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Website: ijcs.stmikindonesia.ac.id | E-mail: ijcs@stmikindonesia.ac.id

Geometry Learning Media Application for Elementary School Students Using Android-Based Augmented Reality Technology

Rian Luthfi Fadilah[1], Sutarman[2]
ryan112luthfi@gmail.com, sutarman@uty.ac.id
[1.2]University of Technology Yogyakarta

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Abstract

Geometry is one of the subject matter in mathematics. Geometry has many type of shape, formula, area and volume. So there are many elementary school students feel no interest in studying geometry material because they feel difficult and don't understand it properly it is clear what each of these geometry looks like. To meet these demands, in line with developments in science and technology, the use of learning media is a solution. Increasingly diverse and interactive technology, one of which comes with utilizing AR technology. The use of augmented reality which is able to present 3D objects in visualizing geometric grids can make it easier to remember geometric shapes and utilizing this technology is able to create learning applications that stimulate students interest in learning to carry out learning activities actively and independently

A. Introduction

Mathematics is a general science and has a role important in various scientific disciplines and in the development of human thinking abilities, as well as being the basis for the development of modern technology[1]. Geometry is one of the subject matter in mathematics. Each type of geometric shape has its own shape and formula for area and volume, so many students do not feel interested in studying shapes[2]. We all know that mathematics is one of the subjects that children don't like. Teachers are aware of this obstacle, but there are still many teachers who do not make every effort to reduce or even turn it into learning that attracts students' interest[3].

In mathematics, one of the materials is studied is the material of geometry. Geometry materials has been taught since elementary school, but in reality students' ability to understand about geometry is still relatively minimal. Geometry has many type, shape, formula, area and volume. So there are many elementary school students feel no interest in studying geometry material because they feel difficult and don't understand it properly it is clear what each of these geometry looks like[4]. This is of course very closely related to the role of the teacher when presenting mathematics teaching and learning activities in the classroom. A study shows that 70% of students at elementary school level do not like mathematics lessons, this is because the use of media, materials and learning methods used do not attract students' interest in learning[5].

Based on facts in the field at one school in Indonesia, learning systems that still use the lecture method in mathematics are still common in the teaching and learning process, there are still very few mathematics learning systems that use technology like today. It is felt that students still have difficulty visualizing geometric objects, especially students who are less able to visualize geometric objects in certain parts[6].

From several things above, it can be seen that the development of learning media needs to be carried out to help students learn independently, especially in understanding the basic concepts of geometry. The media developed must of course be interesting and make students more active in learning, especially in visualizing geometric shapes and solving mathematical problems[7]. To meet these demands, in line with developments in science and technology, the use of learning media is a solution. Increasingly diverse and interactive technology, one of which comes with utilizing AR technology[8].

The use of AR on devices such as smartphones that are familiar to students can be used as an alternative for developing learning media that is innovative and acceptable to students[9]. Moreover, the use of Android on mobile devices by December 2022 has reached around 89.29% of users in Indonesia, ranking at the top of six other operating systems[10]. The development of Android-based learning media is effective in improving students' creative thinking abilities[11]. Technology in education continues to develop, giving rise to many useful tools or media to continue to increase the effectiveness of achieving learning goals. One technology product that can be used in education is Augmented Reality (AR)[12]. In one research, the use of AR in Physics learning was proven to be able to increase understanding of concepts, increase interest in learning, improve learning outcomes and improve students' critical thinking[13]. Likewise, in several other

subjects such as mathematics, science and thematic learning, the use of AR has proven to be effective in the learning process, especially in exact and science subjects[14][15].

Augmented Reality is a virtual reality that can bring into the real world using a camera. AR technology has now been widely developed to create learning media specifically to be operated via smartphone[16]. By utilizing augmented reality technology and Android smartphones combined directly with material from printed books, geometric objects can be visualized concretely through three-dimensional virtual modeling that is similar to the real object[17]. The use of augmented reality which is able to present 3D objects in visualizing geometric grids can make it easier to remember geometric shapes and utilizing this technology is able to create learning applications that stimulate students' interest in learning to carry out learning activities actively and independently[18].

There is a gap between this research and the previous research, where the previous research only focused on a few features and objects that could be used by students and seemed incomplete. This can cause the same problems as conventional learning media, where students will feel bored quickly when studying geometric material. Therefore, in this research more features and objects related to geometry materials will be created using augmented reality technology. and it is hoped that it can fulfill the objectives of this research, it can help elementary school students recognize geometric structures and also help teachers to more easily present learning material, so that a more interesting and effective learning process can be created.

