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Learning media development to improve students' spatial mathematical ability assisted by mobile phones using augmented reality

Yunianto[a*], AN Cahyono[b]

Mathematics Department, FMIPA, Semarang State University, Indonesia
** E-mail Address: yunianto2606@students.unnes.ac.id*

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Abstract

The purpose of this study was to describe the development of learning media to improve the Students' Spatial Mathematical Ability assist mobile phones using augmented reality and to determine the effectiveness of learning media assisted by mobile phones using augmented reality in team assisted individualization learning to improve students' mathematical spatial abilities. The development model used in this study is the ADDIE development model. ADDIE development stages are to Analyze, Design, Development, Implementation, and Evaluation. The population of this study was students of 8th grade at MTs Negeri 5 Magelang. The sample was taken from two classes with a random sampling technique from the population of 8th grade at MTs Negeri 5 Magelang. The results are: (1) a learning media has been developed in the form of an android application that uses augmented reality, which is named Bangun Ruang AR as a support for learning mathematics in build flat side space material. After going through the review and evaluation stage by media and material experts, the AR application is suitable to be used as a support for learning mathematics in build flat side space material with an eligibility percentage of 91 5% and included in the very good criteria and (2) The use of application learning media Bangun Ruang AR in Team Assisted Individualization learning effectively to improve students' mathematical spatial abilities, which is aimed at (a) Students' mathematical spatial abilities in team assisted individualization learning with learning media assisted by mobile phone using augmented reality achieve completeness; (b) There is an increase in students' mathematical spatial abilities in team assisted individualization learning with learning media assisted by mobile phone; (c) Students 'mathematical spatial abilities in team assisted individualization learning with learning media assisted by mobile phone are better than students' mathematical spatial abilities in conventional learning.

1. Introduction

Mathematics is a subject that has an important role in formal education because it plays an important role in supporting other sciences. Suherman in Sumarni (2018) states the position of mathematics as queen and servant of science. In other words, mathematics grows and develops for itself as a science, and to serve the needs of science in its operational development.

One of the branches of science in mathematics is geometry. In studying geometry according to National Council of Teacher of Mathematics(NCTM, 2000), there are four indicators that must be achieved, namely: 1) being able to analyze the properties and characteristics of a two-dimensional or three-dimensional shape and develop the reasons for a geometric shape relationship, 2) determine the location and explain the spatial relationship using a coordinate system or using a system Other presentations, 3) applying transformations and using symmetries to analyze mathematical situations, and 4) using visualization, spatial reasoning, and geometric modeling to solve problems.

Based on the results of the 2015 TIMSS assessment in Mullis IVS et al., (2016) regarding the mathematical abilities of Indonesian students on geometric content, Indonesia obtained a score of 394. Where in the 2015 TIMSS there were four levels to represent the range of abilities of students

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internationally, namely the advanced standard (625), high standard (550), medium standard (475), and low standard (400). So that Indonesian students who get a score of 394 for geometric content and meaningful measurements include a low level based on the 2015 TIMSS international benchmark, the ability of Indonesian students based on this level is that they only have simple abilities related to geometry and measurement but have not been able to describe or translate mathematical problems in visual form geometry.

In studying geometry, of course it is closely related to spatial abilities, namely the ability to perceive space. As expressed by Sherman in Tambunan (2006) that mathematics and spatial thinking have a positive correlation, meaning that in learning mathematics, especially in three-dimensional subject matter, spatial abilities are needed to make it easier to learn mathematics. Apart from being built by flat material which is also abstract, spatial material also requires the ability to transform three-dimensional objects into two-dimensional planes. The importance of spatial reasoning is stated by Pavlovicova & Svecoca (2015) that spatial reasoning plays a role in mathematics, especially geometry. This statement is supported by Yassir in Latifah (2019) who argues that spatial ability is one of the important components that must be possessed by students in an effort to solve geometric problems. Research conducted by Hannafin, Truxaw, Jennifer and Yingjie in Syahputra (2013) found that students with high spatial abilities were significantly more capable in mathematics. Other research has shown that cognitive abilities such as spatial abilities are predicted to succeed in certain learning environments, particularly in geometry. Good spatial abilities will enable students to detect relationships and changes in geometric shapes.

