Ethnomathematics Augmented Reality: Android-Based Learning Multimedia to Improve Creative Thinking Skills on Geometry

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***Abstract*—Based on previous research, an Android-based AR learning media with an ethnomathematical context has been developed. The media was specially developed for vocational students and prospective mathematics teachers in teaching and learning geometry. However, there has been no research on the development of android-based AR learning media using the ethnomathematical context of Yogyakarta, Indonesia, especially for junior high school students. This research is expected to make a new contribution in the field of AR-based learning technology with ethnomathematics for junior high school students. This is development research carried out using the ADDIE model which consists of five categories: analysis, design, development, implementation, and evaluation. The research was conducted in one of the Islamic junior high schools in Yogyakarta. There were 4 expert validators, 4 mathematics teachers, and 18 students involved in this study. The results of the validity test showed that the multimedia developed was regarded as very valid with a material expert score of 0.83 and a media expert score of 0.80. The results of the practicality test revealed that the multimedia was in the practical category with a practicality percentage of 89% based on teacher assessment and 84% based on student assessment. The data analysis which was carried out using one sample t-test obtained a value of t = 9.92 which was higher than the value of t-table = 1.74. Thus, it can be concluded that the multimedia developed in this current research is effective in improving students' creative thinking skills.**

***Index Terms*—Augmented-reality, Android, multimedia, ethnomathematics, creative**

I. Introduction

The era of the Industrial Revolution 4.0 has changed most of human lifeline in various fields such as technology, information, communication, as well as education [1]. The learning process is sought to be able to utilize various technologies as learning media [2]. This is related to the pedagogic competence that must be possessed by professional teachers [3]. One of the skills that must be mastered in this competency is the ability to design and utilize learning media [4]. Learning media, especially technology-based, can help students understand concepts and learning materials [5]. In addition, technology-based media is able to support students in increasing their motivation, curiosity, thinking skills, and learning outcomes [6].

In learning mathematics, technology-based media plays a pivotal role to assist students in constructing a concept [7]. Furthermore, media can also support students in perceiving abstract mathematical objects as real objects, especially geometry learning material [8]. Based on previous studies, students' difficulties in understanding geometry are caused by abstract geometric objects so that media are needed to make it easier for the students to understand them [9–11]. In addition, students' difficulty in perceiving the concept of geometry lies in how to imagine the concept of space, draw, or make illustrations, especially regarding three-dimensional shapes [12]. Thus, technology-based media acts as a real representation, manipulating objects, and making it easier for students to learn geometric objects and accompanying concepts [13].

One of the media that can be used in learning geometry is multimedia [14]. Multimedia is the use of computers to present and combine texts, sounds, images, animations, audio, and videos with tools and links so that users can navigate, interact, create, and communicate [15]. The resulting images, videos, or animations are geometric manipulation of spatial objects into real objects [16]. Multimedia can help students process information [17]. In learning mathematics, multimedia is able to assist students to apply reasoning and creative thinking skills in understanding and solving geometric problems [18].

The latest technological developments which can manipulate two-dimensional or three-dimensional virtual objects into a real environment in real-time are called Augmented Reality (AR) [19]. AR is a multimedia technology that is suitable for use in geometry learning [20]. Previous research reported that AR-assisted geometry learning can improve spatial abilities and geometry learning outcomes [21–23].

In the philosophical context of Realistic Mathematics Education (RME), it is formulated that mathematics must be connected to the real world and must be seen as an activity and construction of human culture [24]. In other words, mathematics is a cultural product so that it can be developed through the elements of the community's local culture by linking it as a context for learning mathematics [25]. Studying mathematical concepts with culture as a context is called ethnomathematics [26].

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This study aims to produce an android-based mathematics learning media using AR technology in an ethnomathematical context. The combination of technology and culture in mathematics learning is expected to improve students' thinking skills, learning motivation, and curiosity, as well as foster the character of love for culture and nationality. Previously, several studies related to AR and Ethnomathematics have been carried out. One of the studies developed an android-based AR learning media with an ethnomathematical context to help prospective mathematics teachers in improving their understanding of geometry materials [27]. Another research described the learning process assisted by android-based AR learning media with an ethnomathematical context to increase the vocational school students' understanding of the concept of transformation geometry [28]. However, there has been no research on the development of android-based AR learning media with an ethnomathematics context, especially the context of the Yogyakarta culture, for junior high school students. Therefore, this research is expected to contribute to the field of AR-based learning technology with ethnomathematics for junior high school students. In addition, the media developed in this study can improve students' mathematical creative thinking skills.

