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Development Of Augmented Reality-Based Geometry Learning Media

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Abstract:
Background*: Learning media play a vital role in improving the quality of learning, especially in geometry material considered abstract by elementary school students. The limitations of learning media teachers use, and the low visualization of geometric shapes in the teaching and learning process, become obstacles to achieving student understanding. Augmented Reality (AR) is an innovative solution that allows the visualization of geometric shapes to be more interactive and engaging.*
Materials and Methods*: This research is development research (R&D) that adapts the Borg & Gall model. Stages include preliminary studies, design, development, limited trials, and validation and revision. Data collection instruments, such as questionnaires and interviews, were conducted with Universitas Terbuka students in several locations (Medan, Yogyakarta, Padang, Jakarta, and Denpasar). The assessment involved expert validation and a one-to-one trial with three students.*
Results*: The results showed that AR-based learning media received a positive response from students, with an average score of 4.17-4.43 in presentation clarity, media suitability, and design appearance. Overall, the media obtained a response percentage of 85%, including in the outstanding category. Input for further development includes improving the display size on several devices. The final product is AR media, "Knowing Spatial Buildings," accompanied by AR cards and usage guides.*
Conclusion: *This study successfully developed Augmented Reality (AR)- based geometry learning media for elementary school students by following the stages of the Borg & Gall model development research. The resulting product is interactive media that helps visualize the building space clearly and interestingly.*
Key Word: *Augmented Reality; elementary school; geometry; learning media.*

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I. Introduction

Learning is an activity that assists educators in conveying knowledge and building character and attitudes in students[1,2]. School learning activities are one way of conveying knowledge from teachers to students. Teachers should prepare various things needed to support learning so that learning activities can be carried out correctly[3]. Teacher skills in preparing learning activities need to be considered. One of the things that must be considered is the preparation of learning media[4,5].

Learning media is one of the most essential components of learning activities at school[6,7]. It is essential because the role of the media in learning is enormous. Learning media can even attract students' attention, so that students' attention can be more focused on the learning that takes place[8]. Learning media also helps students understand the material being taught. However, remember that the learning media must be based on the needs and material to be delivered[9].

Learning media has a strategic role in improving the quality of the teaching and learning process, so it needs to be prepared and developed carefully by considering various aspects, especially the development of learners. Learners from the digital generation certainly have different characteristics, needs, and learning styles than previous generations[10,11]. Therefore, learning media must adapt to these characteristics to bridge the teaching material with how students learn. In addition, the rapid development of technology cannot be ignored in the design of learning media. Technology can enhance students' learning experiences by making them more engaging, adaptable, and readily available at any time. Examples of this include interactive multimedia, digital apps, and internet-based material[11].

However, learning media utilization in the field is still not up to par[12]. Many educators still rely on easily accessible media and have not actively produced creative and relevant material[13]. This is due to several factors, including time constraints, a lack of media development training and competent among teachers, and a limited budget for supporting equipment purchases[14]. Learning is, therefore, usually teacher-centered and uses the tiresome lecture approach. Less active participation from students with this illness may decrease motivation

and critical thinking. Students become inactive due to being prohibited from interacting, exploring ideas, or expressing their creativity[15,16].

Learning media is beneficial in implementing a good learning process, especially in materials that students find difficult[17–19]. One of the materials that requires media to facilitate the delivery of material to students, especially elementary school students, is geometric material. Geometry material is considered difficult because students have limitations in imagining how geometric shapes can be formed and what elements make up geometry. In teaching geometry material, teachers usually use objects around as learning media. However, this media has not been able to visualize geometry interestingly, especially for elementary school children in the present time[20,21].

Technological developments certainly affect various aspects of life, including learning media. Increasingly sophisticated technology demands the development of increasingly sophisticated learning media to attract students' attention without reducing the usefulness of the material's content. One of the developments in learning media that is being done today is Augmented Reality-based learning media.

Augmented Reality (AR) is an application that combines the virtual and real worlds. This application is usually used to make games. However, it has begun to be used also to develop learning media[8]. Based on testing the developed media, this learning application is very interactive and easy to use, so applying this learning media application can help improve the teaching process, making it more interesting and easier to understand. Based on the conditions described earlier, a learning media that can visualize various geometric shapes is needed[22,23]. To realize this, Augmented Reality-based learning media were compiled on geometry material in elementary school. Therefore, this study aims to develop an Augmented Reality-based geometry learning media.

II. Materials And Methods

The method used in this research is research and development (R&D)[24]. The research product offered in this study is the development of Augmented Reality-based geometry learning media. Augmented Reality-based geometry learning media is tested for feasibility, effectiveness, and practicality. The development model in this study refers to the Research and Development (R&D) cycle model, which includes preliminary investigation, design, realization, test, evaluation, revision, and implementation. The stages of research and development using the Borg and Gall method.

