Mathematics learning instrument using augmented reality for learning 3D geometry

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Abstract. Augmented Reality (AR) is one kind of Virtual Reality (VR) technologies that can be used to help students who have difficulties to imagine geometrical objects in three-dimension way. AR can be applied in mobile learning which will improve the efficiency and effectiveness in learning process. The aim of this study was to develop the mathematics learning instruments using AR for secondary students. The methodology that used in this study was research and development. Sketchup software is used to draw geometrical objects and AR application can be used to view the objects in 3D. The subjects of this study were 15 students of grade nine. Experts’ assessments and students’ responses results were used to collect the data. The finding shows that the instrument is categorized as valid and it can be implemented in learning process. The validity aspects consist of languages, contents, and design. Besides, the instrument can be used in learning process, catch students’ interest and help them to understand geometry contents.

1. Introduction

Geometry is a branch of mathematics which deals with the study of various shapes or figures, both objects in two-dimensional (2D) and three-dimensional (3D) shapes, along with their characteristics (Paulina in Fabiyi) [1]. Geometry has an important role in primary and secondary schools [1], because it provides a rich source of visualization for understanding statistical, algebraic, and arithmetic concepts (Battista in Fabiyi) [1]. In addition, Sunsuma, Masocha, and Zezekwa mentioned that by studying geometry, students can develop their intuition and spatial visualization abilities [1]. The results of research were conducted by Mitchelmore, Mullis, Presscott, Mitchelmore and White found out that students have difficulties in learning and understanding geometry [2], even fail to grasp main concepts in geometry (Telima, in Fabiyi) [1]. Akinlade explained that students consider geometry as difficult topics to learn, because it has abstracts and complex characteristics [1], especially 3D geometry, where is students have to imagine in a three-dimension way [3]. Learning and solving geometry problems are really challenging too, but it can be fun if students have a good understanding of geometry concepts [4]. Therefore, it is necessary to find a source of learning that can be used to assist students in understanding the geometry concepts.

Virtual Reality (VR) can be used to help students with geometry learning difficulty, arouse their curiosity and motivation to enhance the high potential learning process [3]. One of variation of VR is Augmented Reality (AR). Augmented reality (AR) refers to technologies that dynamically blend real-world environments and context-based digital information [5]. For example, the AR’s users can see geometrical virtual object, like a cube in 3D superimposed with the picture of a cube in 2 dimensions in
a textbook [3]. An AR system was developed to help students learn geometry concepts and enhance their geometry performance [6]. AR is authentic, interactive, real-time, and can be applied in mobile-based learning and provides better understanding of geometry concepts, creating a real learning environment, which will improve the efficiency and effectiveness in learning [7]. The increased availability of mobile phones with internet connectivity makes possible to use AR applications in these mobile devices, and it is possible for a teacher to develop educational activities using AR technology for improving learning process [8].

AR application was divided into two groups, namely applications that use marker or tracker and application without markers (markerless) [9]. Markers are shapes or symbolic images made using a computer and recognizable through the camera from several points of view, and can be transformed become virtual information desired by users in the real environment [9]. In general, the use of AR systems cannot be separated from the use of the camera, on a mobile phone or tablet. Camera captures images (in the form of marker), and then the AR system translates the marker into a three-dimensional object [10].

Based on the arguments and explanations stated above, the purpose of this study was to develop supplementary learning material using AR for secondary students, in order to overcoming students’ difficulty in learning geometry. We did not need to create our own application, but we used AR app that were already available in android playstore or appstore. Augment’s open platform was used for scanning the tracker, made it possible to upload, share and visualize 3D models, because the Augment for Sketchup plugin makes uploading the models seamless, quickly and easily. Furthermore, teachers could create their own objects related to the topics they were teaching.

2. Methods
The research method in this study was Research and Development (R&D). We used this method because the purpose of this study was to develop mathematics learning instrument using AR for learning 3D geometry. Procedures in this research applied several stages, they were, (1) observing research location, (2) creating learning materials, (3) expert validation, (4) testing into small group, (5) setting up into large group (field test). In this paper, we used Sketchup software with AR extension as the development platform to construct the 3D geometrical objects. The image processing was performed using Augment application, this free application can be downloaded in mobile phone.

There were three experts who had validated the learning materials, they were linguist, material and design experts. Then, the learning materials (supplementary module) with markers was revised and tested into a group of 15 students. Student response questionnaire was filled up by grade nine students and used to assess the learning materials. It was revised again and implemented into large group (used in field test). The data obtained in this research were qualitative and quantitative data. Qualitative data, such as responses, criticisms, and suggestions, were attached in the assessment form. Quantitative data consisted of expert judgment and percentages of student response questionnaire.