II. Literature Review

A. Augmented Reality (AR)

AR is defined as a technology that is able to combine virtual objects in two dimensions and three dimensions into reality and project them in real-time [29]. The use of AR applications in learning mathematics can simplify the teacher's task in presenting material, shorten the time required, and can create more interactive learning [30]. In addition, the advantage is that it has high interactivity, which means AR virtual objects can interact directly with users [31]. Through AR visualization technology, abstract geometric objects can be manipulated into real objects, so they can be clearly understood by students [32]. This application can be utilized as an alternative learning media to help students in perceiving various geometric objects concretely [30].

B. Ethnomathematics

Ethnomathematics can be defined as the study of mathematical ideas found in every element of culture [33]. Ethnomathematics emerged as an approach to learning mathematics with the following objectives: 1) the relationship between mathematics and culture can be understood; 2) mathematics can be more easily comprehended because it is close to students' real life [34].

The culture used as the context in the current research is the culture of Yogyakarta City, Indonesia. This city has a variety of cultures so that it can be adopted in learning, especially mathematics. The embodiment of the culture in the questions is carried out in the form of art and objects created by humans as cultured creatures, as well as in the form of behaviors and objects that are real such as behavioral patterns, language, living equipment, social organizations, religion, art, and so on [35]. The ethnomathematics utilized as a context for geometric material is related to the artifacts found in the Great Mosque of Kauman Yogyakarta and the Yogyakarta Palace.

C. Creative Thinking Skills

Creativity is the result of creative thinking because it is a process used when we come up with new ideas [36, 37]. Creativity will be seen if students can see several possibilities and conjectures and find new ways and strategies for solving a problem [38]. Creativity in mathematics is learning how to solve problems with divergent thinking processes by providing many different possible solutions [39]. Thinking creatively is needed in solving divergent mathematical problems to be able to generate new ideas and new strategies for finding various solutions (multiple solutions) [40]. There are several indicators to determine students' creativity in solving math problems. Silver argued that problem-solving creativity refers to three indicators, including fluency, flexibility, and novelty [41]. Flexibility is students' ability to solve problems in different ways or methods. Fluency is students' ability to provide many solutions in dealing with problems. Novelty is students' ability to provide unusual answers in general or a new strategy which combines the knowledge they have previously obtained [42]. There are 5 levels of creative thinking skills in solving math problems, including level 4 (very creative), level 3 (creative), level 2 (quite creative), level 1 (less creative), and level 0 (not creative). These levels are presented in detail in Table I [43].

TABLE I: Levels of Creative Thinking and Their Characteristics

Levels	Characteristics
Level 4 (Very Creative)	Students are able to show fluency, flexibility, and novelty, or at least they are able to show novelty and flexibility in solving problems
Level 3 (Creative)	Students are able to show fluency and novelty or to show fluency and flexibility in solving problems
Level 2 (Quite Creative),	Students are able to show novelty or flexibility in solving problems
Level 1 (Less Creative)	Students are able to show fluency in solving problems
Level 0 (Not Creative)	Students are not able to show the three aspects of indicators in solving problems

III. Methodology

A. Research Design

The current study employed the research and development method with ADDIE development model. This model consists of 5 stages, including Analysis, Design, Development, Implementation, and Evaluation [44]. The stages of the ADDIE Model are presented in Table II.

TABLE II: The Stages Of the ADDIE Model

ADDIE Stage	Activity
Analysis	At this stage, the researcher analyzed several things, including: 1. Needs Analysis of Media 2. Needs analysis of curriculum and learning material 3. Identification of ethnomathematical objects
Design	1. Designing application storyboards, views, materials, animations, audio, and videos that are appropriate and in accordance with the material 2. Making validation/assessment sheets for media experts and material experts

Development	1. Developing a product in the form of Android-based AR learning media with ethnomathematical context 2. Carrying out media assessment/validity tests through expert judgment, namely material experts and learning media experts
Implementation	1. Testing the practicality of the media to teachers and students. The purpose of this activity is to obtain response data and suggestions from users 2. Furthermore, the media was implemented in one of the junior high schools to test the effectiveness of the media on mathematical creative thinking skills.
Evaluating	1. This section was a continuation after the multimedia was implemented. This section focuses to analyze the results of the evaluation test to measure the improvement of mathematical creative thinking skills after the learning process is carried out. 2. Media and learning were evaluated as a whole by the teacher. The results of the evaluation were in the form of suggestions for improvement.

