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The Effectiveness Application of Learning Model with Augmented Reality on Deaf Student's Geometry Learning Outcomes

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Abstract. Previous studies have reported that many deaf students have difficulty explaining their conceptual understanding of two-dimensional geometry even though they may be familiar with these basic geometric concepts. The purpose of this study was to answer the problems related to the effectiveness of learning model application with augmented reality on deaf student's geometry learning outcomes, especially enhanced understanding of geometry concepts. A learning model with augmented reality (AR) that adapts the technology of the augmented reality (AR) framework, allows deaf students to see the real world while the virtual elements are combined with the real world. In this way, students can visualize abstract objects that were previously difficult for them to imagine so students' conceptual understanding supporting by gained of the direct experiences and it is a new opportunity to support the mathematics learning process. Students were tested before and after learning with the application of augmented reality (AR) technology. Paired sample t-test using SPSS was used to compare pretest and posttest scores to measure the effectiveness of implementing the learning model with AR to enhance students' understanding of geometry concepts. There was a statistically significant enhancement in a score (Sig. = 0.000), which indicates that the application of learning models with augmented reality (AR) in the classroom helps the learning outcomes of deaf students, especially their understanding of geometry concepts. In addition, students' positive responses indicate that the learning model with augmented reality (AR) provides an interesting way to learn two-dimensional concepts.

INTRODUCTION

Mathematics is a subject whose application is often found in everyday life and develops students' awareness of the essential values contained in it. Abstraction of mathematical objects makes many students have difficulty in learning it, so to learn mathematics whose material is arranged systematically and contains logical reasoning, student readiness is required. The success or failure of the mathematics teaching and learning process can be measured through the students' mathematics learning outcomes as a result of the learning process (1). According to Nasution, learning outcomes are changes that occur in individuals who learn, not only changes in knowledge, but also to form skills and self-esteem in individuals who learn (2). Learning outcomes state what students expect from what they are able to do

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as a result of their learning activities. Therefore, learning outcomes are closely related to students' mastery of certain concepts they have learned.

In learning, students are said to have mastered the concept if they have fully understood the concept and are able to apply it to solve problems or explain physical phenomena in the real world or the virtual world ((3), (4), (5), (6)). In fact, several studies have shown that there are still many students who have difficulty mastering concepts (7). Whereas according to NCTM, understanding the concept is a very important aspect in the principles of learning mathematics (8). One of the branches of mathematics that is difficult for students to learn is geometry. Geometry is one of the important aspects in learning mathematics that must be understood by students, because the concept of geometry is very closely related to the context of everyday life ((9), (10), (11)). Basically geometry has a greater chance for students to understand than other branches of mathematics, because geometric ideas have been known by students before they entered school through their toys (12). But in fact, student geometry learning outcomes in the field are still low because students have difficulty in certain geometric materials which can have an impact on the difficulties of other interconnected parts of geometry (13).

One material that has the potential for great difficulty for students to master is circles. Several research results have been shown that students have difficulty in solving circle problems, which is caused by the low mastery of students' concepts, both basic concepts and their application in math problems ((14), (15)). Circle is one of the geometric objects obtained through an abstraction process based on concrete objects that are often seen in everyday life ((9),(16)). Abstraction of the circle material becomes a separate obstacle for students, especially students who are hearing-impaired in mastering the concept of geometry.

According to Thompson, children who are hearing-impaired, usually also experience delays in speaking (17) and have an inability to hear all kinds of sounds fully (18). Therefore, they will have limited hearing and verbal communication (19). The implications of communication and knowledge limitations make children who are hearing impaired have many difficulties in learning mathematics compared to normal children (20). In the Minister of National Education Regulation Number 157 Article 8 of 2014, the content of the special education curriculum is contained in the 2013 curriculum which is adapted to students with special needs and equivalent to the regular education curriculum with a note that several programs for students with special needs can be added if needed. This means that the achievement of geometry competence and geometry material, including circle material, must be achieved by students who are hearing impaired as good as normal students.

