Augmented Reality assisted by GeoGebra 3-D for geometry learning

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Abstract. Geometry becomes a difficult subject for students. The abstract object was one of the factors. Therefore, more concrete learning media are needed. One of them was augmented reality assisted by GeoGebra. The purpose of this study was to determine the ability to understand the geometrical concepts of high school students through augmented reality learning assisted by GeoGebra. Treatment was given to students through learning using GeoGebra-assisted augmented reality. This was a quasi-experimental study with a pre-test post-test control group design. This research instrument was a test of the ability to understand the concept of geometry. The test was used to measure students' initial abilities, and this was referred to as a covariate. Also, to measure the ability to understand concepts after students follow augmented reality learning assisted by GeoGebra. Data were analyzed by covariate analysis (ANCOVA). The results of this study were $F = F_o (A) = 9.150$ with $p$-value $= 0.000 < 0.005$. That means, there are differences in the ability to understand the concept of geometry between those taught with augmented reality which is assisted by GeoGebra and conventional learning. Other results show that $t = 6.723$ with $p$-value $= 0.000 < 0.05$. This shows that the ability to understand the geometry concepts of students taught with augmented reality assisted by GeoGebra was higher than students who were taught conventionally after controlling for covariates. The conclusion was that the ability to understand the concepts of geometry through GeoGebra-assisted augmented reality learning was better than students taught with ordinary learning.

1. Introduction

School mathematics is a subject that contains arithmetic, algebra, geometry, basic calculus, combinatorics, and statistics. Geometry becomes a material that is difficult for students. The abstract object is one of the factors. Therefore, more concrete learning media are needed. One of them is Augmented reality [1] assisted by GeoGebra [2,3].

Virtual reality (VR) and Augmented reality (AR) are two things in common. Both aim to expand an individual's sensory environment by mediating reality through technology. It is dependent on alternative settings to experience, while the latter enhances existing elements with additional layers of meaning [4]. This will be a great opportunity for students to be able to improve their mathematical abilities through a horizontal mathematical process [5]. The process is carried out in mathematics learning.

In the process of learning geometry, the teacher is not the ruler of the class that enforces correct answers [6]. The teacher is here to help students solve problems, and prepare an environment that
allows students to gain broad learning experiences, not just the application of memorization procedures. Therefore, media that are close to reality will make it easier for students to understand the concepts and principles of geometry [7].

The results of the study [8] show that the use of contextual learning media that is appropriate and by needs, can improve students' abilities in the process of achieving mathematical concepts and principles and improve student learning completeness. Contextual learning media can effectively produce patterns that students can easily construct initial statements (conjectures) and with vertical mathematical activities. Students with the help of a more capable friend or teacher can reach the concepts and principles that they are learning. There are 13.75% of students are at level 4 (level trans with the language of mathematics) [9]. Also, more than 82% of students can correctly reach concepts and principles. There are 78% of students able to arrange definitions and theorems correctly. The average level of mastery learning reaches 86.5%; Found 14% of students who can increase as far as three levels of cognitive development (from Intra Level increased to Semi-trans Level in Extended Level Triad-Level ++) [8].

Research on Augmented Reality (AR) learning media, shows that the influence of the use of AR in education can improve student achievement. The media can also accelerate student learning performance. Applications developed with AR technology can be used as effective tools in learning [10].

According to Arbain [11], technology has become one of the strong learning resources. The evolution in using technology in teaching and learning has developed rapidly. There is a lot of Mathematics software that has been developed to help teaching and learning, including GeoGebra, Geometer's Sketchpad and Mathematica. Several studies have been carried out on GeoGebra software to study various aspects of learning. GeoGebra has become a tool that can help teachers to design effective instructional lessons. GeoGebra has not been widely used in teaching mathematics. Especially in learning geometry. Because Geometry is a part of mathematics that must be studied in the ninth, but Geometry is not liked by most students. The material is misunderstood, and the notation is completely ignored [12].

The results of the study [13] showed that there were significant differences between the mean scores of students at the posttest who supported the GeoGebra group. Also, computer-aided learning as a traditional classroom learning medium is more effective than conventional learning.

Based on these arguments, the formulation of the problem of this study were: 1) Is there a difference in the average ability to understand the concept of geometry between students taught with augmented reality assisted by GeoGebra and conventional controlled by the covariate? 2) Is the ability to understand the geometry concepts of students taught with augmented reality assisted by GeoGebra higher than students who are taught conventionally after controlling for covariates?

Augmented reality is a learning medium that makes it easy for students to do the math process. This is a technology that has great potential for educational outcomes. To make full use of this technology, you must understand the psychological factors that influence the design of AR. In the process, the teacher gives an illustration of the existing AR system and produces a guide for the AR application designer. This knowledge will be useful for educators who are interested in understanding the potential of AR as learning technology, and for technology designers who are interested in pursuing Educational applications [14]. Some studies utilize additional learning media, namely YouTube [15]. AR will have a positive impact on students in the process of spatial visualization.