B. Research Subjects

The subjects in this study were 2 lecturers of school mathematics material experts and 2 learning media experts who tested the validity of the media. 4 senior mathematics teachers and 18 junior high school students were also involved in the practicality tests and effectiveness tests on the implementation of the mathematic learning media.

C. Data Collection Instruments

The data collection techniques used in this study were questionnaires and tests. There are 4 types of questionnaires used, including media expert's validation questionnaire, material expert's validation questionnaire, practicality questionnaire for teachers, and practicality questionnaire for students. Meanwhile, the test was performed to analyze the effectiveness of the learning media on students' mathematical creative thinking skills.

The media expert validation questionnaire consists of indicators of presentation, appearance, and compatibility. The material expert validation questionnaire includes indicators of content and language feasibility. The teacher's practicality questionnaire includes indicators of effectivity, interactivity, efficiency, and creativity. While the students' practicality questionnaire includes usefulness, convenience, and satisfaction. The test instrument includes creative thinking indicators, namely fluency, flexibility, and novelty.

D. Data Analysis

There were 3 data analyses carried out in this study, including data analysis of the validity test, practicality test, and effectiveness test. The data of the validity test were obtained from the results of the validator's assessment calculated using the expert agreement index with the Aiken V index. This index is able to show the experts' agreement on validity. The Aiken validity index is calculated by the following formula [45]:

$$V = \frac{\sum s}{n(c-1)} \quad (1)$$

V is the rater agreement index; s is the score assigned by each rater minus the lowest score in the category used ($s = r - I_0$), where r is the score of the rater's choice category and I_0 is the lowest score in the scoring category; n is the number of raters, and c is the number of categories that the rater can choose from. Meanwhile, the calculation result of the Aiken V index can be categorized into: less valid if the index is less than or equal to 0.4; moderate if the index is 0.4–0.8; and very strong if the index is greater than 0.8 [45].

The data of the practicality test were obtained from the results of teacher and student assessments calculated by the following formula [46]:

$$P = \frac{R}{SM} \times 100\% \quad (2)$$

where P is the value of practicality, R is the score obtained, and SM is the maximum score. Multimedia is categorized as practical if the value of practicality is more than 75% [46].

The effectiveness test was carried out by implementing the media in mathematics learning. This implementation involved one class IX consisting of 18 junior high school students. The effectiveness was measured by using a mathematical creative thinking test instrument. The media is regarded as effective if the average score of students' mathematical creative thinking skills is higher than the Minimum Completeness Criteria (75). The data analysis was conducted using a one-sample t-test. The prerequisite test is a data normality test. The data were analyzed using SPSS Version 25 software.

IV. Results and Discussion

A. Analysis Stage

At this stage, the researcher has conducted several analyzes consisting of the need analysis of media, analysis of materials and curriculum, and analysis of ethnomathematics objects.

1) Needs analysis of media

This analysis aims to see the needs of media users (teachers and students). Thus, the developed media can facilitate learning activities to make it easier for the students to understand geometric concepts well, and improve mathematical creative thinking skills. Analysis of teacher needs was carried out through the provision of questionnaires. The questionnaires were given to 41 mathematics teachers in junior high schools from each of the 5 cities/districts in the Special Region of Yogyakarta. This questionnaire instrument consists of 14 questions related to the teacher's difficulties in teaching geometry, students' difficulties in learning geometry, the use of multimedia, and the urgency of developing AR-assisted ethnomathematical media. There were several problems found by the researchers, including:

- Most mathematics teachers find their students to have difficulty in learning geometry
- Most mathematics teachers rarely use culture as a context in teaching mathematics
- All mathematics teachers have never used ethnomathematics-based Augmented Reality-assisted learning multimedia

One of the factors which triggers those problems to occur is the lack of teachers in using learning multimedia, especially to deliver geometry learning materials. In learning

mathematics, multimedia can help students to apply reasoning skills in understanding geometry problems so that it can be used as a medium to increase learning effectiveness [47, 48]. Based on this, learning multimedia is an alternative solution. AR-based multimedia with an ethnomathematical context can support teachers and students in learning geometry. In addition, this multimedia can stimulate students' creative thinking skills.

