules or practical guides can help improve the perception and mastery of concepts students [6]. Results of previous studies show that adding the AR in learning can improve the performance [7, 8], motivation and interest [9, 10], retention of knowledge [11], participation, attitudes [12-14] and process skills [14, 15]. Other than that, the use of augmented reality in practical activities can help students to interact with digital content, thus enhancing the imagination and creativity [16, 17]. However, some studies have found that the addition of AR technology in learning can impact [18, 19] as sensitive to changes in viewpoint marker and requires a lot of memory on the equipment installed [20, 21]

AR applications work with the system tracking (tracking) and reconstruction (reconstruction). The tracking process begins with detecting the 2D marker on a sheet of modules or practical guides via webcam or camera gadget/smartphone. Data from the tracking used to reconstruct the real object coordinate system. 2D Marker must be registered in advance using Vuforia SDK and processed using the Unity game engine by adding a resource such as 3D animation, video, audio, and programming line [20]. To add the complete menu and other additional features, the AR application of Unity exported to Android Studio to be stored in the form of apk. When the application is started, the camera on the gadget/ android smartphone to scan the 2D marker and then send the information to the device [22, 23].

Furthermore, the purpose of this research is to design and develop AR applications that are used in basic physics lab module. AR applications started working with 2D tracking marker that had been prepared in the lab module. Coverage of the material in the lab module created is compatible with a range of material in Physics lab course the Faculty of Education.

2. Methods
The methodology used in this study is the method prototype. Prototype development involves the analysis of functional requirements or software selection, design, evaluation, and implementation [24]. Four prototyping process [25] is to collect and analyse the needs; do the designing and making of the application; expert validation and testing by the user (evaluation), and revision. This process has undergone several iterations (repetitions) in steps three and four for users to accept and be satisfied with the development of the software being developed. Figure 1 shows the flow chart about development process.
Validation of the application involves two experts as validators consisting of media experts and validator mater experts. Both validators provide an assessment of the four markers which has been prepared in the lab module. Validator media will assess the AR application based on the theories of instructional media or practicum that includes aspects of public view, the use of language, animations and sound, on-screen display and presentation while validator material will assess the media based on the suitability of the material presented in the media augmented reality that includes relevance material with the expected competence, suitability of the material with the medium used, the presentation of cutting-edge materials, accuracy of the material according to the principles of truth and science, and packaging material in the media is in conformity with the relevant scientific approaches.

Validator provides an assessment by giving a checkmark on the scale is appropriate. Range grading scale is from 1, 2, 3, 4, and 5 with the criteria of grading scale is 1 = irrelevant / not good, 2 = less relevant / less good, 3 = relevant enough / pretty good, 4 = relevant / well, 5 = very relevant / very good. The validator also provides advice on improvement of AR applications. Comments validator is provided for each marker. Table 1 gives the criteria of media validity [26] which are used as a reference in this research development. The test performed on the user AR application, the students taking the basic physics course.

### Table 1. Media evaluation criteria

| Percentage | Description  | Recommendations          |
|------------|--------------|--------------------------|
| 25 – 40    | Invalid      | Cannot be used           |
| 41 – 55    | Less Valid   | Cannot be used           |
| 56 – 70    | Enough Valid | May be used after major revisions |
| 71 – 85    | Valid        | May be used after minor revisions |
| 86 - 100   | Very Valid   | Very good to use         |

3. Result and Discussion

#### 3.1 Design and manufacture Prototype

AR Design begins with determining the 3D model or animation video that is displayed in the application AR, AR lab module design series, and 2D AR marker design. Flow application design AR app use case shown in Figure 2 and Figure 3 below.
Figure 2. AR product design workflow

Figure 2 shows the flow of the AR application design that starts with setting up the 3D models/animations/videos for records in AR library then set the script and build applications that will read the AR marker that had been prepared in the lab module. Figure 3 provides an explanation Use case or grooves user interaction with the AR application that begins by scanning the AR marker on lab module with a smartphone camera will then display a 3D model/animation/video that has been designed.

Prototype manufacture AR applications require hardware (hardware) the computer/laptop with Windows 10 operating system, 8 GB of RAM. Other hardware is a phone with the Android operating system as the operation of mobile AR applications. Mobile phone specifications used by the processor ARMv version 7 and above, supports OpenGLES 2.0, camera, accelerometers, magnetic sensors, and GPS [27]. While the software used in the manufacture of the AR application is Vuforia SDK, the Software Development Kit to record 2D Marker in Practice Module. Next is the Unity, which serves to create AR applications and process the 2D marker of Vuforia SDK. Other software used is ADT (Android Development Tools), which is software for building applications based on Android; it includes the Android SDK and Eclipse as an IDE (Integrated Development Environment).

AR application process involves the observation of any support needed for Vuforia SDK, and Unity can work. Based on observations in mind that it takes Library Android is a system built using Java, so it needs to be considered whether the JRE (Java Runtime Environment). ADT used was version 22.0.1 and Android used is at least version 4.1 (jelly bean) both devices requires JRE 1.6. USB debugging is required for running the apk after the build in unity. Other Google API Library’s 17, the library is required to run a minimum of Android version 4.1 (jellybean).

3.2 Validation application AR
Table 2 illustrates the results of the assessment augmented reality application validator media and experts. Each validator assesses the four markers.