Spatial visualization is an important ability to understand and solve real-world problems. The characteristic of visual-spatial abilities in learning mathematics is the skills needed to build mental models of mathematical objects. That can be a picture or a declarative sentence. However, the spatial ability is a dynamic process. It can be developed by interacting with real objects or virtually. Therefore, mathematical abilities can be improved by using augmented reality. Augmented reality application makes it easy for students to learn geometry. That is done through spatial visualization. The application provides many benefits that support the teaching and learning process of geometry.
AR makes human-computer interaction more natural by enabling the preservation of the real user environment providing a frame of reference for user actions [16].

In learning geometry, complex models can be presented close to reality through augmented reality and virtual reality. Like, building three-dimensional models that represent real-world objects such as traditional houses, beverage cans, railroad tracks, airplanes, and skyscrapers. The workflow used is the Unity Machine. It was combined with the Virtual Reality headset device to create interactive applications both Virtual Reality and the Augmented Reality Environment. This is to support students in understanding curriculum content through their environment [17]. Therefore, the teacher should be able to arrange geometrical learning planning through 3D content. This can be done through the integration of 3D models into Unity. Thus, the ability of students to achieve a geometrical concept can be meaningfully achieved, namely through functions added to Unity for visualization and interaction with models. AR is a technology that has been applied in many fields. It has advantages that can increase the accessibility of mathematics education through virtual technology. AR technology is very useful for formal education [18].

According to Kiryakova et al. [18], that modern society tries to make itself smart. Education plays a role in meeting the challenges of a changing world. Juna prepares students to become members of civil society. Innovative and effective tools and technology can change education for the better. Students can create environments that can meet their needs and characteristics digitally. Therefore, augmented reality can turn it into smart education. Augmented reality has been used in various fields of technology and can be of great benefit to help mathematics learning [19].

The results from Nadiah [20], showed that a significant increase of student involvement in GeoGebra 3-D and 2-D activities at learning geometry through the Van Hiele-based learning model. Students and teachers benefit from GeoGebra 3-D. It is an application program that can provide more interesting, fun learning and enhance geometric thinking. GeoGebra is a free, practical open-source software. Its contribution is very large towards the application of mathematics education especially geometry in the 21st Century. It is an open-source Dynamic Mathematics software. Also, as one of the new learning tools that attract many researchers and mathematics educators. It is having the potential to revolutionize mathematics learning [2].

GeoGebra 3D was developed with new characters and extensions. It was ready to provide new updates on graphics, commands, and new tools. Also, it can change the perspective and rearrange various parts of the monitor screen to be more interesting. It can be presented in 3D Geometry into GeoGebra as a dynamic model, as well as for 2D Geometry. In mathematics education, it can combine Dynamic Geometry, Computer Algebra, and semantic mathematical formulas. Also, it is for worksheets of dynamic 2D drawings and 3D Dynamic Geometry that can maintain simplicity as well as user-friendliness [21].

Mathematics learning requires integration between software and other technological tools. Teachers should be given training that is good enough to be able to use it. Also, they have pedagogical skills to ensure that learning mathematics is meaningful [2]. Schools should facilitate the integration of technology in the classroom. It also provides the right infrastructure, infrastructure, and professional development support. This is to ensure the relevance of teachers in 21st-century classrooms.

This argument gives the meaning that GeoGebra can help in learning mathematics. It is an interactive application of geometry, algebra, statistics, and calculus. Also, it can be used from elementary school level to university level. Therefore, students can improve their ability to make sketches using GeoGebra. Finally, students can describe and solve mathematical problems [3]. GeoGebra 3-D mathematics learning media is providing a series of basic functions for primitive constructions such as points, lines, planes, cubes, balls, cylinders, and cones. Construction functions include intersections, lines, and normal planes, symmetry operations, and taking measurements [22]. This makes it easier for students to understand the concepts and principles of geometry [6].

Based on the citations, mathematics learning using augmented reality assisted by GeoGebra 3-D makes it easy for students to improve their spatial abilities, geometry especially. It was the media that makes it easy for students to do the horizontal mathematical process correctly. Also, students able to a
vertical mathematical process that is the process of formalizing geometry. Therefore, the authors were interested in implemented augmented reality as a media assisted by GeoGebra 3-D in learning geometry to high school students in Bengkulu. The purpose of the study was to compare learning through AR with the help of GeoGebra and conventional learning.

2. Methods
This research is a quasi-experiment, with the treatment of applying augmented reality media assisted by GeoGebra 3-D in learning geometry. In its implementation, the study used an experimental design pre-test post-test control group design. Geometry learning using augmented reality media assisted by GeoGebra 3-D is for the experimental class and conventional learning, another class. The study population was all high school students in Bengkulu, with a sample of 72 students. Samples were selected using the intact-group technique. Data collection is done by using the instrument is a test of the ability to understand the concept of geometry. The instrument was valid and reliable (r11 = 0.786). It was used to measure the cognitive level of students' mathematical understanding. Data were analyzed with the Covariance Analysis (ANCOVA) test.