Based on the results of a preliminary study conducted by researchers at SLB Negeri 2 Bantul, on 8th grade deaf students, can be concluded that they have a lot of difficulty in mastering the circle material. From the results of the initial learning test, have shown that 76% of students have not reached the minimum completeness criteria for circle material related to the definition and its elements. There are many difficulties experienced by students in understanding concepts of geometry that related to circle material. In addition, from the results of observations and interviews, also known that the expository method was still used in learning circle material and students were still less involved in concept discovery. During learning, students were only given material by the teacher, so that students memorized more of the circle elements and without meaningful meaning. That condition was contrary to the many models and used of circular objects in everyday life. This is where the importance of a teacher in developing a learning model that can stimulate students' understanding of geometric concepts through manipulation of real objects or concrete experiences, so that student learning becomes more meaningful. According to Diyana et al, students need sufficient experience to use scientific concepts as appropriate sources in solving problems (21). It is quite challenging for teachers to be able to design learning appropriately which will determine the achievement of learning outcomes and student learning success in schools ((22), (23), (24)). In other words, the quality of learning is determined by the effectiveness of teachers in teaching (25).

Considering that deaf students have limited hearing and knowledge, the learning model developed by the teacher needs to emphasize the importance of visual displays to accompany verbal illustrations so that the abstract circle learning material can be understood by students (19). Virtual environment can be an alternative to create visualizations through computer graphics. According to Sutherland (26), augmented reality technology allows students who use it to see the real world with virtual elements superimposed on the real world. Augmented reality enriches students' perceptions as users of reality without completely replacing it as in a virtual environment. Thus, students can understand and utilize the properties of these physical objects (27).

According to Woods et al, augmented reality could help in presenting and exploring 2-dimensional object problems that at the beginning it's difficult for students to understand into 3-dimensional form (28). Augmented reality technology is a new opportunity to support the mathematics learning process ([(29), (30)). Augmented reality could help students understand the material given during the learning process. With the increasing interest and understanding of the circle concept, it is expected that student learning outcomes will enhance.

Several studies on development of learning with augmented reality technology have been conducted. Figueiredo's research on the effectiveness of augmented reality to display 3D through QR codes and orthographic images (isometric display) (31); Jerabek's research on the effectiveness of augmented reality through improving the didactic tool system and its function to support cognitive processes (32); and Yoon's research on increasing students' understanding of scientific phenomena with Bernoulli's principle working in a short time (33). The similarity with this study lies in the effectiveness of augmented reality, while the difference lies in the research location, characteristics of subjects with disabilities, and mathematical material with abstract objects. The development of learning models that adapt the augmented reality technology framework has been conducted, while this research was a follow-up study to see whether the significant effect of learning model application with augmented reality to enhance the learning outcomes of deaf students. So, the purpose of this study was to answer the problems related to the effectiveness of learning model application with augmented reality on deaf student's geometry learning outcomes, especially enhanced understanding of geometry concepts.

METHOD

This research was conducted at SLB Negeri 2 Bantul, Yogyakarta. The population in that study were all deaf students at SLB Negeri 2 Bantul. The sampling technique used was a purposive sampling technique. Therefore, in this study, a sample class was taken which was attended by 17 deaf students who take a class on circle learning. The research method used in this study was an experimental one-group pretest-posttest design. Data was collected through given by five test questions about understanding the concept of a circle and its elements (radius, diameter, arc, chord, apothem, sector, and segment) in the form of a description. Before being tested, the test instrument was validated by asking for opinions and input from experts. After the instrument was corrected according to the validator's suggestion, the researcher conducted a limited trial to obtain information on the readability of the instrument. Based on the results of the expert's assessment, the test instrument compiled has met the valid criteria and is suitable for use in the learning process. Before being used in the learning process, an estimation of the reliability of the instrument is carried out. The reliability of the conceptual understanding test was estimated using the Kuder-Richarson formula with KR-20. From the calculation results, the alpha coefficient for the conceptual understanding test instrument is 0.875. Thus, the understanding test instrument is declared reliable.

Before applying the learning model with augmented reality, a pretest was held for students so that the students' understanding of the circle concept could be known. Then the learning was conducted in five meetings. Students were taught the concept of a circle from definition to elements in a circle using several learning steps based on the framework of augmented reality technology. After all the material has been given, at the fifth meeting a posttest was held which aims to assess students' understanding of the circle material.

Data from written test score is presenting in form of descriptive and inferential statistics. Descriptive statistics are used to describe the categories of learning outcomes that have been implemented, while inferential statistics are used to describe the significant enhancement in results before and after being given treatment. The Kolmogorov Smirnov test was used to test for normality, while the hypothesis test was used to see the effectiveness of the learning model by using the paired sample t-test with the help of SPSS 2.0 software. The basis for decision making in that test is H0 and Ha. H0 is rejected and Ha is accepted if, t-value > t-table or significance probability < 0.05. The hypothesis of that research is as follows.

1. Null hypothesis (H0): There is no significant effect of the learning model with augmented reality on learning outcomes of deaf students.
2. Alternative hypothesis (Ha): There is a significant effect of the learning model with augmented reality on learning outcomes of deaf students' geometry.