B. Research Method

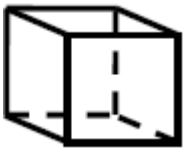
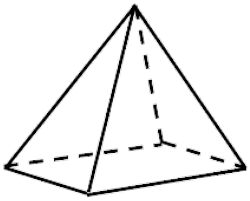
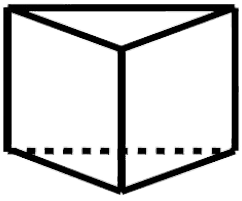
A) Data Obtained

The data obtained as material for this research were obtained from literature in the form of books and modules related to various types of geometric structures originating from websites on the internet, along with information related to explanations of characteristics and formulas in detail of geometric objects that will be used as 3D objects in application creation. The following are books and modules along with website page addresses used as data sources, including:

1. Introduction to geometry and their properties in elementary school by Agus Suharjana, 2008.
2. Happy learning mathematics for elementary school students grade V by Purnomosidi, Wiyanto, Safiroh and Ida Gantiny, 2018.
3. Happy learning mathematics for elementary school students grade VI by Mohammad Syaifuddin, Susanto, Hobri, Dhika Elvira Maylistiyana, Hosnan, Anggraeny Endah Cahyanti dan Khoirotul Alfi Syahrinawati, 2018.
4. Grade 6 mathematics module "chapter 4 geometry" by Susmawati, 2020.
5. Module 2 deepening of mathematics material by Andhin Dyas Fitriani, 2019.

The data that has been obtained in the form of images of geometry objects can be seen in table 1, including:

Table 1. Data Obtained

No	Name	Icon
1.	Cylinder	
2.	Sphere	
3.	Cone	
4.	Cuboid	
5.	Cube	
6.	Pyramid	
7.	Prism	

B) Data Collection Procedures

The data source obtained was carried out by means of literature study. Study and analyze literature in the form of books and modules that are relevant to the research object. Downloaded modules and books are obtained from several websites on the internet in .pdf format using internet download manager software to assist in managing downloads of downloaded files until they are included in local documents. The time period used in collecting data in this research began on

October 27 2022, a period of approximately 2 (two) weeks. The data collection time referred to is the time used to collect materials related to geometry structures and can be used as 3D objects in this research.

C) Business Rules

1. Detailed Analysis of Currently Running Procedures

The current procedure is that students in the process of learning geometry material still refer to a printed book as a learning medium. This media is also a reference for teachers to explain geometric structure material, where it can be seen that geometry are 3D objects. Therefore, this procedure is not yet optimal enough in its application because students are not yet able to understand the characteristics of 3D geometric shapes as a whole, while the geometry objects are only printed in 2D from a book and also the learning process will only be centered on the teacher who conveys it. This can be seen in Figure 1.

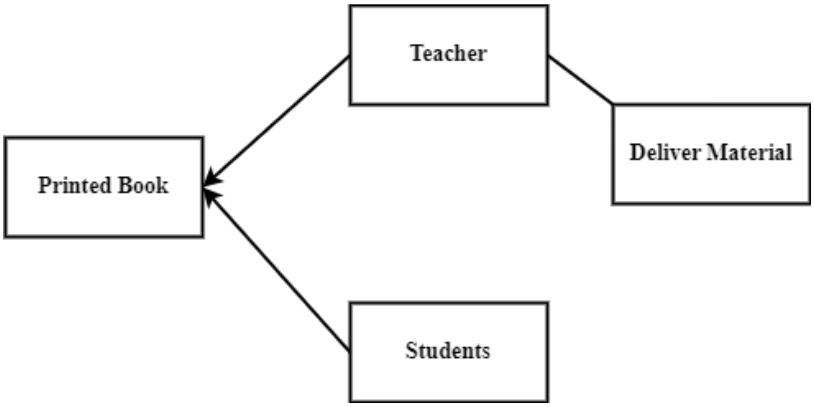


Figure 1. Currently Running Procedures

2. Lack of Current Procedures

The disadvantage of the current procedures is that the learning process will tend to be less interactive, where the learning process will become monotonous due to the lack of interaction from students and it only focuses on the teacher delivering the material. Apart from that, the learning media used, namely printed books, will make it difficult for students to reason about the characteristics of concepts and properties of geometry objects because the learning media can only be seen from the 2D side. These two things will be a factor in reducing students' learning outcomes and interest in geometry materials.

