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The development of Augmented Reality-based learning media to improve students' ability to understand mathematics concept

Heni Pujiastuti[a,*], Rudi Haryadi[a], Alif Maulana Arifin[a]

[a] *Universitas Sultan Ageng Tirtayasa, Jalan Raya Jakarta KM 4 Pakupatan, Serang 42118, Indonesia*

** E-mail address:henipujiastuti@untirta.ac.id*

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Abstract

This research aims to develop an Augmented Reality-based learning media. This research is a type of development research. The development model used is the ADDIE model, which consists of five stages, namely, analysis, design, development, implementation, evaluation. The results of this study are in the form of cards that have been coded, Augmented Reality applications in Android, and student guide worksheets. The results of the validation of media and material experts indicate that this Augmented Reality-based learning media product is valid and feasible to use. The use of Augmented Reality based learning media in learning activities can improve students understanding of mathematical concept ability. This can be seen from the average n-gain obtained 0.61, which is included in the height category. Each indicator of the concept of understanding also shows big and medium improvement. This Augmented Reality based learning media also gets positive responses from students with an average percentage score of 87.50%.

1. Introduction

Understanding is a person's ability to understand or understand something after something is known and remembered (Heni Pujiastuti, Suviati, Haryadi, & Marethi, 2020). A student is said to understand something if he can provide an explanation or give a more detailed description of it using his own words (Harti & Agoestanto, 2019). In learning mathematics, the ability to understand concepts is essential for students. The mathematics material is always related to one another mathematics is a subject taught to students from the elementary school level to the junior high school level even to college (Tsai, 2019). Mathematics is often regarded as a subject that is difficult to understand, boring, troublesome, and frightening (Heni Pujiastuti, Utami, & Haryadi, 2020). This is because mathematics has abstract properties, so mathematics requires the ability to understand good mathematical concepts because understanding previous concepts is a prerequisite for understanding new concepts (Heni Pujiastuti, Ayatullah, & Haryadi, 2019). So that in learning, it must be coherent and continuous. If students have learned to understand mathematical concepts, it is easy for students to learn the next concepts that are more difficult (Harti & Agoestanto, 2019).

Understanding good concepts influences the improvement of the quality of education (Haryadi, 2019). But learning in schools has several other factors that influence teacher factors, students, school environment, and the media used in the learning process (Hornburg, Rieber, & McNeil, 2017). Learning media includes tools that are physically used to convey the contents of teaching materials, which consist of books, tape recorders, tapes, video cameras, video recorders, films, slides, photos, images, graphics, television, and computers (Haryadi & Pujiastuti, 2020). It can be said that one of the teacher's tools in delivering learning material is learning media (Ibáñez & Delgado-Kloos, 2018).

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In studying mathematics learning material that requires good understanding of concepts, learning media is often needed as an intermediary for teachers to convey material in the form of abstract so that it's easier for students to understand because students are easier to understand learning material if students can imagine it (Zuin, Rigatelli, Faggian, & Roncon, 2018).

Along with the development of technology, a technology emerged called Augmented Reality (AR). AR is a technology that makes it possible to combine real and virtual worlds that make it possible to display 3D objects in the real world through camera media so that the camera looks as if the 3D object exists in the real world and allows it to display illustrations that are difficult to form in real (Coimbra, Cardoso, & Mateus, 2015).

In the field of education, AR has often been used in learning activities, one of which uses AR in geography learning on Earth Surface Area material that gets a good response from subject teachers and students who strongly agree to apply augmented reality learning to the material (Trifonov et al., 2018). And also, research that uses AR to explain physics subjects with molecular structure material that can display molecular structure shows that material that is difficult to display its shape is capable of being displayed through Augmented Reality (Martín-Gutiérrez, Fabiani, Benesova, Meneses, & Mora, 2015). In addition to the subjects of geography and physics, AR also has the potential to be used in mathematical learning, one of which is the construction of flat-side space materials that require students to understand forms that are quite difficult to be displayed in a real way in classroom learning (Salinas & Pulido, 2015). Augmented reality in the world of education can also be applied in learning activities to increase knowledge in the use of information and communication technology in learning by efforts to improve student learning outcomes and abstraction power (Heni Pujiastuti & Haryadi, 2020).