3. Results and discussion
The following are some augmented reality displays assisted by GeoGebra 3-D during geometry learning in high school. This is the display for the experimental class.

Figure 1. Tubes with \( r = 4 \) and \( t = 5 \) using GeoGebra 3-D.

Figure 1 is a tube drawn by students using GeoGebra 3-D with base radius \( r = 4 \) and height is 6 (all are in one length). With augmented reality, students can rotate and see the shape of the tube from all directions. This makes it easier for students to understand the concepts and principles of tubes geometrically.

The same thing is done by students for cones (Figure 2) and balls (Figure 3). In Figure 2, students draw a cone with radius 4 and height 6. This will also be used for further learning about calculus. The principle achieved is integral, namely the volume of a rotary object.
Furthermore, students are faced with the activity of drawing a ball using GeoGebra 3-D. Students also utilize the augmented reality application via Android, students can study it in more detail. That can be done by approaching reality without touching the original object. It facilitates the kinesthetic of students, also visually works and optimally.

In Figure 3, students can show the ball with radius 5. This also becomes one of the pictures with the help of GeoGebra 3-D. Students have a complete picture of the ball. That can be done through its augmented reality and GeoGebra 3-D display.
Through augmented reality, students can see and use their kinesthetic understanding of the properties of isosceles triangles as can be seen in Figure 4. It was obtained based on the informal/horizontal mathematization of the Kejei Dance. The dance is a typical culture of Rejang Lebong (Please read the results of ethnomathematics research in Bengkulu, Indonesia [23-32]. This will also make it easier for students to recall they are natural knowledge well. When displayed in GeoGebra, students can manipulate it into a flat shape. For example, students try to apply it to understand two concurrent triangles. Take a look at Figure 5. That is the look of GeoGebra for the concordance of two triangles.

By utilizing augmented reality, students can develop geometrical understanding good more. Previous research utilizing real media brought into pictures can improve students' understanding of concepts and metacognition abilities. The following are the results of research by [7] about building space.
Figure 6. Triangular prisms.

Figure 6 shows a triangular prism. A triangular prism is a three-dimensional building that is bounded by identical base and lid in the shape of a triangle and square sides [7]. The following formula is the volume and surface area of the prism:

\[
\text{Volume} = \text{Area of base} \times \text{height} \\
\text{Surface Area} = (2 \times \text{Base Area}) + (\text{Flat} \times \text{Height})
\]

It is ethnomathematics that can be a starting point for the achievement of mathematical concepts [33].

Based on the pretest-posttest data the ability to understand the geometry concepts of students of SMA N 2 Bengkulu City, analyzed using SPSS version 25 software, can be presented as follows.

Levene's test of variance errors showed the results of F = 0.496 with df (2, 70) and p-value = 0.958 > 0.05, which means that Ho was accepted. That means that the mean parameters of the three sample data groups are of the same/homogeneous variance.

In the ANCOVA test section, line A * X is obtained for the price Fo = 1.089; df = (2, 70) with p-value = 0.627 > 0.05 or Ho Accepted. This means that the regression coefficient/slope of the three groups is the same/homogeneous. The third regression equation of the three groups was parallel.

The two tests above are ANCOVA test requirements. Therefore, it can continue the analysis to test the hypothesis. The result is F arithmetic = Fo (A) = 9.150 with p-value = 0.000 < 0.005. That means that there are differences in the average ability to understand the concepts of geometry between GeoGebra and conventional aided augmented reality which is controlled by a covariate. In the test section, the count is obtained t = 6.723 with p-value = 0.000 < 0.05. It states that the ability to understand the geometry concepts of students taught with augmented reality assisted by GeoGebra is higher than students who are taught conventionally after controlling for covariates. This supports the results of previous studies such as Augmented Reality (AR) is a technique that can make classrooms more interesting and fun. This can increase students' interest and motivation. Using geometric drawings in textbooks as a tracker to create AR objects, students pay more attention to class and they learn more from textbooks. This shows a very strong impact on improving the learning environment in mathematics classrooms or even self-study anywhere [34]. Using AR is a three-dimensional geometry construction tool specifically designed for mathematics and geometry education. It is based on the collaborative augmented reality system of cellular. This can increase your spatial ability and maximize the transfer of learning. This can encourage experimentation with geometric constructions, and improve spatial skills [35]. As such, we believe that GeoGebra 3D-assisted AR can improve the ability to understand geometry. This can make it easier for students to empirically achieve concepts and proof of principle.

4. Conclusions

This paper concludes that the ability to understand geometric concepts through augmented reality learning assisted by GeoGebra was better than students taught with conventional learning. Students were able to optimize their five senses to be actively involved in learning, starting from kinesthetic (hands), spatial (eyes), and hearing. Therefore, augmented reality learning assisted by GeoGebra was a practical and effective innovative medium for learning geometry.
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