D) Research Stages

The initial condition that became a problem in this research was the lack of effectiveness of the teaching and learning process. The teacher's delivery of material at this time is still conventional and less interesting. This can influence students' interests and learning outcomes.

From this problem, a proposed model that could be an alternative solution is the use of learning media applications in delivering material related to geometry. This application has a mechanism for use, there are 2 stages of the mechanism. Stage 1 is, visualizing geometry objects in 3D with markers that can be accessed via

smartphone. Stage 2, namely, can bring up features related to object information to introduce geometry objects.

It is hoped that the final conditions of the proposed model that have been explained will help teachers in delivering the material. The material presented is to introduce geometry objects using augmented reality learning media applications. This application will be able to increase students' interest and learning outcomes. The research stages can be seen in Figure 2.

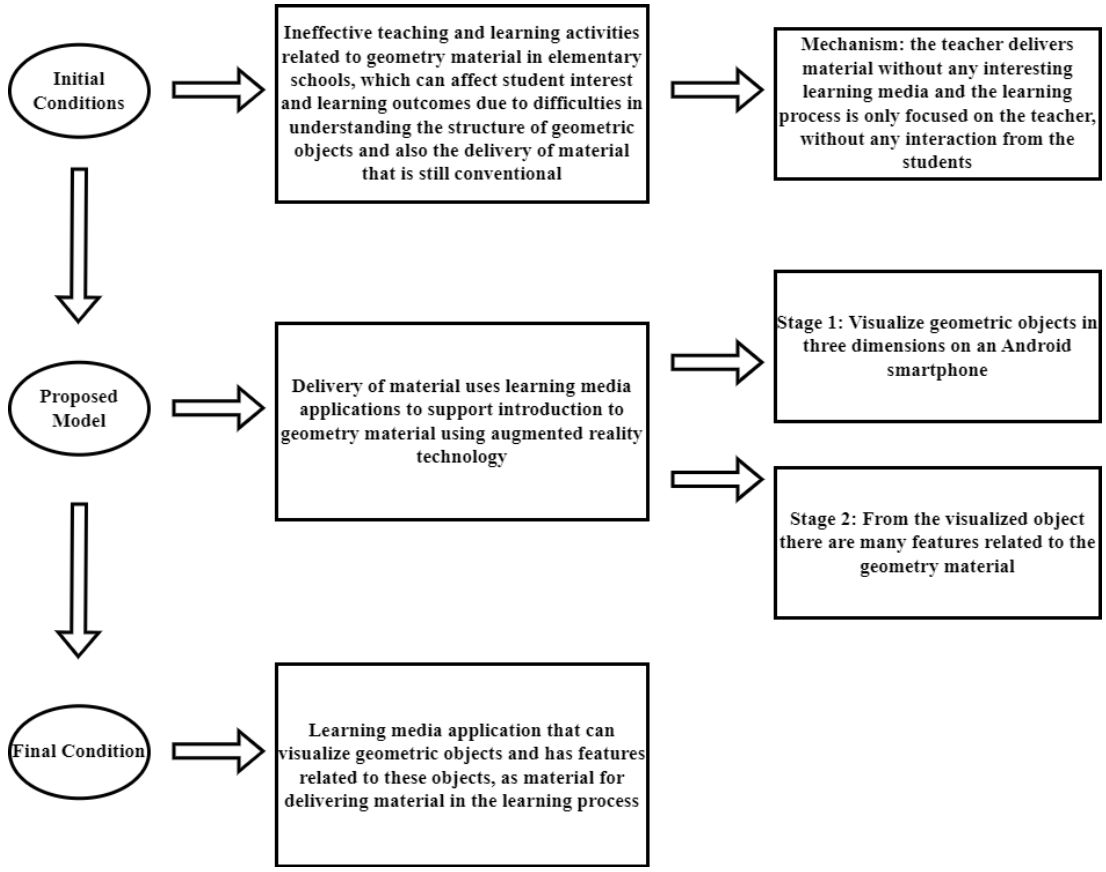


Figure 2. Research Stages

E) Analysis of The Proposed System

This geometry learning media application will run on the user's Android-based smartphone and has a camera in it, where the camera will be used as a tool to identify or scan the markers created. The camera will be connected to the Vuforia SDK that has been configured, with a database containing markers in the form of images of geometric objects. The marker that is scanned by the user will display a 3D object which will be displayed on the smartphone screen in real time and the object displayed has several features related to geometric object information and can produce audio and animation that can be displayed, from the display of the 3D object it can also be displayed. moved in the form of rotation and zooming in on the object. Analysis of the proposed system can be seen in Figure 3.