Table 2. AR application improvement recommendations by Validator

| Validator  | Score | Objects Ratings | Recommendations put forward |
|------------|-------|-----------------|-----------------------------|
| Media      | 80%   | Marker 1 (tools and materials) | Need to add information on tools and materials, such as the size and length of the wire, the type of bulb, the number of switches, etc. |
|            |       | Marker 2 (series circuit)      | Need to add sound effects on the AR object, information barriers and the battery voltage value needs to be raised in the AR display |
|            |       | Marker 3 (parallel circuit)    | Need to pay attention, any part of the lab module that needs and do not need to be made AR |
|            |       | Marker 4 (measurement technique) | Using standardized and appropriate language EYD in the display explanation of the concept |
| Content    | 85%   | Marker 1 (tools and materials) | |
|            |       | Marker 2 (Series circuit)      | |
Based on Table 2 above, every validator provides an assessment of the four markers. Marker 1 contains an AR view of the tools and materials lab, load the AR marker 2 on the circuit Series, 3 loads the AR marker on the parallel circuit and load the AR marker 4 on the measurement of voltage and current in series and parallel circuits. Media expert assessment on each marker, indicating a valid application of AR in the category, with a percentage of 80% value in the range of 71-85% with a valid category, may be used after minor repairs. While the expert assessment of material on each marker, indicating that a valid application of AR in the category, with a percentage value of 85% in the range of 71-85% with a valid category, may be used after minor repairs. Both Validator provides AR app ratings in the category of valid and may be used after minor repairs on each marker 2D. The second recommendation validator, in general, is all the AR marker on the module is less clear and less sensitive at the time of scanning. Also, improving the appearance of the AR to add sound effects, using operational and communicative language.

### 3.3 User trials

The next stage is to test the AR application users are students taking basic physics practicum courses. Table 3 shows the student's response to the AR application in practical implementation.

**Table 3. Test Results AR applications on User**

| User            | The response stated                                                                 |
|-----------------|-------------------------------------------------------------------------------------|
| College student | 2D marker on lab module of less legible (vague), less sensitive at the time of scanning marker |
|                 | AR app helps practical implementation, but it takes time to be able to scan the marker |
|                 | AR appearance less attractive, because of the layout and the menu list is less appropriate color selection |
|                 | If the added sound effects in the video display will be more easily understood |

Table 3 shows the test results in AR applications that respond to the AR application. Based on the response stated, AR applications still need improvement in 2D Markers and display video from the results of the scan to be added sound effects.

### 3.4 Revision

The final stage of development of AR applications is the revision based on the recommendation validator and test results by the students as a user. Revision 2D dominant marker contained in the lab module so that the AR application can help the general practical implementation and the AR content to support the practical implementation. Revision markers are done by making markers with clear color and have a level of complexity levels 4-5 in Vuforia. Revisions are also made on the AR display object with color adjustment and setting a better menu list and add sound effects that make it easier for students to support the practical implementation.

After the revision, the AR application response time observation was conducted to determine how fast the device can respond when the camera is scanning the marker to bring up the AR object. These observations were made by scanning the markers pieces in good lighting conditions and the angle of 0° or parallel straight directly opposite the marker distance of 10-20 cm. Table 4 shows the results of performance testing of the AR application response time scanning activity marker.
Based on the data in Table 4, shows that the AR application has worked well with the response time of 1 - 1.5 seconds. This data illustrates that the AR application can support practical implementation so that it becomes easier. The time difference scanning in Table 4 relates to the processor, memory capacity, storage capacity, screen resolution, the resolution of the camera, and the lighting of each device used. Subsequent observations were done by giving variation to determine the maximum slope angle of the device when scanning marker. Table 5 shows the test results of the scanning angle marker by AR applications.

Table 5. Testing with the scanning angle variation

| Aspects of Observation | Scan angle 0° | 30° | 60° | 90° |
|------------------------|--------------|-----|-----|-----|
| Erect                  | ✓            | ✓   | ✓   | ✓   |
| Rotation to the right and the left 90° | ✓ | ✓ | ✓ | ✓ |
| Rotation to the right and left in 180° | ✓ | ✓ | ✓ | ✓ |
| Rotation to the right and left in 270° | ✓ | ✓ | ✓ | ✓ |
| Rotation to the right and left 360° | ✓ | ✓ | ✓ | ✓ |

Table 5 illustrates that AR applications can work optimally at an angle of <90° between the smartphone's camera with a 2D marker on the module. AR applications can also function when the rotation reaches 360° to the right and the left of smartphones. This finding is slightly different from the results of previous studies which found [28] the fastest marker scanning time of 0.33 s, but the scanning angle capability was only a maximum of 300 with an orientation of the upright marker.

4. Conclusion
Has successfully developed AR applications in fundamental physics experiment module as the media are supporting practical implementation. AR application is designed to prepare and make arrangements of hardware and software, prepare and configure marker 2D into modules and software AR, 3D modeling/video, setting the 3D models/video is displayed AR in the library AR, testing, building, and running applications AR on the PC and Device/Gadget. AR application developed to function well in supporting the practical implementation by the response time between 1-1.5 second scan at a distance of 10-20 cm and successfully used in the experimental module at an angle of <90°.

5. References
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