2) Need analysis of learning materials and curriculum

Analysis of learning materials and curriculum refers to the regulation of the Minister of Education and Culture of the Republic of Indonesia Number 37 of 2018 concerning core competencies and basic competencies. The selection of material is focused on geometry at the junior high school level. Meanwhile, curriculum analysis refers to core competencies and basic competencies as well as learning objectives related to the focus of the materials. The basic competencies used include: (1) distinguishing and determining the surface area and volume of geometric shapes (cube, cuboids, prism, pyramid); (2) solving problems related to the surface area and volume of geometric shapes.

3) Need analysis of ethnomathematics

This analysis aims to identify the culture that can be associated with mathematical materials, especially spatial structures. The identification results were in the form of cultural heritage, particularly in the form of artifacts found in the Great Mosque of Kauman Yogyakarta and the Yogyakarta Palace.

B. Design Stage

At the design stage, researchers designed development flowcharts, storyboards, views, materials, animations, audios, and videos that were appropriate and in accordance with the materials and assessment. In this media, the main menu consists of basic competencies and learning objectives, materials (Cube, Cuboids, Prism, Pyramid), the AR camera, and the user guide.

In the AR camera section, there are several choices of information which include audio and visual explanations of ethnomathematical elements, animation of spatial elements, diagonal concepts, finding the surface area and volume of space, and exercises. This section also features zoom and rotate buttons.

C. Development Stage

The development stage is the realization of the product that has been designed [49]. In the initial multimedia display, there are 4 menus including the formulation of basic competencies (KD), geometry materials, AR camera, and user guide.

Fig. 1. Main menu.

In the material menu, there is an overview of geometric shapes (cube, cuboids, prism, pyramid), while on the camera AR menu, there are 3D animations of geometric shapes and other animations to help students understand the concepts of cube, cuboids, prism, and pyramid. The android-based AR multimedia with ethnomathematical content is displayed in Fig. 1:

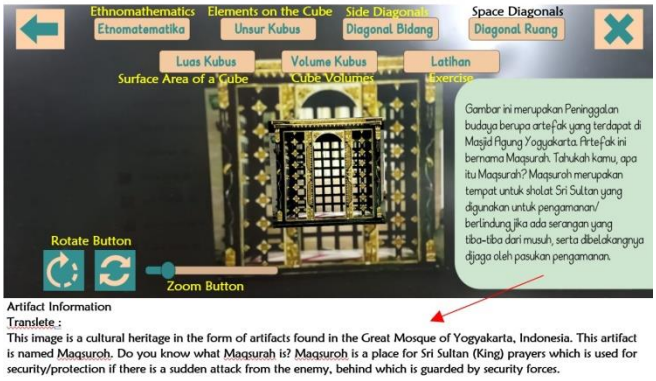

Fig. 2. AR animation display of cube.

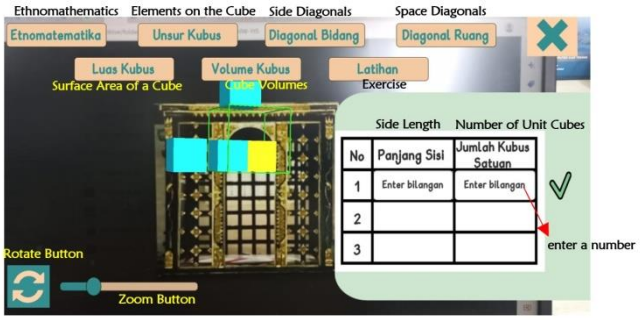

Fig. 3. AR animation display of cube volume.