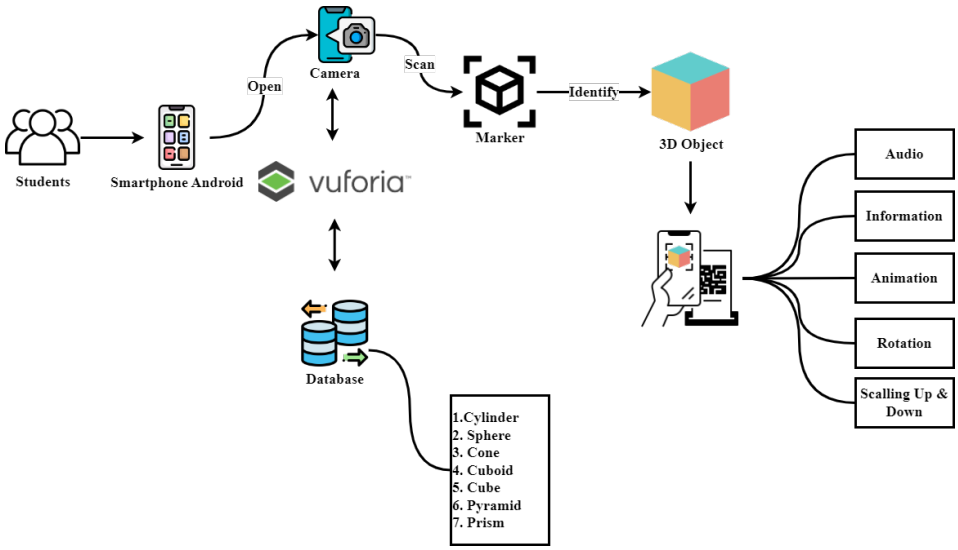


Figure 3. Proposed System

F) Logic Design

The logical design used in the AR geometry application is a use case diagram. Using UML diagrams can explain how a system works in an application and its interactions with students when using this application system. Each defined functionality will be described through a use case. this diagram. Use cases will present actors or students interacting with the application system. When the application is run, the user will access the main menu. In the main menu there are 5 main buttons, each button will direct you to another scene. The scene that is the main feature in this application is the AR scene, in which there are many features that can be accessed by users such as audio explanation of objects, object formula information, object animation, object rotation, object scale up, object scale down and object refresh. Use case diagram of system can be seen in Figure 4.

