# Facilitating 3D Geometry Learning with Augmented Reality in Authentic Contexts

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**Abstract.** In this study, we developed 3D-UG with augmented reality (AR) to facilitate students while learning 3D geometry in authentic contexts. 3D-UG provided exploring activity with real-time measuring the authentic 3D objects in surrounding with AR. Students learn 3D geometry, measure 3D objects and calculate the volume or surface of the authentic 3D objects in their home during pandemic Covid-19 for one month. Participants were forty fifth-grade elementary schools' students that divide into two groups, twenty students in the experimental group (EG) used our purpose 3D-UG and twenty students in the control group (CG) used ruler. The results found that students in EG have improved geometry ability and outperformed compared with CG. Students in EG has a better understanding of geometry concept than CG. In addition, students in EG made fewer mistakes in their formula input and calculation process. It is because students carefully complete the solution and 3D-UG has clear steps to accomplish the solution. Therefore, our 3D-UG with AR could facilitate students to learn geometry learning in their home during Covid-19, exploring 3D objects their surroundings, and experienced 3D object measurement with augmented reality to enhance their geometry ability.

**Keywords:** Geometry learning · Authentic contexts · Augmented reality

## 1 Introduction

Recognizing and making a shape or measuring shape in geometry learning could increase student motivation because they feel playful with lots of fun [1]. However, students need to have a good understanding of 3D geometry thinking skills to visualize, to interpret, and to form representations of 3D figures [2]. Students will have the capability to recognize 3D objects as well by understanding the concepts of geometry and the measurement of geometry objects such as measuring volume and surface areas.

On the other hand, the students should have the capability to engage their understanding of 3D geometry with real 3D objects in their surroundings [3]. Several studies showed that learning geometry in authentic contexts could improve students learning achievement and students' abilities, including geometry ability, estimation ability, and spatial ability [4].

A problem in the learning process, especially in 3D geometry learning, is the lack of students' understanding of geometry [5] and interaction between students and real 3D objects in the surrounding [6]. In authentic contexts, students will be easy to understand


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the types of 3D objects which surround them and to classify the objects according to their shape. However, very few studies addressed the issue of learning 3D geometry in authentic contexts and investigated learning behaviors of measuring 3D objects to know their influence on learning achievement. This is because there are difficulties when the students measure objects which are large if they only use a ruler. This issue could solve to use augmented reality technology which has the capability to measure the real world through cameras [7].

Based on the problems above, researchers developed an innovative system named 3D-UG to facilitate geometry learning in authentic contexts. The following are research questions to answer in this study:

1. Are there any significant differences in learning achievement between experimental group using 3D-UG and control group using a conventional method with a ruler?
2. What are the relationships between learning behavior and learning achievement in experimental group?

## 2 Literature Review

### 2.1 Geometry Learning in Authentic Context

There are several kinds of 3D objects like a cube, cuboid, cylinder, pyramid, etc. In addition, recognizing 3D shapes, measuring volume and surface area of 3D objects in daily life with and without standard units is also important to students because this real experience of applying geometry in daily life can consolidate understanding of geometry concepts [8].

Learning geometry can improve students' understanding when interacting with objects around them. Nowadays, understanding how to measure the volume and surface area of an object is very important and can be used in certain conditions. For example, when traveling that requires carrying a suitcase, but with limited baggage, we can estimate the volume of our suitcase so that it is not overloaded. But commonly, geometry is taught using textbooks, blackboard, and 2D images can be effective, but measuring volume and surface area are not highly effective [9, 10].

### 2.2 Geometry Ability in Geometry Learning

To visualize, to interpret, and to form representations of 3D figures, students should have good 3D geometry ability [2]. There are several dimensions of 3D geometry ability, including the ability to recognize and create 3D shapes, the ability to manipulate and translate representations of different views of 3D solids, the ability to structure 3D arrays of cubes, the ability to determine the properties of 3D geometric shapes, the ability to calculate the volume and area of 3D solids, the ability to compare features of 3D shapes. In this study, we conducted 3D geometry ability, including the ability to manipulate, to recognize, to structure, to determine properties, and to calculate volume and surface area of 3D objects.

