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The Use of Geometry Learning Media Based on Augmented Reality for Junior High School Students

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Abstract. Understanding the geometry especially of three-dimensional space is still considered difficult by some students. Therefore, a learning innovation is required to overcome students' difficulties in learning geometry. In this research, we developed geometry learning media based on augmented reality in android flatform's then it was implemented in teaching three-dimensional objects for some junior high school students to find out: how is the students response in using this new media in geometry and is this media can solve the student's difficulties in understanding geometry concept. The results showed that the use of geometry learning media based on augmented reality in android flatform is able to get positive responses from the students in learning geometry concepts especially three-dimensional objects and students more easy to understand concept of diagonal in geometry than before using this media.

1. Introduction

Geometry is an area of mathematics which is essential to be learned at schools. By learning geometry, students may be able to identify shapes and space around them. Geometry can also help them to represent their surroundings. The comprehension of geometry models and their properties may give students a new perspective [1]. Thus, they are able to analyze and communicate geometry-related things in their daily lives. The geometry comprehension relates to spatial ability.

Basically, geometry lesson has been taught to students since they are enrolled in elementary schools. This competence is one of the fundamental aspects which is important to be acquired by students to understand further lessons regarding geometry. The material for geometry lesson at elementary school itself is designed to introduce students with simple geometric shapes by adjusting it with children's level of thinking.

To achieve the required geometry competence, the geometry material is included in the mathematics curriculum, starting from elementary school to university. Every student shall try to develop their spatial ability and sense which is very useful in solving problems in mathematics and everyday life [2]. The importance of spatial ability which is required in engineering sciences and mathematics, especially geometry [3]. It is in line with [4] opinion which argues that spatial ability has a significant role in developing science, technology, engineering and mathematics skills.

The process of learning geometry is not always running well. Although, geometry instruction as one main factor of improving the students' spatials abilities [5]. Moreover, there is an assumption that geometry or mathematics is one of the most difficult subject and is not preferred by most learners [6]. In learning geometry particularly, many students are facing difficulties [7]. Points out that many geometrical problems require certain visualization in problem solving and students generally find it difficult to construct three-dimensional spaces.

It is emphasized that the learning process in all subjects should apply a certain method which involves students more (student center) and optimizes the use of innovative learning media. However, what actually happen in the current situation is that the requisites have not been properly implemented.

The learning method used is still dominated by teachers and the utilization of innovative learning media is still limited. This particular learning process is not appropriate, because children's memory is limited and they only remember visible things. Learning mathematics with applying rote learning method will only burden the brain memory and make students reluctant to learn mathematics, decrease their motivation and mathematical ability.

To anticipate these problems, a multimedia is tried to be applied to improve student learning outcomes, such as Graphical User Interface (GUI) based applications such as Augmented Reality (AR) application. AR-based multimedia is able to display both two-dimensional and three-dimensional objects by showing every part of the objects in detail. By having this capability, we are able to explain geometric concepts to improve students' spatial ability. However, to date, the use of multimedia learning using AR technology is still very limited, whereas AR technology is very promising and has advantages when it is applied in learning processes.

Therefore, this study is conducted to facilitate the process of learning geometry and attract students' interests, as well as provide them with new experiences in interacting through learning media. The formulation of the research problem is: 1) How to develop augmented reality media that can be used in teaching geometry? 2) How are the studenst responses and learning activities of junior high school students when they are using augmented reality-based geometry learning media?

2. Literature Review

2.1 Augmented Reality

Augmented Reality (AR) is the combination of two concepts which are *Virtual Reality* (VR) and *world reality*. Therefore, two-dimensional or three-dimensional virtual objects are seemingly real and compromise within the real world. The AR is a new technology which is capable in presenting possibilities that are difficult for other technologies to offer and meet. In this research paper, we will give a brief description of what is Augmented Reality and how it will change the way we see the world. Augmented reality (abbreviated as AR) is a new technology that blurs the line between what's real and what is computer generated by enhancing what we see, smell, hear and feel. It is said to change the way we see the world around us. It basically adds a layer of graphics and other sensory enhancements on the natural world as it exists in real time [8].