The development stages can be broadly mapped into three, namely: (1) pre-development stage, (2) development stage, and (3) model implementation stage. The pre-development stage of Augmented Reality-based geometry learning media includes preliminary study activities, reviewing relevant theories, literature, and research results, and conducting field observations. The model development stage includes activities to determine, and design Augmented Reality-based geometry learning media. The application stage of Augmented Reality-based geometry learning media includes validation, trials, evaluation, revision, and presentation of the final product/final model.

The research design will carry out this development research in several stages:

1. Pre-development: The data instrument will be taken at *Universitas Terbuka* (UT) Medan for the initial survey. It will be given to tutors who have taught Mathematics Education II courses and students who have taken Mathematics Education II courses.
2. In the development stage, the initial trial will be conducted at UT Yogyakarta, and the field trial will be conducted at UT Padang. Both trials were conducted in two classes that were taking Mathematics Education II courses.
3. In the model implementation stage, the feasibility trial will be conducted at UT Jakarta and UT Denpasar. Four Mathematics Education II classes will be selected from each UT for the feasibility trial (two classes as experiments and two as controls).

Data collection in this study was divided into an initial survey, a pilot test, and an FGD (Focus Group Discussion). Data were collected using questionnaires and direct interviews with the survey and pilot test sample. In the FGD, data were collected from the day of the interview and input from FGD participants. The data analysis used in this research is descriptive. The data were analyzed to determine whether the Augmented Reality-based geometry learning media developed met the validity, practicality, and effectiveness criteria. The data obtained from the expert team is analyzed and used to determine whether the model meets the criteria of validity. Field trial data is used to answer whether the learning model developed has met the criteria of effectiveness and practicality.

III. Result And Discussion

Trial Data

AR-based geometry learning media was developed based on the results of a needs analysis of the implementation of learning in Elementary Mathematics Learning courses. This needs analysis aims to examine

and obtain findings related to implementing learning in Elementary Mathematics Learning courses. Needs analysis is done by distributing questionnaires to students. After analyzing the questionnaire results, several answers were obtained that were the same for one student and another. Students have learned and understood flat and spatial shapes. The shapes they have learned include cubes, beams, tubes, cones, prisms, and pyramids. Most students do not find it challenging to learn and teach spatial shapes. However, some students find it difficult to learn and teach the material in the classroom, especially for nets, the area of various spaces, and the volume of prisms and pyramids.

Some students revealed that the existing media is inadequate, so learning is sometimes not going well. The media used so far are books, pictures, and concrete media, and some students have learned and taught geometry with video shows. The time and development of students use some media. When answering questions about the need to use AR-based learning media in teaching geometry, all students wrote that the media is necessary. The reason is that the development of AR-based media occurs when students are more interested in digital media. They also stated that AR media can help visualize abstract concepts to understand and structure objects, especially space.

Results of Small-Scale Trial (one-to-one)

After obtaining data on the results of expert validation and small-scale trials (one-to-one), small-scale trials were carried out with a subject of 3 UT Yogyakarta students. Small-scale trials aim to get responses and information from students about the AR media developed. There are three things that students will respond to the AR media developed. These three things are about the clarity of presentation, the suitability of media in learning, and the quality of appearance and design. Data obtained from small-scale trials on student responses to presentation clarity can be seen in Table 1.

Table no 1: Student Response to Clarity of Presentation.

Student response to the clarity of presentation		Total	Average
1	AR learning media shows the clarity/sharpness of images	13	4.33
2	AR learning media shows the relevance of illustrations	13	4.33
3	AR learning media introduces geometry with clear illustrations	12	4
4	AR learning media displays the introduction of geometry with a visual display, with an attractive color composition	13	4.33
5	The use of AR learning media can introduce the shape of the object clearly	12	4
6	AR learning media can show changes in geometry into nets clearly	13	4.33
7	AR learning media is equipped with instructions for use	12	4
	Total	88	4.17

In Table 1, students responded agreeably and firmly to the AR media developed in the presentation clarity category. From Table 1, a total score of 88 was obtained from a maximum of 105 for three respondents, with an average of 4.17. After responding to the clarity of presentation, students responded to the suitability of the media in learning, which can be seen in Table 2.