### 2.3 Augmented Reality for Geometry Learning in Authentic Context

Augmented Reality (AR) is a technology that displays virtual objects produced by computers in the real world using camera sensors [11]. For example, ARCore that developed by Google to build AR app for Android devices [7]. As a platform to build AR, ARCore has been widely used to build authentic learning media based on AR. It is because can understand the surrounding environment and easier to integrate. Based on the feature of ARCore above, in this study, we provide AR with ARCore technology in our app. It will be more powerful for measuring 3D objects in the real world.

## 3 System Design

We developed 3D-UG to facilitate geometry learning with AR. Our 3D-UG app has features such as learning, measuring 3D objects with AR, and calculation. Figure 1 shows the learning material including theory, 3D representation, and calculation. The theory will give students learning material to learn the formula either for volume or surface area. The virtual 3D representation will show a virtual 3D object that students can make interaction with. The calculation will show students the step how to calculate, this function like a calculator that will show the step.

After students learn, students continue to measure real time 3D objects with AR that shown in Fig. 2. For example, students measure the volume and surface area of a suitcase in the real world, then students adjust the properties of virtual 3D objects such as the length, width and height to know the real properties. Finally, students calculate the volume or surface of 3D object to complete the geometry learning.

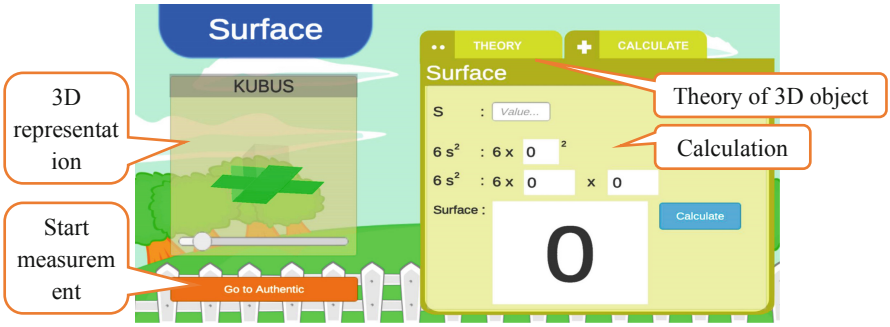


**Fig. 1.** Learning material on 3D-UG app

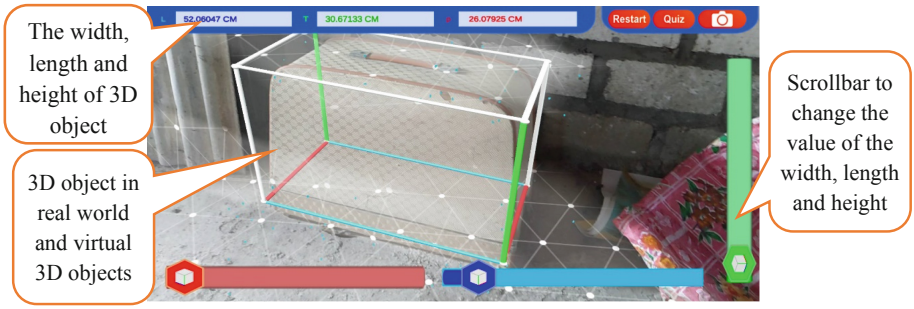


**Fig. 2.** Measuring 3D objects with 3D-UG app

## 4 Methodology

The participant of this research is forty people of fifth-grade elementary students which separated into two groups. The experiment group (EG) consisted of 20 students using 3D-UG app and the control group (CG) consisted of 20 students with a ruler. Students learn concepts of 3D Geometry and measuring volume and surface area in authentic contexts. The experiment conducted 1 month with pretest, learning with exploring activity and posttest. All activities were conducted in students' home because of pandemic Covid-19 situations and assisted with a teacher with an online meeting. In details, the teacher gave the pretest and the tutorial of use the 3D-UG via online meeting in the 1st week. In the 2nd until 3rd week, the students used 3D-UG app to explore and measuring 3D object in their surroundings. In the 4th week, teacher gave posttest content and submit it via online meeting. The topics for this study were measuring volume and surface area of cube and cuboid. As seen in Table 1, the research variables about learning behavior and learning assessment to measure 3D geometry ability. The analysis uses ANOVA to analyze the significant differences between EG and CG in both pretest and posttest. In addition, Pearson correlation analyze will conduct to know the relationship learning behaviors from 20 students in EG with post-test. The learning behaviors data collected from two weeks activities. At least, students measure and calculate both one volume and surface of cube and cuboid.

**Table 1.** Research variables

| Variable | Description |
|---|---|
| Learning achievement | |
| 1. Geometry ability | Ability to visualize, interpret, and form representations of 3D [2] |
| Learning behavior | |
| 2. Error calculation | The number of errors in the calculation process |
| 3. Error formula | The number of errors in the formula while trying to calculate volume & surface area |