One of the factors that affect spatial abilities in mathematics learning is the use of learning models. So far, teachers still use conventional strategies that are only teacher-centered so that the process of using classroom learning is less meaningful. Students are not free to issue their ideas because learning is dominated by the teacher. Students memorize a lot of math concepts given by the teacher and solve problems procedurally. As a result, spatial geometric reasoning is still low.

The solution to the problem to improve the learning process is the application of the Team Assisted Individualization (TAI) model in learning. The Team Assisted Individualization (TAI) model is a cooperative learning model that emphasizes students' abilities, where students are grouped based on various abilities and each student has the opportunity to succeed in achieving learning goals (Huda, 2011: 125). According to Fauzi (2019) in his research entitled Increasing students' mathematical spatial abilities through the Team Assisted Individualization model at SMPN 1 Pinangsori, states that the mathematical spatial abilities of students at SMPN 1 Pinangsori have increased through the use of the TAI learning model. The main components of TAI according to Slavin (2011: 195-200) are the Placement Test, Teams, Student Creative, Team Study, Team Score and Team Recognition, Teaching Group, Fact Test, Whole-Class Units.

In addition to applying the right learning model, the use of media in the learning process is an effort to create more meaningful and quality learning. In the field, in learning geometry, for example, the space of a cube or a block that is done is only to provide information about the number of edges, the number of fields, ways to find the area, and how to find volume without inviting children to explore geometric shapes when rotated, reversed and viewed from an angle. a different view (Syahputra, 2011). According to Nasution (2017) in his research entitled Improving Student's Spatial Ability through 3D Cabri Assisted Geometry Learning, stated that the increase in students' mathematical spatial abilities in learning using Cabri 3D software was better than students who received conventional learning.

Therefore it is necessary to use learning media that is able to facilitate students to carry out exploration related to geometry material, one of which is learning media assisted by mobile phones using Augmented Reality which is able to facilitate children to explore geometric shapes when rotated, reversed and viewed from a point of view. different.

Also, this research was chosen because the development of learning media using mobile phones assisted by augmented reality is still rare. Even though this learning media is in the form of an android application that can be run using a device. That way students can take advantage of the device for learning, especially mathematics. In line with Presidential Instruction No. 6/2001, the government has initiated the use of ICT in education. To support the implementation of the Presidential Decree, the Directorate General of Higher Education at the Ministry of National Education facilitates the development of ICT infrastructure and networks for higher education institutions in Indonesia. The main purpose of using technology is to increase the efficiency and effectiveness, transparency and accountability of learning.

Based on the descriptions that have been described, the problem formulations to be discussed in this study are (1) how to develop assisted learning media mobile phone use augmented reality on learning team assisted individualization to support the improvement of students' mathematical spatial abilities ?;

(2) what is the effectiveness of assisted learning media mobile phone use augmented reality on learning team assisted individualization on students' mathematical spatial abilities?

The purpose of this research is to (1) describes the development of instructional media to improve the assisted students' mathematical spatial abilities mobile phone use augmented reality on learning team assisted individualization; (2) determine the effectiveness of assisted learning media mobile phone use augmented reality on learning team assisted individualization to improve students' mathematical spatial abilities.

The hypotheses in this study were (1) the students' spatial ability in team assisted individualization learning with mobile phone assisted learning media using augmented reality achieved the completeness criteria; (2) There is an increase in students' mathematical spatial abilities in team assisted individualization learning with mobile phone assisted learning media using augmented reality; (3) Students 'mathematical spatial abilities in team assisted individualization learning with mobile phone assisted learning media using augmented reality are better than students' mathematical spatial abilities in conventional learning.

2. Research methods

This research is a type of development research. Development research is also known as developmental research or design research. The research that is intended is to produce a certain product (Sugiyono, 2015). The development model used in this study is the ADDIE Model. The ADDIE development stage is Analyze, Design, Develop, Implement, and Evaluate. Branch (2009: 2) states that product development using the ADDIE process is a very effective tool because ADDIE is simply a process that provides a guiding framework for complex situations.

In this study, the product assessment criteria set on this learning media are from the aspect of efficiency which represents ease of use, the aspect of the display which presents how attractive the appearance of the media to be used for learning, the aspect of technical quality which represents the systematics of the program and added 2 more aspects namely educational aspects that represent the achievement of learning objectives and aspects of material provisions that represent the suitability of material on learning media. The assessment uses a questionnaire given to media experts and material experts.

