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Effectiveness of Learning through Augmented Reality Media on Calculus Learning for Actuarial Science Study Program Students

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ABSTRACT

This research aims to test the effectiveness of Augmented Reality (AR) through the GeoGebra AR application in increasing students' understanding of the Actuarial Science Study Program regarding calculus concepts, especially standard surface materials in space. The method used was a one-group pre-test post-test design experiment involving 20 students. Data was collected through description tests (pre-test and post-test) and analyzed using the paired t test. The research results showed a significant increase in the average post-test score (83.02) compared to the pre-test (71.80) with a p-value of 0.000356 (< 0.05). AR visualization successfully transforms abstract mathematical concepts into easy-to-understand 3D interactive objects, increasing student engagement and encouraging contextual understanding. These findings prove that AR is effective as an innovative learning medium for complex calculus material. Research implications support the integration of AR technology in mathematics curricula to improve the quality of higher education.

Keywords: augmented reality, Calculus, geoGebra AR

1. INTRODUCTION

Learning calculus is an important component in the higher education curriculum, especially for students in the Actuarial Science study program. However, many students experience difficulties in understanding abstract calculus concepts, such as discussing the concept of standard surfaces in space. With the current development of multimedia equipment, it has become possible to display mathematical concepts visually with the help of computers. One solution that has emerged is the use of Augmented Reality (AR) technology as a learning medium. AR can increase student interaction and involvement in the learning process, so it is hoped that it can help them understand complex and abstract concepts well because they can be demonstrated concretely through technology. AR can be defined as a real environment to which virtual objects are added with the integration of computer technology [1] Augmented Reality brings new offerings in learning closer by combining digital elements with the real world.

The potential of augmented reality in learning calculus can reduce the note-taking process carried out in conventional lectures so that the available time can be used more effectively for discussing and solving problems. AR is developing rapidly, so there are many choices of applications that can be used in learning with AR media. Some of these applications are public domain/free, including GeoGebra AR, AR Math, and Matific. The implementation of AR provides greater benefits for students, especially in understanding complex and abstract concepts [2]. This makes AR the right tool to help users interact and understand the real world because the data displayed by virtual objects helps them do things in the real world [3].

Overall, AR can create a more interesting and relevant learning experience because it can see how mathematics is applied in the real world, thereby encouraging student creativity in problem solving [4]. The use of augmented reality is an alternative that is expected to increase understanding of calculus concepts among students in a more interesting and effective learning manner to improve the quality of higher education in the field of mathematics. Therefore, it is hoped that this research can be an in-depth study regarding the effectiveness of learning through augmented reality media in the context of calculus learning for students.

2. METHODS

This research is a type of experimental research involving a one-group group, and the experiment is to obtain treatment on students' understanding of the concept of standard surfaces in space in calculus material. The method for measuring the effectiveness of learning through Augmented Reality (AR) media is by conducting a paper-pencil test [5]. The measurement design used is a pre-test and post-test design, which means that the experiment is given to one group for the reason of comparing student learning outcomes before and after using Augemented Reality (AR) media with the Geogebra AR application [6].

Table. *One Group Pre-test Post-test Design*

Pre-test	***Treatment***	***Pos-test***
O_1	X	O_2

O_1 : The initial state of the experimental class before receiving treatment
X : The treatment consists of using Augmented Reality media with Geogebra AR
O_2 : The final state of the experimental class after receiving treatment

This research was conducted at Darunnajah University which is located on Jl. Ciledug Raya-Ulujami, Pesanggrahan District, South Jakarta City, Special Capital Region of Jakarta. The sampling technique in this research uses saturated samples which allows researchers to obtain more accurate and representative data because all members of the population are involved [7], with research subjects being 20 students of the 1st semester Actuarial Science study program class SA11B for the 2024/2025 academic year.

The data collection technique used by researchers was conducting pre-tests, post-tests and direct observations in the classes that were given treatment. The form of the test instrument given is in the form of essay questions.

Data from the pre-test and post-test will be analyzed using descriptive statistics to calculate the average value and standard deviation. Next, inferential analysis such as the paired t test (*pairedt-test*) for paired samples will be carried out to determine whether there is a significant difference between the pre-test and post-test results [8]. The following is the process of analyzing experimental data with One Group Pre-test Post-test Design. The data is processed using SPSS software to facilitate the data analysis process, so the data is presented in the form of tables and diagrams.

3. RESULTS AND DISCUSSION

After conducting research by obtaining pre-test result data before students used Augemented Reality media, and post-test result data after students used Augemented Reality media. Next, the data was tested to see whether there were differences between the pre-test and post-test results, which can be seen in Figure 1.

Based on Figure 1, it shows that the results of students' pre-test and post-test generally do not intersect. This shows that there is a difference between the students' pre-test and post-test results. However, to find out more clearly whether there is a difference in student pre-test and post-test results, it is necessary to carry out statistical testing through a paired t-test. The following is a descriptive statistics table to determine whether there is a difference between students' pre-test and post-test results in terms of increasing or decreasing scores.