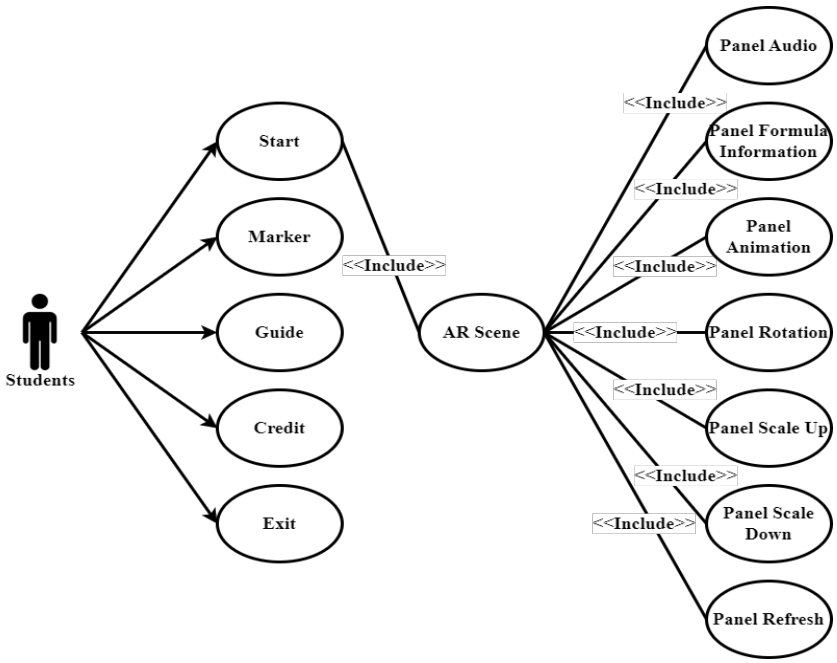


Figure 4. Use Case Diagram

C. Result and Discussion

A) Result

The results stages in this sub-chapter are a continuation of the implementation stage. This stage shows the results of the implementation process created, such as interface scenes, features and objects in the application. These components have been programmed with the core script in the application system. This research produces a product that matches the desired design. There are complete objects and features related to geometric objects. The UI consists of several scenes produced such as main menu, AR scene, credits and guide. for the main menu scene contains buttons such as start, marker, guide, credit and exit. Users can access and download markers on the markers button in this scene, all saved markers are in cloud storage. UI of application can be seen in Figure 5.

a) b) c)

Figure 5. UI of Application

When accessing an AR scene, there will be a camera that is automatically opened by the system. This camera will function to scan geometric object markers obtained from cloud storage. The marker will be printed into a sheet that can be scanned. As soon as the object is displayed, the system will immediately display the core features of this application related to the object displayed. AR scene can be seen in Figure 6.

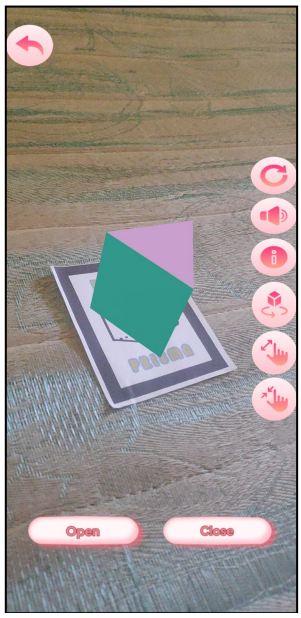
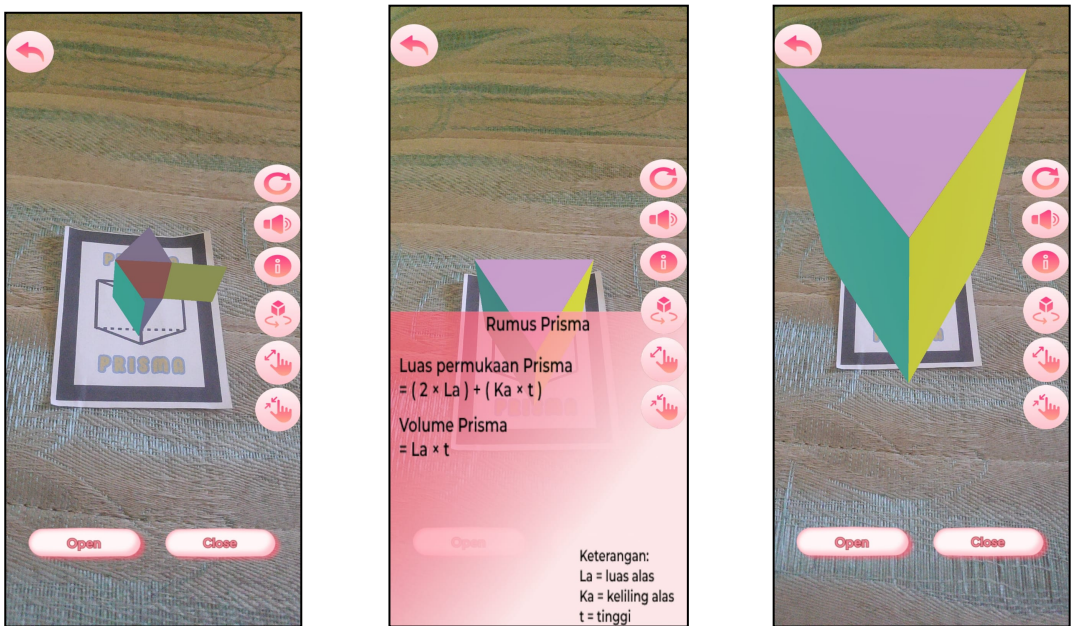


Figure 6. AR Scene

Users can explore the features there, such as the audio feature for explaining geometric object information, the info feature for displaying geometric object formula information, the rotation feature for rotating geometric objects 360 degrees, the scale up feature for increasing the size of geometric objects, features scale down to reduce the size of the geometric object, a refresh feature to reload the object if a bug occurs and an animation feature which will display an animation of opening or closing the mesh of the displayed geometric object. The results of the objects displayed have been compared to their original form so that users can recognize the shape of the geometric objects displayed and users can also learn about the characteristics and concepts of geometric structures as a whole.