Augmented Reality (AR) allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. However, the users cannot see the real world that surrounds them. In AR technology, users can see the real world around them by adding virtual objects which are generated by computer [9]. To make the AR 3D objects appear directly on the media, a special device called Head Mounted Display (HMD) is required [10].

Figure 1. The example of the use of AR.

In general, the work principle of ARToolkit is as follows.

1. The camera captures images from the real world in real time and sends them to the computer.
2. The software in the computer will search for markers on each video frame.
3. If the marker has been found, the computer will mathematically proceed the relative position of the camera to the black box contained in the marker.
4. If the camera position is known, then the model will be depicted in the same position.
5. The 3D object model will be displayed on the marker as if the virtual object is added into the real world.

2.2 Spatial Ability

Spatial ability is children's high level of understanding skill towards three-dimensional objects, what they can see from the objects, and what the objects' names. Spatial ability or the development of geometry ideas can be stated according to these purposes: (a) Include various characteristics or properties of the objects in categorizing and building activities; (b) Use a suitable language to describe geometry (correspond with students level of thinking); (c) Show the evidence of geometrical thinking in solving puzzles, exploring shapes, designing, and analyzing shapes; (d) Recognize shapes in environment; and (e) Solve problems regarding spatial ability

Spatial ability is an essential competence; thus, NTCM explains required geometry abilities which are important to be understood by students [11], which are:

1. Able to analyze the geometry characteristics and properties of both two-dimensional and three-dimensional.
2. Able to construct mathematics arguments concerning geometric relationships and so on.
3. Able to decide the position of a more specific point and spatial relationships by using coordinate geometry and connect it with other systems.
4. Apply the transformation and use it systematically in analyzing mathematics situation.
5. Use visualization, spatial thinking, and geometry model in solving problems.

The standard of geometry and spatial ability is when students are able to identify, classify, compare and analyze the characteristics of properties and relationships on areas and one, two and three-dimensional geometry objects [12]. Students apply spatial reasoning, the properties of geometry objects and transformations into mathematical situation analysis and problem solving. The general indicator of spatial ability in geometry are: (1) Identify and draw geometric shapes; for example, circles, squares, rectangles, and triangles; (2) Identify solid objects; for example, cylinders, cones, spheres, quadrilic prisms; (3) Build three-dimensional objects using blocks; (4) Compare and group two-dimensional shapes according to their attributes, then explain the reasons for their grouping and comparison; (5) Able to describe, and show the relative position of the object, for instance: its upper view, lower view, inside view, outside view, side view, and between view; and (6) Investigate and predict the results of two-dimensional shapes which are placed together and taken separately.

Several experts state the definition of spatial visualization in [13]: 1) Spatial visualization as the mental skills concerned with understanding, manipulating, reorganizing, and interpreting relationship visually 2) Spatial visualization is the process of representing, transforming, generating, and recalling symbolic, non-linguistic information.

Some experts in [14] argue that, two major components of spatial visualization have been identified: spatial relations and spatial visualization. In standardized spatial ability tests, spatial relations tasks involve 2D and 3D rotations and cube comparisons. Spatial visualization is described as the ability to imagine rotations of objects or their parts in 3-D space.

3. Research Methodology

This study is started by developing augmented reality media for teaching geometry. Steps conducted in developing augmented reality media includes: the analysis of software and hardware necessity, designing, development, and testing.

In analyzing step, researchers conducted introductory study in the form of exploratory and literature. Exploratory study was carried out by using browsing technique, i.e. the search for looking information about spatial ability of yunior high school students and the media usage, including learning methods used. While the literature study was conducted by collecting writings both in the form of journals, books, and articles related to interactive multimedia that can be used in learning geometry. Continued with user analysis, software analysis, and hardware analysis for knowing a sufficient hardware is also needed so that augmented reality media will run well in minimum specifications of hardware. Then designing and developing step was also done. A testing toward multimedia is conducted to make sure the functions run well. The testing is conducted by using blackbox testing. After that the AR media is judged to be considered eligible by experts and the repair related to theirs suggestion and recommendation. After that steps continued by investigate the implemented media to know students responses towards the use of geometry learning media based on augmented reality by using questionnaire. This steps was to examining students' responses towards the implementation of geometry learning media based on augmented reality. Because this media is still prototype the implementation is in limited scopes, it was implemented to below some students in Bandung.