TABLE 1. Categorization of the Percentage of Learning Outcomes of Deaf Students

Percentage of Learning Outcomes	Category
≥ 80%	Very High
60% - 79%	High
40% - 59%	Medium
20% - 39%	Low
< 20%	Very Low

The effective criterion here is if the percentage of success in classical student learning outcomes, for the students obtaining a score of 70 is in the very high category (34) as shown in Table 1.

RESULT AND DISCUSSION

Researchers have succeeded in developing a learning model with learning stages that adopt an augmented reality technology framework. An augmented reality framework based on the tangible interface metaphor was adopted to construct a learning model. In an augmented reality framework, physical objects are used to intuitively manipulate virtual information, then combined with virtual elements. This framework is then applied in a form of learning model related to students' cognitive, especially students' understanding of concepts. The learning model with augmented reality developed in this study is illustrated in the activity flow in Figure 1. below.

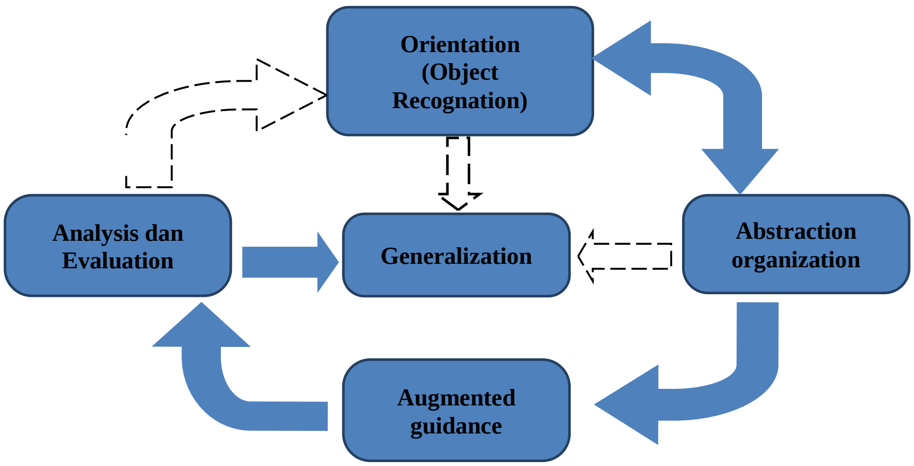
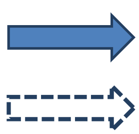


FIGURE 1. Activity Flow Diagram of Augmented Reality Learning Model



The stages in the learning model with augmented reality are conducted systematically starting from the orientation of the introduction of concrete objects, the organization of the abstraction of concrete objects, guidance in expanding the results of the introduction of concrete objects, analysis and evaluation, and generalizations. In this learning model, certain stages can occur without having to go through a sequence so that certain stages have their own alternative stages as indicated by arrows bounded by dotted lines. The activities of the five steps of the learning model are represented in Table 2 below.

TABLE 2. Activities of Learning Model Steps with Augmented Reality

Action/Steps	Activity
Orienting students to concrete object recognition	▪ students find certain information through exploration and manipulation of concrete objects around them
	▪ can be done in groups
Organizing students to abstract concrete objects	▪ students discuss knowledge related to the properties of concrete objects manipulated in the previous stage ▪ students have been organized their knowledge so as to produce new objects that are no longer in the form of concrete objects, but have been extracted through mental action into new objects that are abstract and contain unique important elements.

Action/Steps	Activity
	▪ can be done in groups or individually
	▪ This stage produces knowledge schemas that can be represented in visual form
Guiding students in expanding the results of recognizing concrete objects	▪ students are monitored by the teacher for the knowledge imparted by linking it to other relevant context
Analysis and Evaluation	▪ students investigate the results of knowledge expansion and review the organizational structure of knowledge in the previous stage
	▪ This is done to achieve understanding if there is a possibility of errors in relating knowledge and context ▪ can be done in groups by way of discussion
Generalizing the development of object recognition results	▪ students summarize or make simpler ideas on the results at the analysis and evaluation stages according to their interpretations

In the first step, the teacher orients students to the introduction of concrete/real objects. At this step, students are asked to find certain information through exploration and manipulation of real objects around them which are in the form of circles in groups. In the second step, the teacher organizes students to abstract objects that they find. In this case, students and their groups will discuss the characteristics and elements of the circle that exist in the circular objects which they found such as the radius, diameter, arc, chord, apothem, sector, and segment. At this step, the abstraction occurs in students' minds after they explore the objects, so that knowledge schemas are formed that can be represented visually. In the third step, the teacher guides students in expanding the results of recognizing real objects that have been explored and related them with other relevant contexts. Then, students and their groups analyze and evaluate the learning outcomes from the previous step to anticipate possible errors in linking knowledge and context. Finally, students generalize the exploration results of the real object by making simple ideas according to their interpretations.