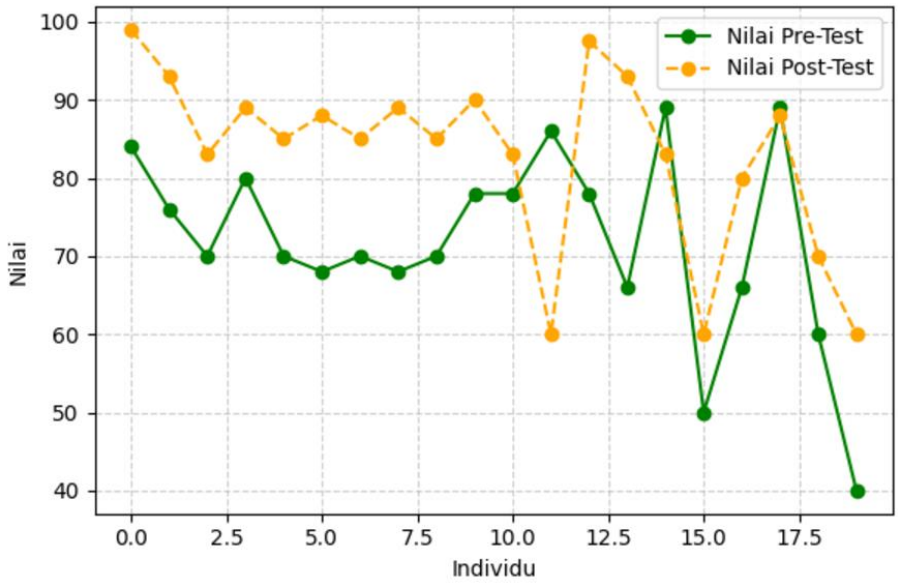

Figure 1. Graph of Student Pre-test and Post-test Results

The data in Table 2 shows the descriptive statistics of pre-test and post-test data which shows that the average (mean) student pre-test score is 71.80 and the average (mean) student post-test score is 83.02. This shows that there is a difference in students' average (mean) pre-test and post-test scores in the form of an increase in scores. In other words, there is an increase in the quality of calculus learning for students in the Actuarial Science study program. Next, it is necessary to carry out statistical testing through a paired t-test to compare the means of two groups that are related to each other through pre-test and post-test data.

Table 2. Descriptive Statistics of Pre-test and Post-test Data

	N	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Pre-test	20	49	40.00	89.00	71.8000	12.30575
Post-test	20	39	60.00	99.00	83.0250	11.72993
Valid N	20					

In parametric testing with a paired t-test, the data must have a normal distribution [9]. Therefore, respondents' pre-test and post-test score data must be checked first before distributing the data. The results of testing the distribution of pre-test and post-test data are presented in Table 3.

Table 3 Normality Test of Pre-test and Post-test Data

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	.164	20	.595*	.928	20	.141
Post-test	.249	20	.140	.857	20	.070

Based on Table 3, the results of the normality test for student pre-test and post-test data using the Kolmogorov-Smirnov and Shapiro-Wilk statistical tests show that the significance value (*p-value*) for all data in both the Kolmogorov-Smirnov and Shapiro-Wilk statistical tests has a significance value of > 0.05 so it can be concluded that the normality assumption is met [10].

Inferential analysis with a paired t-test was carried out to test whether the use of Augmented Reality media as a learning aid had a positive impact in improving the 1st semester calculus learning outcomes for class SA11B for the 2024/2025 academic year at Darunnajah University. Testing will be carried out by comparing the learning results (pre-test and post-test) of the experimental class. The criteria for hypothesis testing are as follows:

a. Null Hypothesis (H0): There is no difference in students' average (mean) pre-test and post-test scores in the form of an increase in scores.
b. Alternative Hypothesis (H1): There is a difference in students' average (mean) pre-test and post-test scores in the form of an increase in scores.
c.

Table 4. Paired t-test results for pre-test and post-test

	t	df	*p-value*
Pre-test-Post-test	-4.335	20	0.000356

With a significance level of α=0.05 and degrees of freedom ($\boldsymbol{df = n - 1 = 20 - 1 = 19}$), the t table value is ±2.093. Because the tcount (-4.335) is outside the ttable range (±2.093) and the p-value <0.05, there is a statistically significant difference between the average pre-test and post-test scores. In other words, the post-test average is significantly higher than the pre-test average. AR technology users using the Geogebra AR application can see in real life a shape formed from two parabolic equations that looks real on a flat plane in Figure 2.

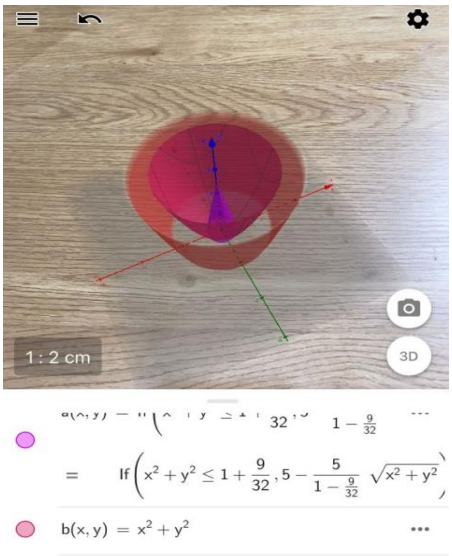

Figure 2. Example of using AR

Figure 2 shows that using the Geogebra AR application has succeeded in visualizing abstract mathematical concepts, such as 3D surfaces from calculus equations, into interactive objects that can be observed in real physical space.

CONCLUSION

This research clearly shows that the use of Augmented Reality (AR) through the Geogebra AR application is effective in increasing the Actuarial Science Study Program students' understanding of calculus concepts, especially standard surface materials in space. Statistical analysis using paired t-test proved that there was a significant increase (p-value = 0.000356 < 0.05) between the average value of the pre-test (71.80) and post-test (83.02). This confirms that the visualization of abstract mathematical objects into concrete forms through AR has succeeded in reducing learning difficulties, increasing interaction, and encouraging active student involvement. Additionally, AR creates a more dynamic and relevant learning experience, allowing students to see the application of calculus concepts in real contexts. This finding is in line with constructivism theory, where experience-based learning (experiential learning) through interactive technology such as AR strengthens conceptual understanding and creativity in problem solving. Thus, the integration of AR into the mathematics curriculum not only improves academic outcomes, but also builds a stronger foundation of knowledge for students.

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