4. Results

4.1 AR-based Geometry Learning Media

The learning media that is used in this study is the geometry learning media based on augmented reality for three-dimensional objects lesson. The marker that is used is in the form of a figure which is deliberately made to display three-dimensional objects. The three-dimensional objects which are covered in the lesson include: cubes, prisms, beams, pyramids, and cones. In this lesson, it is discussed how to determine the face diagonal, the space diagonal, the height or altitude, and the slant height on three-dimensional objects. The AR media illustration is shown in figure 2. The AR media illustration used is shown below.

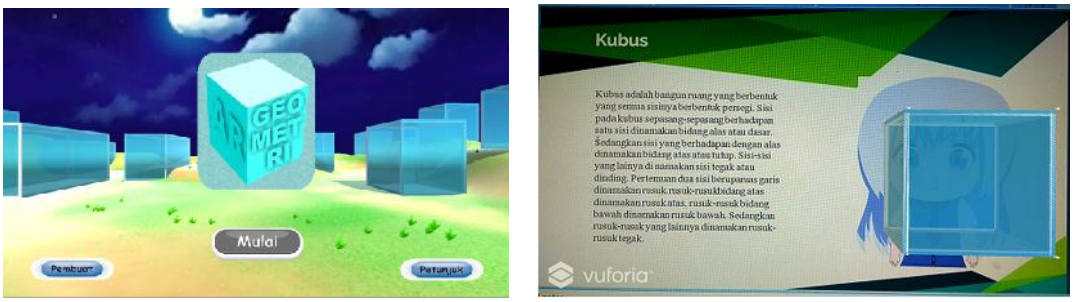

Figure 2. The main display of AR geometry media and geometry shape appears

Based on the implementation of AR-based geometry media, it can be seen that junior high school students, who learn three-dimensional objects, find the media helpful and can quickly understand the concept of space which is discussed. They can see three-dimensional objects from various perspectives: front, side, back, top and bottom part of the objects. All this time, students have difficulty if they are asked to determine the location of the diagonal in a three-dimensional object, especially if the diagonal is located beside or behind the objects. They find it difficult to imagine how the form of the diagonal is. However, by using AR-based geometry media, they can rotate the three-dimensional objects freely, by merely moving the highlighted marker, rotating it, until they can find the part that they want to see.

4.2 Questionnaire Results for Student Response

After AR-based geometry learning media is implemented, students give their responses towards the use of media. Students' responses are collected gradually from the first phase to the third phase. The following results are obtained.

Table 1. Students' responses towards the use of geometry learning media based on AR

Indicators	1st phase	2nd phase	3rd phase
Learning Goal Alignment	63%	73%	75%
Feedback and Adaptation	68%	72%	78%
Motivation	65%	74%	80%
Presentation Design	70%	70%	78%
Interaction Usability	69%	69%	77%
Accessibility	68%	72%	80%
Average	67,1%	71,7%	78,0%

Based on Table 1, there is an increase in all indicators. In the aspect of learning goal alignment, the increase is from 63% to 75%, the percentage of feedback and adaptation increases from 68% to 78%, the percentage of motivation goes up from 65% to 80%, the percentage of presentation design increases from 70% to 78%, the percentage of interaction design usability increases from 69% to 77% and the percentage of accessibility aspects increases from 68% to 80%. Averagely, students' responses towards the use of geometry learning media based on AR increase along the phases from 67,1% to 78,0%.

5. Conclusions

Based on the results, the conclusions are obtained as follows:

1. AR media is used in teaching geometry developed in accordance with the steps appropriate media development, by considering aspects of students' needs and the material being taught.
2. AR-based geometry media facilitate students in understanding the concept of three-dimensional geometry objects. They can rotate the three-dimensional objects freely, making them easier to see the three-dimensional objects from various perspectives.
3. AR-based geometry media gets positive responses from students. Hence, this media is suitable to be applied in the process of learning geometry in junior high schools.

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