The population of this study was students of class VIII MTs Negeri 5 Magelang in the academic year 2020/2021. Quantitative research uses a quasi-experimental design. Sampling for the experimental class and control class was carried out by using a randomized class consisting of 27 students of class VIII A and 27 students of class VIII B.Class VIII A uses TAI learning with mobile phone assisted learning media using augmented reality as an experimental class. Class VIII B uses conventional methods.

The data collection techniques used were tests, questionnaires/questionnaires, and documentation. Documentation in this study was carried out to obtain written data or pictures about the list of names of students who were sampled in this study, photos of learning activities, and other data used for research purposes. The test was used in this study to obtain data on students' mathematical spatial abilities in the experimental class and the control class where the test was carried out online via a google form. The questionnaire is a data collection technique that is done by giving a set of questions or written statements to the respondent to be answered, namely using an application eligibility questionnaire filled out by media and material experts.

The data obtained in this study are the results of the mathematical spatial ability test and the results of the application feasibility test.

3. Results and Discussion

This research produces a product in the form of mathematics learning media in the form of an android application for junior high school students/equivalent class VIII in build flat side space material. Development is carried out with the ADDIE model as follows:

3.1 Analysis Stage

At this stage, the information needed to develop learning media is carried out to maximize the function of the learning media that will be created. There are several aspects to consider in media development, namely:

1) Learning Process Analysis

The curriculum used by MTs Negeri 5 Magelang is the 2013 curriculum. However, in the implementation process, the learning process is still very much dominated by teacher activities. The learning methods used are still lacking to invite students to take an active role in the learning process and build their own knowledge. This happens because, in the learning process, the learning media used to help convey the material is still less varied.

2) User Analysis

The user analysis here includes mathematics teachers and students. Almost all teachers and students at MTs Negeri 5 Magelang can operate the smartphone. In learning the instructional media that are usually used are still very limited, only presentation slides that present text and images. In the use of augmented reality applications, there is no need for special skills, such as running ordinary applications on smartphones and in LKPD instructions that can be followed by their use.

3) Analysis Means

The analysis of means includes the ownership of a smatphone for both teachers and students. Almost all teachers and students at MTs Negeri 5 Magelang have personal Android smartphones. This can be used to support better learning for students. Where the Augmented Reality application made has light specifications so that it can be installed on smartphones with the Android 4.1 operating system and above.

3.2 Design Stage

The design stage is the planning stage for making learning media based on the needs analysis that has been done previously. These stages include:

a. Competency Map

Competency maps are goals that are achieved in learning. The basic competencies used are KD 3.9 and 4.9 for class VIII which are described as follows.

3.9 Distinguishing and determining the surface area and volume of flat side spaces (cubes, blocks, prisms, and pyramids).

4.9 Solving problems related to the surface area and volume of a plane-side (cube, block, prism, and pyramid).

b. Material Map

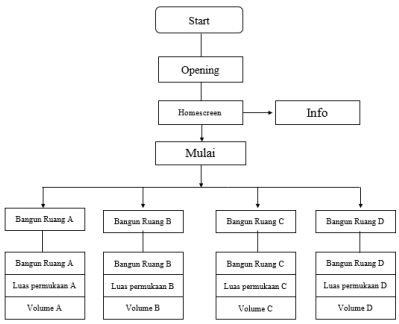
Is a chart or flow of competence from the subject of building a flat side room. Making a material map is done by describing in detail the topics of flat-sided space in the form of topics, sub-topics, and sub-topics. Making material maps is of course adjusted to the competency standards and basic competencies.

c. Media Content Outline (GBIM)

GBIM contains the main material of flat side building which is translated into media design. The subject matter taken is the surface area and volume of the flat side room. In its preparation, GBIM refers to Competency Standards and Basic Competencies in build flat side space material. The outline of media content is an application that displays 3D objects from a flat-sided space using augmented reality so that students can see directly 3D objects and students can manipulate objects. Manipulation of 3D objects in question is that students can rotate, zoom in / zoom out, and move 3D objects.

d. Media Script

Media manuscripts are a detailed description of the learning media that will be made. One of them is making a flowchart. A flow chart is a diagram that shows a workflow or application process. This application has a main menu consisting of Start and Info. The application flow diagram is shown in Figure 1