a) b) c)

Figure 7. Application Features

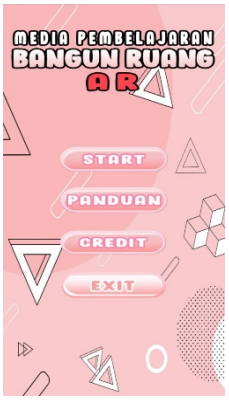
B) Discussion

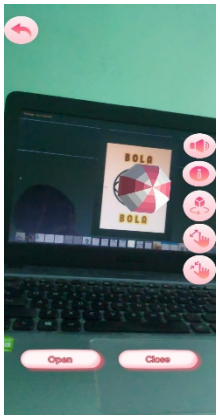
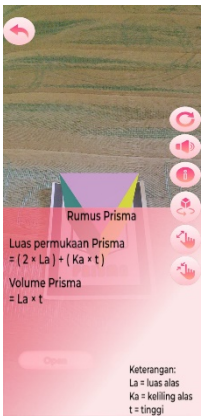
This sub-chapter will explain the discussion of testing implementation results in the AR geometry application. There are several tests carried out on this application, namely testing the system using the black box testing method, manual marker detection testing and user testing on the application. The following is a discussion of testing the AR application for geometry.

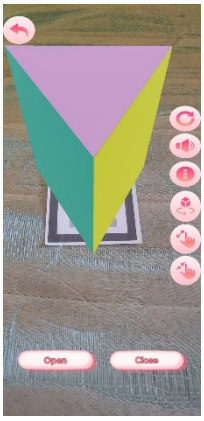
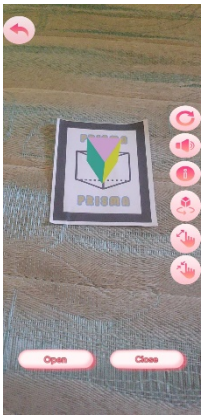
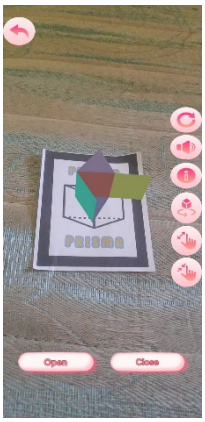
1) Blackbox testing

Black box testing will be used to test all components and elements contained in the AR geometry application system. This testing makes it possible to see which components and elements are functioning as expected and makes it possible to find errors or errors that occur in the AR geometry application system. The tests carried out will only observe the results of the system being run and check the functionality of the AR geometry application. The following is a black box testing table which can be seen in table 5.1

Table 2. Blackbox Testing

No.	Testing	Information	Results	Conclusion
1	Main menu	The main menu will appear when the application is first run. On the main menu there are several buttons, namely start, guide, credit and exit.		Succeed
2	Start button	When select the start button on the main menu, the scene that will appear is the AR scene, where the student's Android smartphone will access the AR camera.		Succeed

3	Scan Marker	When on the AR scene and the camera has been accessed, students direct the camera view towards the available markers. The 3D object will appear right above the marker according to the scanned marker and buttons in the form of object features will also appear.		Succeed
4	Information Button	On the AR scene, when the marker is successfully scanned, an information icon button will appear. When accessed, the information button will bring up a panel on the AR scene containing information on geometric object formulas.		Succeed
5	Audio Button	On the AR scene, when the marker is successfully scanned, an audio icon button will appear. When accessed, the audio button will produce a sound on the student's Android smartphone explaining the geometric object.	Make sound on Android smartphone	Succeed
6	Rotation Button	On the AR scene, when the marker is successfully scanned, a rotation icon button will appear. When accessed, the rotation button will rotate the object in one direction on the Android smartphone.	Rotate the displayed object in one direction 360°	Succeed

7	Scale up button	On the AR scene, when the marker is successfully scanned, a scale up icon button will appear. When accessed, the scale up button will increase the size of the object to a predetermined limit.		Succeed
8	Scale down button	On the AR scene, when the marker is successfully scanned, a scale down icon button will appear. When accessed, the scale down button will reduce the size of the object to a predetermined limit.		Succeed
9	Animation Buttons	On the AR scene, when the marker is successfully scanned, an animated icon button that says open close will appear. When you access the open close button, it will run an animation in the form of closing and opening the net of objects displayed.		Succeed
10	Refresh Button	On the AR scene, when the marker is successfully scanned, a refresh icon button will appear. When accessed, the refresh button will reload the object from the scanned marker to its initial state.	Reloads the scanned object to its initial state	Succeed