The development of AR-based learning media is very important because student's ability to understand mathematical concepts is influenced by the learning media used by the teacher (Mota, Ruiz-Rube, Dodero, & Arnedillo-Sánchez, 2018). In terms of media, besides being efficient because it is lighter and smaller in size, this learning medium is also easier to reproduce (Rau, Zheng, Guo, & Li, 2018). Therefore, the purpose of this study is to improve students understanding of mathematical concept ability.

2. Methods

This research is a type of development research. This research's developmental model is the ADDIE model because it is complete and detailed to be used in developing learning media (Sharifah & Faaizah, 2015). This model consists of five stages: analysis, design, development, implementation, and evaluation (Munoo & Abdullah, 2018). The procedures for developing learning media in this study can be described in Figure 1 below (Heni Pujiastuti & Haryadi, 2019).

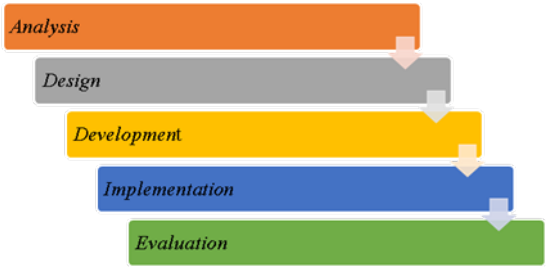

Figure 1. ADDIE Models'

The first stage in the ADDIE model is the analysis stage. In this stage, we analyze the existing problems and the right solutions to overcome the problem. The analysis carried out relates to students and teachers' material and problems who will later be targeted by users of the learning media created. The stages of analysis include: a) needs analysis, b) analysis of learning materials, c) formulating learning objectives, and d) determine learning strategies (Ozdilek & Robeck, 2009).

The design stage or the stage of visual thinking is to prepare the things needed in developing learning media. At this stage, a flowchart is created, which is a description of the steps and sequence of procedures that will be carried out to be made and what will be done on what is needed to develop this learning media. In this design stage, more clearly can be seen in Figure 2 below.

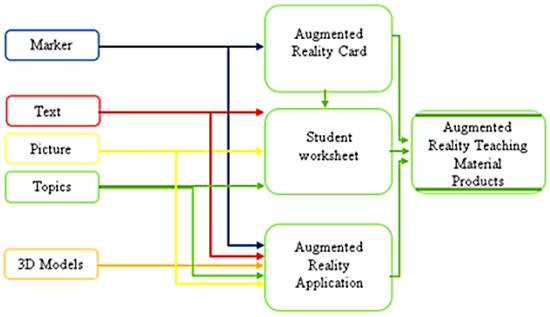

Figure 2. Design of augmented reality

Development is the stage of implementation of plans that have been made at the design stage to become a product that will be implemented. In this stage, there is also a test of the validity of the product both from media experts as well as from material experts. The percentage of the average score for each expert response is calculated by the following formula (H. Pujiastuti & Fitriah, 2019).

$$\text{Percentage (P)} = \frac{\text{Total Score}}{\text{Ideal Score (100)}} \text{x100\%} \qquad (1)$$

The feasibility criteria of the product used can be seen in Table 1 as follows (Meltzer, 2002).

Table 1. Feasibility criteria

Percentage (P)	Category
< 21%	Very not feasible
21– 40 %	Not feasible
41– 60 %	Enough
61– 80 %	Feasible
81– 100%	Very feasible

The next stage is the implementation phase. In this stage, the product is tested on a number of students in learning activities to know the student's responses to the product and the improvement of students understanding mathematical concepts. The last is the evaluation stage. This stage is done to evaluate the learning that has been done by using products that have been developed. The improvement of students understanding of mathematical concepts ability is calculated using n-gain. In this study, the n-gain referred to a normalized gain (n-gain). The n-gain score is done by comparing the student test results before (pretest) and after learning using AR-based learning media (post-test). N-gain formula is as follows (Hake, 1998).

$$\text{n-g} = \frac{X_{post} - X_{pre}}{X_{max} - X_{pre}} \qquad (2)$$

Explanation:
n-g = n-gain
x_{pre} = pretest score
x_{post} = posttest score
x_{max} = maximum score
The n-gain coefficient is interpreted using the criteria that can be seen in Table 2 (Hake, 1998).