Picture 1. Application flow chart

3.3 Development Stage

This stage is the stage of carrying out the process of making learning media concerning the script that has been made. The first step is to make all 3D objects and animations using the Blender 3D application. 3D objects consist of Cube, Cuboid, Prism, and Pyramid objects. An example of how to create a cube object in Figure 2

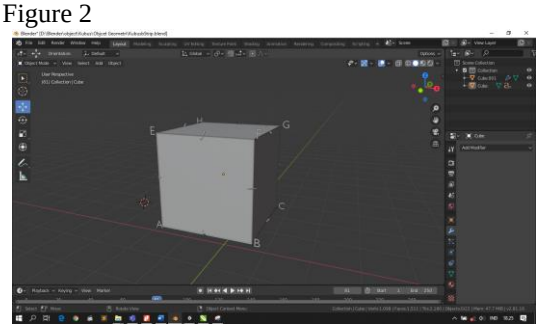


Figure 2. Cube Object Creation

In the object surface area, the volume of the prism and the volume of the pyramid, there are differences in the object of space where in addition to the object there is also an animation which uses the armature feature in the blender. This feature is like bones in humans which can be used to move objects. An example of creating an object with an armature feature on the surface area of the cube in Figure 3

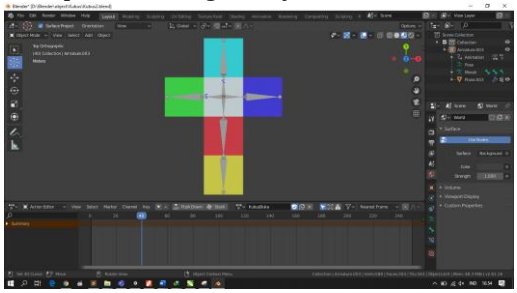


Figure 3. Creation of a cube mesh object

The next step after all the objects have been created is to create an application user interface using Unity which consists of a home screen, main menu, and info menu. In unity, it is called a scene. The total scene created is 15 scenes. The first scene created is the homescreen. The home screen is the first menu display that appears when the application is opened. In the home screen scene, there are three buttons, namely the start button, info, and exit. The home screen display can be seen in Figure 4

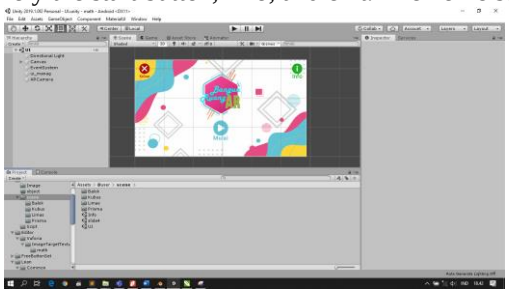


Figure 4. Making the home screen scene

The next scene that is created is the starting scene. The starting scene is selected using the slide menu. This menu consists of 4 building spaces, namely cubes, cuboids, prisms, and pyramids. Each room consists of one button, namely the shape. The starting scene creation view can be seen in Figure 5

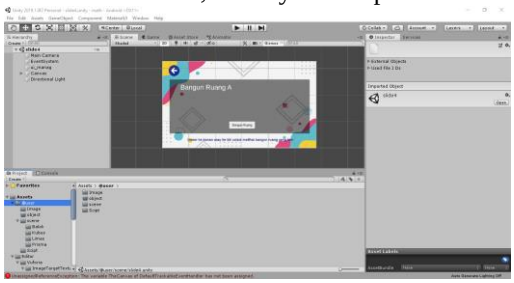


Figure 5. Scene creation begins

The next step is to insert the 3D model that was created into Unity. The 3D model that is made is inserted into each marker that has been made. The display of 3D object input into the marker can be seen in Figure 6

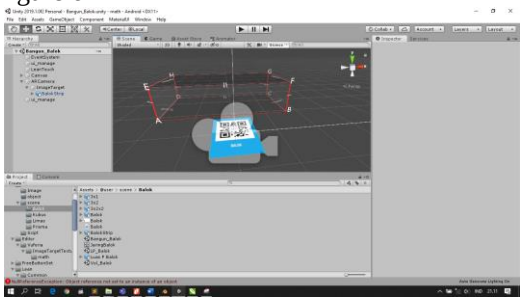


Figure 6. Input 3D Object to Marker

In the surface area scene, the volume of the prism and the volume of the pyramid, besides displaying 3D objects, also displays animation features that have previously been made in Blender to display the animation, so the animator in unity needs to be set first. The animator's display can be seen in Figure 7