By using these learning steps, teachers are expected to improve students' perceptions and their interactions with the real world so that the learning outcomes of geometric materials also enhance. During learning, deaf students move around virtual images of the concepts they are learning and then look at them from various points of view, such as real objects. The information conveyed by the virtual object will help students perform real-world tasks

Based on the results of the pretest and posttest, five criteria for the learning outcomes of deaf students were obtained as shown in Table 3 below.

TABLE 3. Percentage of students' geometry pretest and posttest results related to the application of learning models with augmented reality

Categorization	Pretest		Posttest	
	Count	Percentage	Count	Percentage
Very High (90-100)	0		1	5,88
High (80-89)	0		4	23,53
Medium (65-79)	2	11,76	10	58,83
Low (55-64)	12	70,59	2	11,76
Very Low (<55)	3	17,65	0	

Table 3 descriptively shows that there is an enhance in the category of geometry learning outcomes for deaf students as indicated by an enhance in the percentage of students in the very high, high, medium, and low categories from pretest to posttest. Based on the results of data analysis, it is known that the learning model with augmented reality has an influence and can effectively improve the learning outcomes of students with hearing impairment.

In addition to increasing the percentage of students belonging to certain categories, the researchers also analyzed the achievement of the minimum completeness criteria for the pretest and posttest scores of students classically based on the established categories so that the results are as presented in Table 4 below.

TABLE 4. Percentage of achievement of the minimum completeness criteria

Score	Pretest		Posttest		Category
	Count	Percentage	Count	Percentage	
< 70	16	94,12	3	17,65	Incomplete
≥ 70	1	5,88	14	82,35	Complete

From Table 4, it can be seen that the high percentage of students who have not met the minimum mastery of geometry learning outcomes when given a pretest, because the percentage of students who meet the minimum mastery of learning outcomes is less than 20%. This is in line with the basis for determining the criteria for completeness presented by Himawan and Purwanto (34) and Novianti (35), namely the achievement of classical geometry learning outcomes is met if students get a score of 70 in the very high category or with a percentage of at least 80% of all students. After being given a learning model with augmented reality, the percentage of students who met the minimum completeness of learning outcomes for geometry material enhance. This can be seen from the results of the posttest that the percentage of classical completeness for the very high category reaches more than 80% of all students. Thus the application of learning models with augmented reality can be said to be effective.

The effectiveness of the application of learning models with augmented reality is also seen from the results of comparative hypothesis testing between the average student learning outcomes obtained from the pretest and posttest. Before carrying out the test, the researcher tested the normality of the distribution of the pretest and posttest value data with the results as presented in Table 5 below.

TABLE 5. Output normality test for pretest and posttest data

Tests of Normality							
	Test	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Outcomes	Pretest	.183	17	.132	.962	17	.662
	Posttest	.196	17	.080	.936	17	.276

Based on the output table, it is known that the significance value of Asymp. Sig for the pretest result is 0.132 and the posttest result is 0.080. Because the value is greater than 0.05, it can be concluded that the pretest and posttest data values are normally distributed. Thus, the assumption of normality in the use of the paired sample t-test sample has been reach. Next, the researcher tested the paired sample t-test comparative hypothesis with the results as presented in Table 6 and Table 7 below.

TABLE 6. Output of descriptive statistics for the average pretest and posttest

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	pretest	57.47	17	6.236	1.512
	posttest	74.47	17	8.994	2.181

The output in Table 6 above shows the descriptive statistical results of the posttest mean value which is higher than the pretest mean, or there is a difference between the pretest mean and the posttest mean. To prove the significance of the difference in the mean, it is necessary to interpret the results of the paired sample t-test.

TABLE 7. Output of Paired Test Results Sample t-test on learning outcomes of geometry

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	pretest - posttest	-17.000	3.921	.951	-19.016	-14.984	-17.876	16	.000

Based on the output in Table 7, it is known that the student's geometry learning outcomes when given the pretest and posttest have a Sig value. (2-tailed) of 0.000 < 0.05. So it can be concluded that Ho is rejected or there is a difference in the mean between the results of the pretest and posttest. Shows that there is a significant effect of the application of learning models with augmented reality in improving learning outcomes of deaf students.