The experts filled up the assessment form to find out the quality of the AR learning materials. The learning materials quality was reviewed from several aspects, such as (1) compatible materials, (2) suitable language for secondary students, and (3) suitable design and visualization of leaning materials. Another instrument was a questionnaire about the student response to AR leaning materials. The result of experts’ assessment was analyzed descriptively. The output of the students’ responses was analyzed by calculating the average score multiplied by 100% and then the output would be analyzed descriptively.

3. Results and discussion
In this paper, we used marker based AR technology to conceive geometry concepts. Using marker based codes for presenting information in a mobile device was very simple to use and straightforward. The teacher could use simple QR (Quick Response) two dimensional codes for associating information such as geometry object. In this way, figure 1 showed the use of marker based augmented reality to present geometry objects for students.
Then, the students could use their own mobile phones to view 3D objects which were coming out from the pages, and the virtual objects could be seen from different angles in a three-dimensional way. The sample of this idea showed in the figure 2.

3.1. The experts assessment
The scales of the score took out from experts’ assessments result. We used the range between 1-10. The details were: (a) 1-2 (less once); (b) 3, 4, and 5 (less); (c) 6, 7, and 8 (good); (d) 9 and 10 (very good). The experts’ assessment result showed that the learning material was valid and could be implemented in teaching learning process. Linguist suggested that the learning materials could be applied in learning
process with some revisions, regarding spelling and grammar. Material expert stated that the learning materials was very good and no need a revision. The content of the materials was in accordance with syllabus, and provided more motivation to students in learning geometry. Based on the assessment of design expert, the learning materials could be used in geometry class, but required several revisions, display of AR objects, placement of the material title and image description. The result could be summarized as follows as shown in table 1.

| Aspect     | Score  | Category | Conclusion                                      |
|------------|--------|----------|-------------------------------------------------|
| Language   | 8.4 = 8| Good     | Leaning materials worth a trial with a revision  |
| Material   | 8.6 = 9| Very good| Leaning materials worth a trial without a revision|
| Design     | 7.8 = 8| Good     | Leaning materials worth a trial with a revision  |

3.2. The students responses
Students’ responses showed that the learning materials were easy to understand and being used. They found out the learning process was fun, interactive and motivated them to learn more about geometry. Furthermore, the students stated that the leaning materials had an interesting appearance. The data based on students’ responses were obtained as shown in table 2.

| Aspect     | %       | Conclusion                                      |
|------------|---------|-------------------------------------------------|
| Design     | 86.7    | Agree that the learning materials easy to use and interesting |
| Language   | 80.0    | Agree that the language used is easy to understand |
| Contents   | 73.3    | Agree that leaning materials can be motivating in learning geometry |

In table 2, it can be clearly seen that the majority of those students’ considered the AR technology as a tool to better understand and visualize the 3d geometry, and they also showed great curiosity and interest in learning process. Besides, students seized opportunity to install AR application on their mobile phones, so they can test AR contents in their own devices by scan an object (tracker/ marker) from specified viewing degrees and to subsequently display a three-dimensional view of the object on a screen. By using mobile phones, students can visualize the three-dimensional views of the composed object from different viewing angles. In general, the students can experience the ability to combine their physical environment to a pre-designed virtual one [11]. AR makes learning easier to understand mathematical concepts, because it caters for better visualization and interaction [12]. Besides, the AR could be very motivating, by fostering students’ interest in using technologies, and it also helps in delivering lectures, hands-on activities, and customized study modules. AR is another way for teacher to make geometry class fun, interactive and more interesting [3]. By using geometrical pictures in the textbooks (module) as trackers to create AR objects, the students paid more attention to geometry class and they studied more from textbook [3].

4. Conclusion
The result showed that AR learning materials could be categorized as valid and practical. The validity was measured by using the aspect of language, contents, and design. Based on the experts’ suggestions, the materials that we created could be implemented easily in the teaching-learning process. In addition, the result of the students’ responses showed that the material was interesting as well as easy to understand, and the technology was accessible and simple to use by teachers and students.

Furthermore, the students had more understanding to learn geometry. The AR material deserves to be given to eighth grade students. In this paper, we showed that using AR to create interactive materials that could be motivating the students and contribute to extend the class into a virtual space where students could have more chances to improve their geometry ability.
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