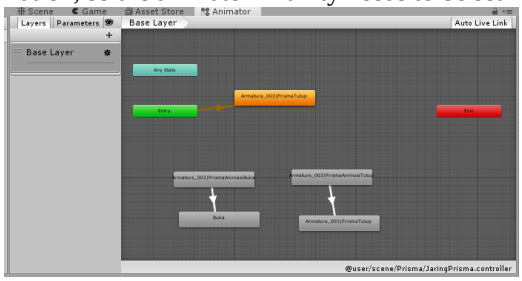


Figure 7. Animator view

In addition to creating the scene, code is also needed to run the system in the application. The code used in unity is in C#. Code is used so that each button in the application functions so that each scene is connected to other scenes. Code is written using visual studio code . Writing code can be seen in Figure 8

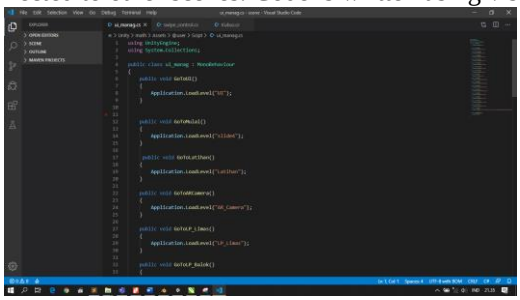


Figure 8. Writing Code

After everything is finished the application is built into an android installation file with the format * .apk. The Bangun Ruang AR installation file is 36.2 MB in size. To run this application, the following minimum specifications are required:

1) Android Jelly Bean 4.1 operating system
2) 1 GB ram
3) 70 MB of free internal space

The Bangun Ruang AR application that has been completed is reviewed and evaluated by the validator to get an evaluation of deficiencies in the application. After improvement, the media is validated for its feasibility so that it can be used in the learning process. The validator itself consists of material experts and media experts. The media was validated using a questionnaire provided by the researcher. Based on the questionnaire that has been filled in by the validator, the learning media that have been made are suitable for use in the classroom with several revisions.

1) Material Expert

Learning media that have been made are tested on material experts so that deficiencies in the media that have been made can be identified. This test aims so that the media that have been made are in accordance with the material to be studied. The material experts in this study were Lecturers of

Geometry, Department of Mathematics, UNNES and Teachers of Mathematics at MTs Negeri 5 Magelang. The following results were obtained:

Table 1. Material Expert Validation Results

No	Assessment Aspects	Average score	Percentage	Criteria
1	Educational Aspects	34.5	86%	Very good
2	Aspects of Material Accuracy	21.5	86%	Very good

Based on Table 1, the results of the material expert validation can be seen, the results of the assessment of the educational aspect are 86% and the accuracy of the material is 86%, where these two aspects fall into the very good category. This shows that the AR Space Building Application is included in the very good category seen from the learning aspect and the material provision aspect.

2) Media Expert

Learning media that have been made are also tested on media experts so that there are deficiencies in the media that have been made. This test aims to make learning media that is made easy to use and attractive when used in the learning process. The media experts in this study were two UNNES Mathematics Department lecturers who are experienced in the field of instructional media. The following results were obtained:

Table 2. Media Expert Validation Results

No	Assessment Aspects	Average score	Percentage	Criteria
1	Efficiency Aspects	20	100%	Very good
2	Application Display Aspects	30	95%	Very good
3	Aspects of Technical quality & Program Effectiveness	15	96%	Very good

Based on Table 4.2 the results of the validation of media experts can be seen, the results of the overall assessment are obtained on 3 aspects, namely aspects of efficiency, aspects of application appearance and aspects of technical quality for the total average value of all aspects of media expert 1 and media expert 2 is 97% which means fall into the very good category. These data indicate that the AR application is included in the very good category in terms of efficiency, appearance. and technical quality and program effectiveness.