Table 2. N-gain coefficient criteria

N-gain Coefficient	Classification
$0 \leq$ n-g < 0.3	Low
$0.3 \leq$ n-g < 0.7	Medium
$0.7 \leq$ n-g < 1	Height

3. Results & Discussions

This study's results are in the form of products consisting of four cards that correspond to each a type of polyhedron, namely cubes, cuboid, pyramid and prism. Each card is given a Quick Response Code (QR-Code) and also given a text with the name of each polyhedron so that it is not interchanged between one card and the other and makes it easy for users to find a particular type of card. The display design of each card surface that has been made can be seen in Figure 3.

Figure 3. The display cards of cube, cuboid, pyramid, and prism

In addition, the main menu display is also made as a front view that is seen by the user. The display of material that can be used for student learning and the usage guidelines for applications to be used can be seen in Figure 4.

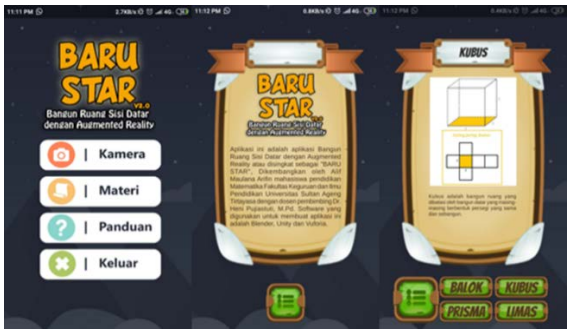

Figure 4. The main display on the screen

The results of this study can be seen from the camera view. The following results of the camera display can be seen in Figure 5 below.

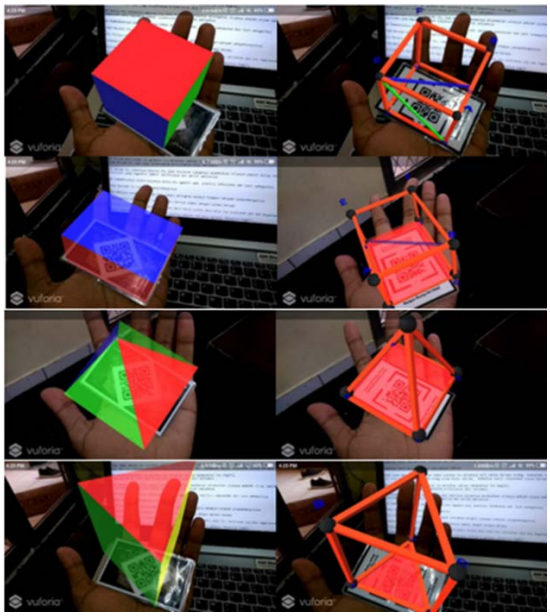

Figure 5. The display of augmented reality of polyhedron

To use AR applications to be easier and directed, the student worksheet guide is also included with the material polyhedron in which activities integrate into the use of AR applications. Student worksheets contains guidelines that must be done by the user. In the worksheets guide there are steps in using AR cards and AR applications created. Besides, the worksheets guide made are also accompanied by problem exercises to be done in groups by students as a training tool for students to improve their abilities, especially the ability of mathematical understanding concepts. The student worksheet guide can be seen in Figure 6.

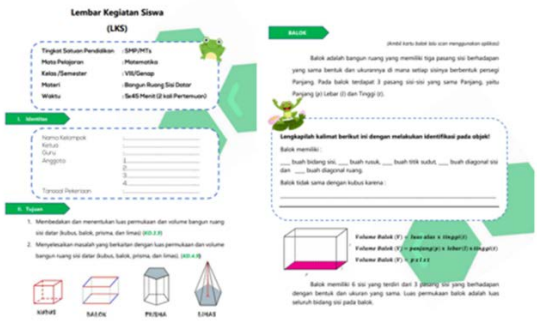

Figure 6. Student worksheet guide

Furthermore, the products in this study were validated by media and material experts. Each expert consists of five lecturers according to their expertise. The validation results from media experts can be seen in Figure 7.