11	Guide Button	When you select the guide button on the main menu, the scene that will appear is a guide scene, where this scene will contain a guide display for using the AR geometry application.		Succeed
12	Credit Button	When you select the credit button on the main menu, the scene that will appear is the credit scene, where this scene will contain the name of the AR geometry application developer.		Succeed
13	Home Button	When you select the back or home button on each scenes, the scene that will appear will return to the main menu.	Return to the main menu after another scene	Succeed
14	Exit Button	When you select the exit button on the main menu, the application will stop and automatically exit the AR geometry application. Exit the application	Exit from application	Succeed

2) Marker detection testing

Testing to detect this marker will help determine minimum requirements for users. In this test there are several parameter conditions used such as distance, tilt angle, light intensity and time needed to detect the marker. In this test, 2

devices will be used in the form of Android smartphones with different specifications to be able to compare the results of the test data. Light testing will be carried out using light meter software, where the unit for measuring light is a lux meter. The light intensity test will be carried out indoors with 2 conditions, namely the lights when they are on and the lights when they are off. The assessment indicators used in this test are success and failure, where if the marker can be detected in the condition of the parameter being tested, it can be interpreted as a successful test, and if the marker cannot be detected in the condition of the parameter being tested, it can be interpreted as a failed test. Test results can be seen in table 3.

Table 3. Marker Testing Poco F1

Light intensity (lux)	Device	Tilt angle (°)	Distance (cm)	Time (sec)	Description
35 – 55 lux (Light on)	Pocophone F1	0°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	1 sec	Succeed
			41 – 50 cm	1 sec	Succeed
		30°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	1 sec	Succeed
			41 – 50 cm	1,5 sec	Succeed
		60°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	1 sec	Succeed
			41 – 50 cm	-	Fail
		90°	0 – 10 cm	-	Fail
			11 – 20 cm	-	Fail
			21 – 30 cm	-	Fail
			31 – 40 cm	-	Fail
			41 – 50 cm	-	Fail
0 - 15 lux (Lights out)	Pocophone F1	0°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	1 sec	Succeed
			41 – 50 cm	1,5 sec	Succeed
		30°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	1 sec	Succeed
			41 – 50 cm	2 sec	Succeed
		60°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	2 sec	Succeed
			41 – 50 cm	-	Fail
		90°	0 – 10 cm	-	Fail
			11 – 20 cm	-	Fail
			21 – 30 cm	-	Fail
			31 – 40 cm	-	Fail
			41 – 50 cm	-	Fail

In table 3 it can be explained that the results of the marker detection test using the Pocophone F1 achieved a fairly high success rate in various conditions. It can be seen that only in some conditions the test fails. From the use of the Pocophone F1 device in the data table, it proves that the tilt angle, light intensity and distance will affect the 3D visualization time of the scanned object and can even cause failure in visualizing the 3D geometry object.

Table 4. Marker Testing Realme 3 Pro

Light intensity (lux)	Device	Tilt angle (°)	Distance (cm)	Time (sec)	Description
35 - 55 lux (Light on)	Realme 3 Pro	0°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	1 sec	Succeed
			41 – 50 cm	1 sec	Succeed
		30°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	1 sec	Succeed
			41 – 50 cm	1 sec	Succeed
		60°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	-	Fail
			41 – 50 cm	-	Fail
		90°	0 – 10 cm	-	Fail
			11 – 20 cm	-	Fail
			21 – 30 cm	-	Fail
			31 – 40 cm	-	Fail
			41 – 50 cm	-	Fail
0 - 15 lux (Lampu Lights out)	Realme 3 pro	0°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	1 sec	Succeed
			41 – 50 cm	1 sec	Succeed
		30°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	1 sec	Succeed
			41 – 50 cm	1 sec	Succeed
		60°	0 – 10 cm	1 sec	Succeed
			11 – 20 cm	1 sec	Succeed
			21 – 30 cm	1 sec	Succeed
			31 – 40 cm	1 sec	Succeed
			41 – 50 cm	-	Fail
		90°	0 – 10 cm	-	Fail
			11 – 20 cm	-	Fail
			21 – 30 cm	-	Fail
			31 – 40 cm	-	Fail
			41 – 50 cm	-	Fail

In table 4, it can be explained that the results of the marker detection test using Realme 3 pro are almost the same as the previous device, namely, getting a

fairly high success rate in various conditions. It can be seen that only in some conditions the test fails. From using the Realme 3 Pro device in the data table, it proves that the tilt angle, light intensity and distance do not really affect the time for 3D visualization of scanned objects, but can only affect failure in 3D visualization of geometry objects.