The following is a visualization of the results of the development of the Bangun Ruang AR Application:

1) Application

When you open the Bangun Ruang AR application, the Unity logo will appear and the Bangun ruang AR Application Logo will appear. The unity logo shows that the application was created using the Unity software. The opening display can be seen in Figure 9

Figure 9. Opening

The main menu or home screen contains the start button, info button, and exit button. The background on the main menu display is made as attractive as possible so that users like it when using this application. The bac,kground uses a geometric background type to adjust to the material associated with this application, namely Build a flat side space.The home screen display can be seen in Figure 10

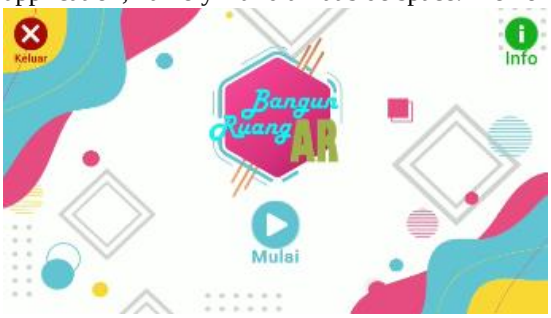


Figure 10. Homescreen

The info menu contains developer and destination info. In the info menu, there is also a download marker button that is connected to the internet. The info menu display can be seen in Figure 11

Figure 11. Menu Info

When pressing start the user will be directed to the user-interface. This menu contains a slide bar where the user can swipe right or left to select the building space to aim for. In each shape, there will be one button choices, namely Bangun Ruang. The start menu display can be seen in Figure 12

Figure 12. Start menu

If the Bangun Ruang button is pressed, it will be directed to the camera and if it is pointed at the appropriate marker, a 3D object will appear. 3D objects are made transparent so that all the building elements of the space can be seen. This 3D object can be shifted, enlarged or reduced and rotated. The menu display can be seen in Figure 12

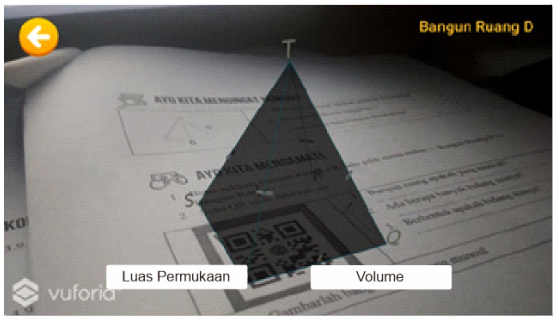


Figure 13. Build Space Menu

On the surface area menu, the camera appears and if it is pointed at the appropriate marker, the 3D object will appear. When space appears, there will be two buttons, namely "Buka" and "Tutup". This button is used to bring up the animation of opening or closing the building network. Display surface area can be seen in Figure 14

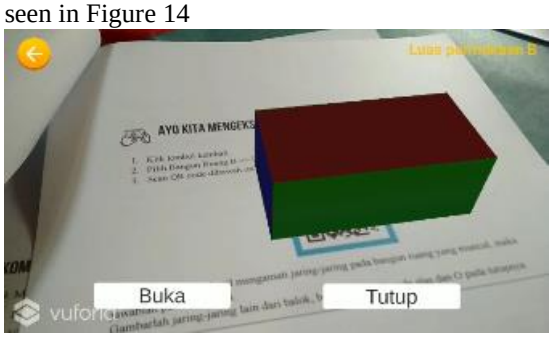


Figure 14. Surface Area Menu

In the volume menu, the camera will appear and if it is pointed at the appropriate marker, a 3D volume object will appear. This 3D object can be shifted, enlarged or reduced, and rotated. The volume display can be seen in Figure 15

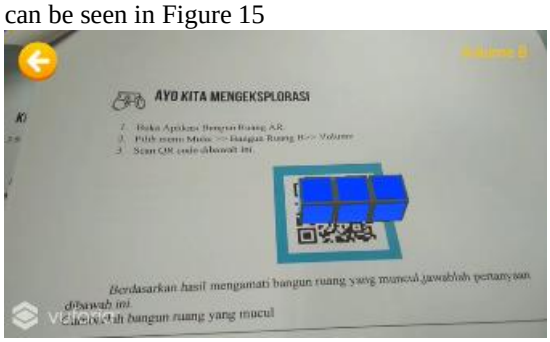


Figure 15. Volume menu

2) 3D model

3D models are created using Blender 3D software. The 3D model that is created consists of 3D objects from cubes, cuboids, prisms, and pyramids. The 3D model of the space is shown in Figure 16