| 4. Number attempts | The number of trying to calculate the volume & surface area |

# 5 Results and Discussions

## 5.1 Learning Achievement of Geometry Learning Between EG and CG

The ANOVA analysis was conducted to test in between the EG and CG, as shown in Table 2. It shows that students' prior knowledge not significantly different ($p > 0.05$) between EG and CG on the pretest. In other hand, the results found that there is a significant difference in geometry ability ($F = 12.434, p < .05$) also students' geometry ability in EG outperformed CG. This indicates that students significantly improved their geometry ability after using 3D-UG app.

A possible reason is that 3D-UG app with AR facilitated students which can identify the 3D object in their surroundings and define the properties such as length, width, and height and do the calculation. Therefore, students in the EG can understand the concept of geometry better than students in the CG.

**Table 2.** Learning achievement between EG and CG.

| Group | *N* | Pretest | | | | Posttest | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *M* | *SD* | *F* | *Sig* | *M* | *SD* | *F* | *Sig* |
| EG | 20 | 27.200 | 7.179 | .525 | .410 | 34.850 | 2.231 | 12.434 | .001 |
| CG | 20 | 25.400 | 6.468 | | | 30.150 | 3.528 | | |

## 5.2 Learning Behavior of Geometry Learning in EG

The correlation analysis in Table 3 shows that error calculation has a negatively significant correlation with geometry ability ($r = -.521$, $p = .018$). The results show that students who got higher scores were made fewer mistakes in the calculation process. It indicates that students need to be aware of their calculation process when they tried to solve the geometry problem in authentic contexts.

**Table 3.** Learning behavior on EG

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Learning achievement | | | | |
| 1. Geometry ability | 1 | | | |
| Learning behavior | | | | |
| 2. Error calculation | −.521* | 1 | | |
| 3. Error formula | −.446* | .318 | 1 | |
| 4. Number attempts | .178 | −.391 | −.239 | 1 |

The number of error formulas also has a negatively significant correlation with geometry ability ($r = -.446$, $p = .049$). The results shows that most students who got higher scores were made fewer mistakes in the formula. It indicates that students should make sure that the formula is correct before they do the calculation.

## 6 Conclusions

Regarding research question one, the results show that there is a significant different between EG with our 3D-UG app augmented reality and CG with a ruler. Our 3D-UG app with augmented reality can help students to learn geometry concepts and improved their geometry ability on learning achievement. Furthermore, the EG outperform in their learning achievement' score compared with CG. It is because EG can understand the concept of geometry learning when learning with 3D-UG.

Regarding research question two, the results found there is relationship between learning achievement and learning behavior. The results found that students in EG checked the calculation carefully before submitting the solution and checked the formula before the calculation.

In addition, the limitation in this study, students learning with 3D-UG on their home because of pandemic Covid-19 situations that imply the difference of 3D object that measured by students. The geometry learning in this study was limited to measure volume and surface on cube and cuboid. We analyze the learning behavior only in the EG group. We suggested that the future study can use collaborative measurement because students in their home and 3D-UG extend with other 3D objects.

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