3) User Testing

User testing or testing on users is carried out to determine the feasibility of the AR geometry learning media application. This test was carried out by collecting opinions through a questionnaire form. This testing was also carried out at SD ISLAM AL-AZHAR 58 BALIKPAPAN, where there were 8 grade fourth students and 1 teacher who were respondents in testing this application. The questionnaire form provided consists of 5 answer choices including strongly agree, agree, neutral, disagree and strongly disagree. There are 6 questions as assessment indicators for this application. The results of the questionnaire for user testing on the AR geometry application can be seen in table 5.

Table 5. User Testing

No	Question	Evaluation					Total value	Index%
		SA (5)	A (4)	N (3)	D (2)	SD (1)		
1.	Can the application be easily used and understood?	8	1	-	-	-	44	97,8%
2.	Are the features contained in this application functioning properly?	7	-	2	-	-	41	91,1%
3.	Can the information presented be easily understood?	8	-	1	-	-	43	95,5%
4.	Does the appearance of each menu and button in this application look attractive?	6	2	1	-	-	41	91,1%
5.	Does the displayed 3D geometric object model match its actual shape and characteristics?	8	1	-	-	-	44	97,8%
6.	Can this application help you to recognize the shapes and characteristics of geometric shapes?	9	-	-	-	-	45	100%
	Total	46	4	4	-	-	258	95,6%

The table above shows the overall assessment of respondents who participated in the AR geometry application testing questionnaire. It can be seen that the results obtained are with an average index value of 95.6%. This indicates that overall the respondents who participated Strongly Agree with the questions asked regarding the AR application for geometry. The curve for calculating the average index results from the user testing questionnaire form can be seen in Figure 8.

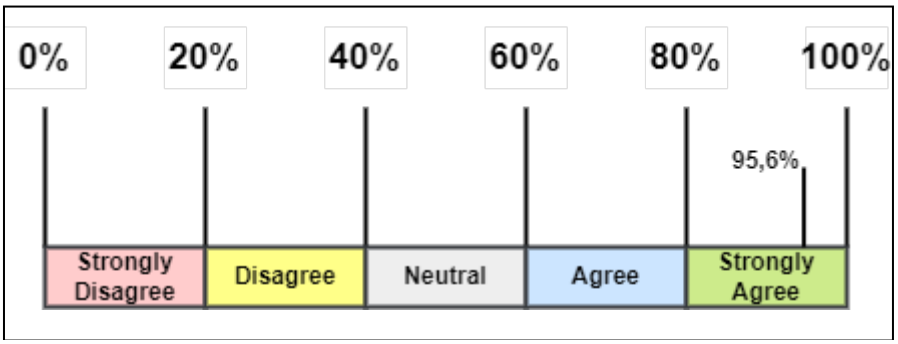


Figure 8. Curve of Average Total Index

D. Conclusion

A) Conclusion

Based on the research that has been carried out, several conclusions can be drawn regarding the augmented reality application for Android-based geometry recognition, namely as follows:

1) The application of augmented reality technology in the geometry AR application to represent objects in 3D can help students understand the shape and nature of each 3D geometry object.
2) This application can be run on the Android platform, which can help make it easier for students and teachers to use the application and can use this application as a reference in geometry learning media.
3) This application has features and an attractive appearance regarding learning about geometry shapes which can be accessed anytime and anywhere with markers in the form of images of objects related to geometry shapes that have been provided, so that this can increase students' learning interest in studying geometric objects. room.

B) Suggestion

Suggestions that can be considered for the development process of the application that has been produced so that it becomes better in the future include:

1) Added a question quiz feature related to learning about geometric shapes, so that it can hone students' abilities in recognizing geometric shapes.
2) Carrying out further development on other operating systems, so that the application can be applied to smartphones with other operating systems, such as iOS and others.
3) Adding other methods to the object visualization process, for example the markerless method using the lean touch feature. This will make students have many options regarding studying geometric objects and the application will become more interesting which will increase students' interest in learning related to geometric shapes.

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