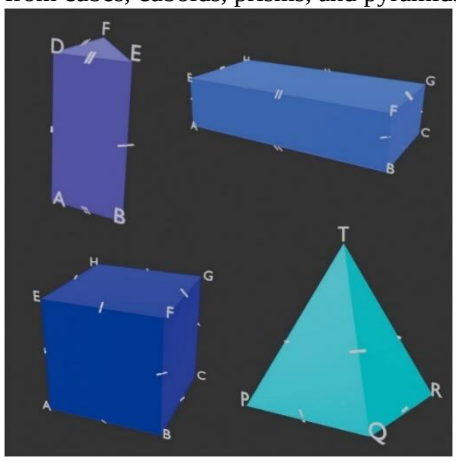


Figure 16. 3D Model of Solid Figure

The 3D model of the space building will later be made transparent in the application view so that all its elements are visible. The 3D model of a transparent solid figure is shown in figure 17

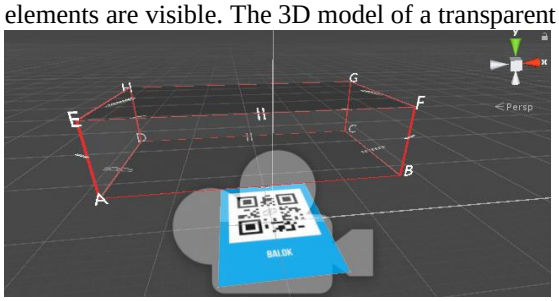


Figure 17. 3D Model of a Transparent solid figure

Next is the 3D object for the net. The mesh object is created using the armature or bone feature in the blender so that later animations can be run in Unity. The net model can be seen in Figure 18

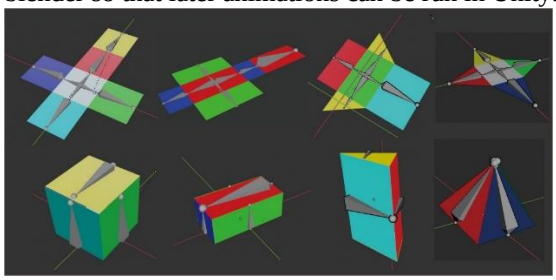


Figure 18. Nets 3D Model

Next is the 3D volume object. The 3D objects created are 3 cubes with different sizes, that is cube $2 \times 2 \times 2$, cube $3 \times 3 \times 3$,cube $4 \times 4 \times 4$ and, 3 cuboids with different sizes, that is cuboid $3 \times 1 \times 1$, cuboid $3 \times 2 \times 1$, cuboid $3 \times 2 \times 2$, and the volume of a triangular prism by approximating the volume of a cuboid and volume of a pyramid with an approximation of the volume of a cube.. Especially for a prism and pyramid volumes, 3D objects are created using the armature feature or bones in the blender so that animations can be run in Unity later. The volume model can be seen in Figure 19.

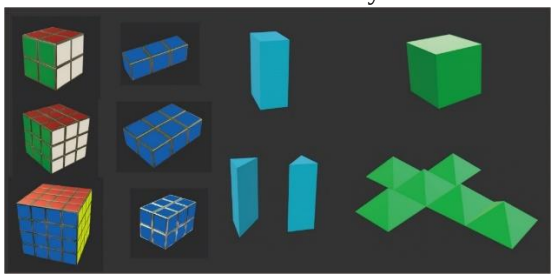


Figure 19. 3D Volume Model

3.4 Implementation Stage

The implementation stage is the stage where the learning media that has been created and validated are used in the learning process. The Bangun Ruang AR application was tried out at MTs Negeri 5 Magelang to determine the effectiveness of this learning media to improve students' mathematical spatial abilities in TAI learning. The population of this study was students of class VIII MTs Negeri 5 Magelang which consisted of classes VIII-A to VIII-G. This study involved 3 sample classes, namely one class as the experimental class, one class as the control class, and another class as the trial class. The class sampling technique in this study used random sampling techniques. Class VIII-A was randomly selected as the experimental class, class VIII-B as the control class, and class VIII-C as the trial class.