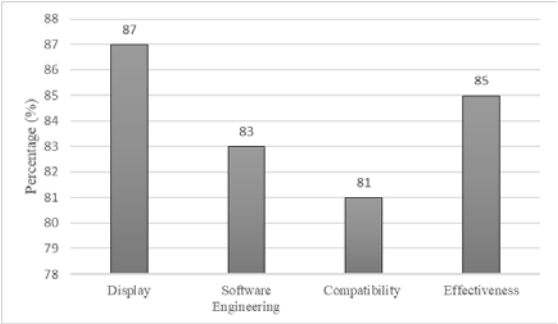

Figure 7. The validity of media experts

The validity results from all media experts obtained an average score of 84%, which belongs to the feasible category. The average score obtained for each assessment indicator from media experts is also above 80%. It means that this application is feasible for use in learning mathematics. Some of the suggestions from media experts are to improve the learning media that have been made, including adding images of nets into student worksheets and the application must be able to read more than one AR card at the same time, so that the students can compare between one of polyhedron with another one. The results of the validation from the material experts can be shown in the Figure 8.

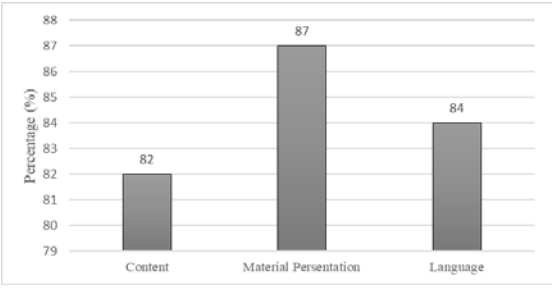

Figure 8. The validity of material experts

Learning media applications in this study obtained an average score of 84.33% from all the material experts included in the feasible category. Likewise, based on Figure 8, the results of the validity of material experts obtained an average value of 80% for each indicator. It can be said that this application is feasible for use in learning mathematics. Some material experts provide suggestions for improving student worksheet's instructions and adding more questions to measure students' conceptual understanding abilities. All suggestions from experts, both media and material experts, have been made as improvements to the learning media.

After AR-based media learning was improved based on expert advice, this media was tested in learning to find out its effectiveness in improving the ability to understand concepts and to know students' responses to products to 40 junior high school students in class VIII. All students are in one school consisting of 20 male students and 20 female students. The results of this implementation received a positive response from students. The following Figure 9 is the results of student responses to AR-based learning media.

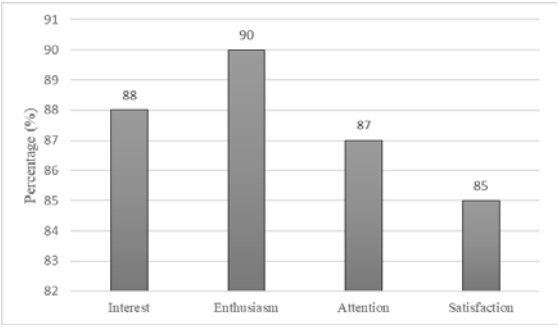

Figure 9. Student responses

Based on Figure 9, the results of student response questionnaire obtained an average score of 87.50%. This result indicates that the use of AR-based learning media can improve students' interest, enthusiasm, attention, and satisfaction in learning. The utilization of learning media using Augmented Reality is useful in increasing student interest in the learning process because Augmented Reality technology displays animation can be a stimulus to students to be more active in learning activities. Students can project the forms of polyhedrons in real terms and involve interacting with their five senses. This is because students have never used AR media and used Android in learning before. In fact, in general, high school-level students currently use Android for their daily needs. Several study results revealed that android-based learning media can increase student interest in learning (Kurniawan & Witjaksono, 2018).

Furthermore, the results of using augmented reality on understanding mathematical concepts through learning activities can be seen in Table 3.