Table no 2: Student Response to the Appropriateness of Media in Learning

Student Response to the Appropriateness of Media in Learning		Total	Average
8	The material in the AR learning media is based on the material needed/learned	13	4.33
9	The material in the AR learning media regarding the introduction of geometry is based on the learning objectives	14	4.67
10	The material in the AR learning media can introduce students to geometry material in elementary school	15	5
11	The display of material in the learning media is presented sequentially	13	4.33
12	AR learning media can support geometry learning	14	4.67
13	AR learning media is easy to use to learn geometry material	13	4.67
14	AR learning media is easy to operate	12	4
15	AR learning media helps me learn independently	13	4.33
16	AR learning media can overcome the limitations of teaching aids	13	4.33
17	AR learning media can be used anywhere	13	4.33
	Total	133	4.43

In Table 2, students agree and strongly agree with the AR media developed in the category of media suitability in learning. From Table 2, a total score of 133 was obtained from a maximum score of 150 for three respondents, with an average of 4.43. After responding to the suitability of the media in learning, students responded to the quality of appearance and design, which can be seen in Table 3.

Table no 3: Student Response to Display and Design Quality

Student Response to Display and Design Quality		Total	Average
18	AR learning media display is detailed	12	4
19	The color composition of the AR learning media display is attractive	12	4
20	The suitability of the display size of objects in AR learning media	12	4
21	All symbols and components displayed in AR learning media are by the provisions	12	4
22	The images displayed already represent the original component form	15	5
23	The instructions given are presented and easy to follow	12	4
	Total	150	4.17

In Table 3, students responded that they strongly agree with the AR media developed in appearance and design. Three respondents obtained a total score of 150 out of a maximum of 180, with an average of 4.17. In addition to responding to the developed media, students also provided comments. The following are comments from students.

1. Respondent 1
   The media developed is very useful for improving the learning process and attracting students' interest, so that later, it can impact their value.

2. Respondent 2
   The media developed is very interesting, especially for me, the 6th-grade teacher who studies the subject in class. In addition to being helpful for students, this media is also helpful for me in teaching and understanding more about geometry material. The improvement needed is in the size of the layer, which is too large.

3. Responden 3
   The media developed is very useful and interesting. I hope this kind of media can be developed also in other materials and subjects. Only a little media display that is too large and cannot be minimized; hopefully, it can be fixed.

Data Analysis

After obtaining data from expert validation results and conducting small-scale trials (one-to-one), small-scale trials were carried out with a subject of 3 UT Yogyakarta students. The small-scale trial aims to get responses and information from students about their responses to the AR media developed. There are three things that students will respond to in the AR media developed. These three things are about the clarity of presentation, the suitability of media in learning, and the quality of appearance and design. The data obtained from the small-scale trial on student responses to the AR media developed can be seen in the diagram listed in Figure 1.

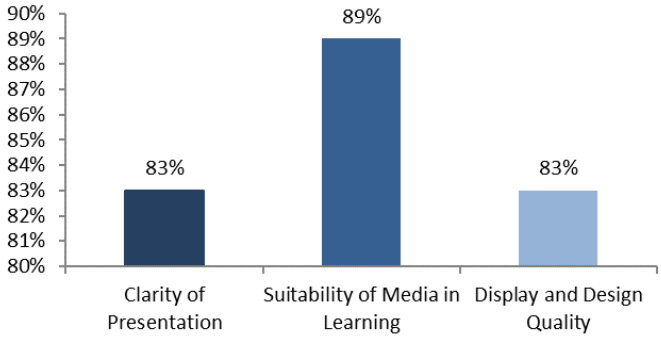

Figure no 1: Students' Response to AR Geometry Media

Figure 1 shows that overall, student responses to the AR media obtained an average score above 4. This can be interpreted as the developed AR Geometry media receiving an excellent response from students, with an overall average of 85% from all three aspects of the assessment. However, students hope there will be improvements to the media developed because, in some devices, AR media is too large to fit within the layer's width, so some images are cut off, and buttons are difficult to select.

Final Product Review

The final product of this research is a compilation of AR-based geometry learning media that has undergone revisions through input from validators. The developed product consists of AR media titled "Recognizing Spatial Shapes" equipped with AR cards and a guide to using the developed media.

Figure no 2: 3D display of prism nets in the developed AR application

Figure no 3: 3D display of pyramid ribs in the developed AR application

IV. Conclusion

This development research produces a product in the form of AR-based geometry learning media with the title of recognizing building space development using the Borg & Gall model, which will be implemented in 2 years. Product development, validation, and small-scale trials (one-to-one) were carried out in the first year. The next stage will be carried out in the second year. This development research shows that the AR-based Geometry learning media produced is suitable for use with improvements according to suggestions from validators. This development research shows that the media received an excellent response from students, with a response value of 85%, and is included in the outstanding category.

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