Before starting the use of the Bangun Ruang AR application in learning, students are first given a pretest. This is to determine students' initial mathematical spatial abilities. The pretest given was in the form of 25 items. The pretest was held online on July 21, 2020, using the google form. The pretest was followed by 27 students of class VIII-A and 27 students of class VIII-B. Furthermore, learning was carried out in 4 meetings with class VIII-A as an experimental class using TAI learning with AR learning media and class VIII-B as a control class using conventional learning.

After the treatment process is complete. Students will be asked to work on posttest questions to determine students' mathematical spatial abilities after being given treatment. The posttest given is in the form of 25 items. The posttest was held online on August 25, 2020, using the google form. The posttest was attended by 27 students of class VIII-A and 27 students of class VIII-B.

3.5 Step Evaluation

Evaluation is a stage for evaluating the learning media that has been implemented. In this study, the evaluation was carried out by testing the effectiveness of the AR application in TAI learning to improve students' mathematical spatial abilities.

Researchers analyzed the results of the students 'mathematical spatial ability test to determine the effectiveness of the AR application in TAI learning to improve students' mathematical spatial abilities. Mathematical spatial ability data is in the form of quantitative data which is the test result from the experimental and control classes. Based on SPSS calculations related to the normality test, it was found that the test value data came from populations that were normally distributed. Based on SPSS calculations related to the homogeneity test, it was found that there was no difference in variance between the experimental class and the control class. Based on SPSS calculations related to the average similarity test, it was found that there was no difference in the average initial ability between the experimental class and the control class.

The first hypothesis test used the average completeness test of one right-hand side and the proportion completeness test of one right-hand side. The completeness of learning in this research is complete individually and classically (Baharun, 2015). Based on the results of the calculation, it was concluded that the average spatial ability of students in learning TAI with AR learning media was more than 61.26 or completed individually and the proportion of students who completed learning in learning TAI with AR learning media was more than 0.745 and achieved classical completeness.

The second hypothesis test used paired t test and N-gain. In the second hypothesis test, it aims to find out whether the mathematical spatial abilities of class VIII junior high school students in team assisted individualization learning with AR Building Space learning media have increased. Based on the results of the calculation, it was concluded that the posttest average of students 'mathematical spatial abilities in TAI learning with AR Building Space learning media was better than the pretest average of students' mathematical spatial abilities in TAI learning with AR Building Space learning media and obtained N-Gain of 0,40 this indicates that the increase in students' mathematical spatial abilities in TAI learning with AR learning media is in the medium category.

The third hypothesis test, the mean difference test, and the two-proportion difference test are used. Based on the results of the calculation, it was concluded that the average results of the students 'mathematical spatial ability tests in TAI learning with AR learning media were more than the average results of the students' mathematical spatial ability tests in conventional method learning and the proportion of students who thoroughly studied in class using learning TAI with learning media Bangun Ruang AR is more than the proportion of students who complete learning in class with conventional methods. This is in line with the results of research by Nasution (2017).stated that the increase in students' mathematical spatial abilities in learning using Cabri 3D software was better than students who received conventional learning. In addition, it is also in line with Fauzi's research (2019) which states that students' mathematical spatial abilities at SMPN 1 Pinangsori have increased through the use of the TAI learning model.

4. Conclusion

Based on the results of research and discussion, the following conclusions can be drawn: 1) Based on the research that has been carried out, learning media assisted by mobile phones using augmented reality have been developed in the form of an android application called Bangun Ruang AR as a support for learning mathematics in build flat side space material. Development using the ADDIE model. After going through the review and evaluation stage by media experts and material experts, the Bangun Ruang AR application is suitable to be used as a support for learning mathematics in build flat side space material with

an eligibility percentage of 91.5% and is included in very good criteria 2) Use of application learning media Bangun Ruang AR in Team Assisted Individualization learning effectively to improve students' mathematical spatial abilities, This is obtained from the following points: (a) Students' mathematical spatial abilities in team assisted individualization learning with learning media assisted by mobile phone using augmented reality achieve completeness; (b) There is an increase in students' mathematical spatial abilities in team assisted individualization learning with learning media assisted by mobile phone; (c) Students 'mathematical spatial abilities in team assisted individualization learning with learning media assisted by mobile phone are better than students' mathematical spatial abilities in conventional learning.

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