Table 3. The score of students understanding Mathematics' concept

Data	Pretest	Posttest	N-G
Minimum	15	40	0.25
Maximum	40	92	0.87
Average	32.33	73.78	0.61

The analysis results in the table above can be seen that the average n-gain obtained is 0.61 which is included in the medium classification. Of 40 students, 30% of students improved their understanding concept ability included in the height category, 62.5% included in the medium category, and only 7.5% of students who improved their abilities were included in the low category. This result has shown that using AR-based learning media can support students learning to understand the material of polyhedron. It means that, in general, there has been an improvement of students understanding mathematical concepts due to the use of AR media. Several studies report that Augmented Reality media facilitates student learning and enhances student ability to understand concepts (Ibáñez & Delgado-Kloos, 2018).

In this study, understanding mathematical concepts is measured based on five indicators: the ability to interpret, classify, compare, explain, and connect mathematical concepts (Bujak et al., 2013). The mathematical understanding concept ability test that measures the five indicators is given the essay questions. The test is given to students before and after learning to use AR-based media. The percentage of n-gain from each indicator of understanding mathematical concepts can be seen in Figure 10.

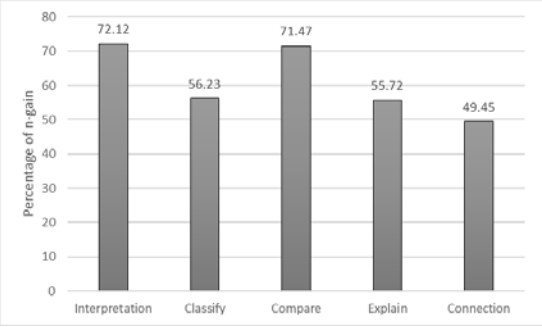

Figure 10. The average n-gain of each indicator of understanding mathematical concepts

Based on the results shown in Figure 10, although the percentage of the n-gain ability of students' conceptual understanding of mathematics in each indicator is different, all of them show good improvement. The percentage of n-gain for the first and third indicators included in the height category and other indicators included in the medium category. This result shows that the use of AR-based media has improved the ability of students to understand mathematical concepts. In several studies, it has also been shown that the use of AR learning media can improve students' ability to understand concepts (Mahony, 2015).

Students are more active during the learning process by using Augmented Reality media and are motivated to learn the material of polyhedron. With the appearance of Augmented Reality, students can understand the concept because they can combine virtual world objects into real-world views in real- time. By utilizing Augmented Reality technology and an Android smartphone, the polyhedron objects can be visualized through virtual 3-dimensional modeling similar to the original object. To display a 3-dimensional image of a polyhedron, students simply scan the card created using the Augmented Reality application installed on the Android. Students can also easily understand the concept of a polyhedron with animations that are displayed Augmented Reality. Augmented Reality has an attractive visual display that can display 3D objects and their animations as if they were real (van Esch et al., 2019).

4. Conclusion

The product developed in this research is Augmented Reality-based learning media, which consists of card-given QR-Code, Augmented Reality applications, and student worksheet guides. The results of media experts' assessment showed valid in all aspects including display, software engineering, compatibility, and effectiveness. Likewise, the material experts' results show valid for all aspects, namely content, material presentation, and language. The results of testing to a small group of students show that understanding mathematical concepts can be improved through learning using Augmented Reality-based learning media. This can be indicated by the average n-gain obtained by students as a whole of 0.61, which is included in the medium category. In addition, also shown by the acquisition of 30% of students improved their understanding of concept ability included in the height category, 62.5% included in the medium category, and 7.5% included in the low category. The n-gain results also show this good improvement for each indicator of students' concept understanding ability. The average n-gain for aspects of interpretation and compare, including in the height category. To classify, explain, and connection aspects are included in the medium category. Augmented Reality-based learning media also get positive responses from students with an average score of 87.50%. These results indicate that students' interest, enthusiasm, attention, and satisfaction in conducting the process of learning mathematics through learning by using Augmented Reality-based learning media. Based on the results of this study, researchers suggest that Augmented Reality-based learning media can be used as an alternative media that can be used in mathematics learning, especially for polyhedron material. The teacher can use it in learning activities in groups, individually or classically.

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