The inventions related to the effectiveness of applying augmented reality learning models in improving student learning outcomes in this study were in line with the results of research by several other researchers such as Rasalingam and Muniandy about the effectiveness of Augmented Reality learning in Malaysia compared to learning using conventional learning media (36); Figueiredo research on the effect of augmented reality on improving learning outcomes (31); Jerabek's research on the effectiveness of augmented reality in improving didactic tool systems (32); Yoon's research on the effect of augmented reality in improving understanding (33); and Sungkur, Panchoo and Bhoyroo research on augmented reality which was effective in helping students have difficulty understanding complex concepts (37).

Augmented reality is a technology that allows the merging of digital data processed by a computer with data from the real environment. Augmented reality provides users with things that are virtual by modeling the real world they experience, so that information related to certain contexts can be accessed directly by users. According to Furht, augmented reality's work step is to combine 2-dimensional or 3-dimensional virtual objects into a real environment and then project these virtual objects in real time (38). This makes students better to imagine abstract concepts that have been difficult to imagine to be more illustrated in real, when learning the concepts using a learning model based on an augmented reality framework.

Based on the results of the posttest, also known that there were students whose learning outcomes enhance but were still below the minimum completeness criteria. Meanwhile, other students completed the minimum completeness criteria and enhance. It was because of the unfinished students, need more time to understand math lessons due to limited vocabulary and knowledge due to hearing loss. The results of the posttest ware in line with what Nunes said, that the deaf have severe delays in learning mathematics (39). The delay is related to the weakness of the deaf due to hearing loss which has implications for lack of knowledge, social skill deficits, language delays, vocabulary delays, literacy delays, background knowledge gaps and dependence on assistive technology (40).

In addition to the condition of students who still cannot achieve minimum completeness, the posttest results also shown that there are students whose scores were already good, after applying the learning model their scores enhance to several points. However, there are also students whose scores were already above the minimum completeness criteria and also enhanced by several points. Some children were also improving very well. The diversity of learning outcomes for deaf students also shown that students' responses and understandings are different, the impact of applying the learning model felt by each student was also different. Some were very easy to understand the geometric concepts given, some feel they understand the material the same as regular lessons.

Direct experiences experienced by students when teachers apply learning models with augmented reality, made students more interested and enthusiastic in participating in the learning process. Learning model using augmented reality is a new idea in the world of education, especially learning mathematics. It aims to make learning mathematics relevant and meaningful for students. In addition, this learning model using augmented reality can also be used to improve collaborative tasks and innovative learning alternatives that combine the virtual world and the real world to improve face-to-face and distance collaboration (41). In fact, augmented reality is more similar to natural face-to-face collaboration than screen-based collaboration (42). The enthusiasm and collaboration of deaf students during the application of the learning model with augmented reality is presented in Figure 2 below.

FIGURE 2. Collaborative activities and student enthusiasm during learning

The inventions support previous research related to enthusiasm and how to interact with students in participating in learning because of the novelty of learning using augmented reality such as the results of research by Wulansari, Zaini and Bahri (43) and research by Agrawal, Kulkarni, Joshi, and Tiku (44). Learning with the use of augmented reality technology can help students visualize abstract concepts or certain concepts whose content is difficult for students to imagine so that student learning outcomes on the materials they learn enhance. In addition, learning models that involve visualization displays and 'present' real-world objects tend to attract students' attention, so that learning materials will be more easily delivered.

CONCLUSION

Learning models with augmented reality that are applied as didactic tools in schools can be used as alternative learning models that attract interest in learning, stimulate curiosity, are interactive when used, without reducing the essence of the material presented by the teacher. On the other hand, learning using augmented reality technology can help students visualize abstract concepts or certain concepts that are very difficult for students to imagine or reach. With the ability of physical interaction in augmented reality applications, students are also helped to explore objects that are very difficult to imagine or reach. This is supported by the results of research related to the application of learning models with augmented reality for the geometry material of deaf students which shows the results of the paired sample t test with a significance value of 0.000. This means that there is a difference in the mean of the pretest results with the posttest results. So it can be concluded that the application of learning models with augmented reality on deaf students is effective in improving their geometry learning outcomes. By looking at the results of these studies, teachers should consider the application of learning models with augmented reality with comprehensive observations, especially the implications for student enthusiasm and learning steps that further activate the student learning experience, so that it affects the improvement of learning outcomes. In the future, teachers also need to consider modifying this learning model to suit the characteristics, constraints and learning needs of deaf students.

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