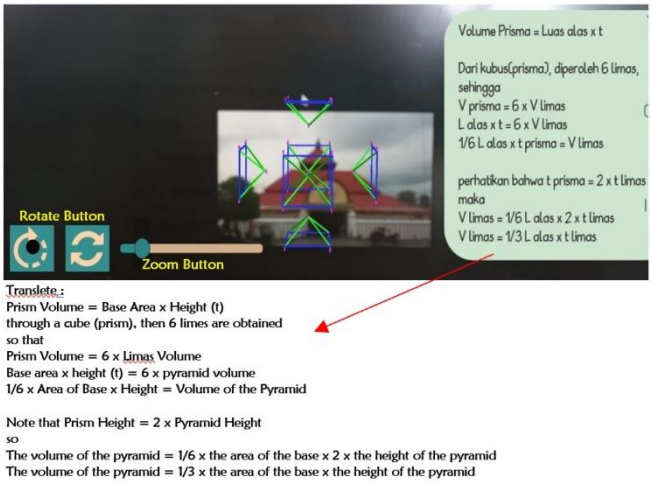

Fig. 4. AR animation display of cube pyramid.

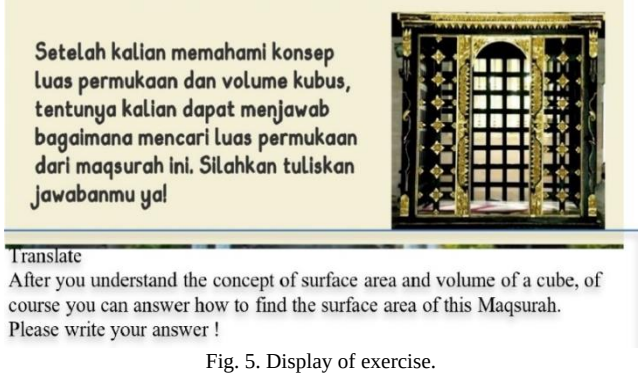

Fig. 5. Display of exercise.

After the multimedia product was developed, the product validation test was carried out by 2 validators as material experts and 2 validators as media experts. The score of the assessment results was analyzed using the Aiken (V) index formula. The validity value obtained from the assessment of material experts was 0.830. Meanwhile, the validity value obtained from the assessment of media experts was 0.805. Both were classified into the high validity category. Based on these results, the multimedia developed in this research is feasible to be implemented for the users, particularly teachers and students.

D. Implementation Stage

The android-based AR multimedia with ethnomathematical content has been implemented at Ibad Ar Rahman Islamic junior high school. This stage aims to test the practicality of the product and to implement the product in learning. The practicality test aims to figure out whether the developed multimedia has fulfilled the practicality criteria. The practicality was analyzed based on data obtained from the assessment results of 4 mathematics teachers and 18 students. The practicality value obtained from the analysis of the average score of 4 mathematics teachers was 89%. Meanwhile, the practicality value obtained from the analysis of the average score of 18 students was 84%. These values indicate that the developed multimedia has met the practicality criteria. After the product was proven practical, its implementation in mathematics learning was carried out. Implementation is part of the process to test the effectiveness of the product. The effectivity test aims to discover whether the application of multimedia in learning is effective in improving mathematical creative thinking skills.

Fig. 6. Implementation in learning mathematics.

E. Evaluation Stage

The evaluation stage is a continuation of the multimedia implementation activities. In this stage, a learning experiment with one group post-test design was conducted. To figure out the improvement of students' mathematical creative thinking skills, they were given a mathematical problem test instrument at the end of the learning activities. Their answers were scored and analyzed using the one-sample t-test. This effectiveness criterion is determined by the average value of students' mathematical creative thinking skills which was higher than the Minimum Completeness Criterion (75). The data analysis results are presented in Table III.

TABLE III: RESULTS OF DATA ANALYSIS

Variable	Tests of Normality (Kolmogorov-Smirnov) Sig.	t-test	t-table	Sig.
Creative Thinking Mathematics	0.200*	9.929	1.74	0.000

*This is a lower bound of the true significance

As can be seen in Table II, the result revealed that students' score was normally distributed. The normality test is a prerequisite for the one-sample test. The SPSS calculation result obtained a Sig value of 0.200. The value was higher than ($\alpha = 0.05$), so the data is normally distributed. The one-sample test obtained a t-value of 9.929 which was higher than the t-table value of 1.74. Thus, there is a significant difference between the minimum completeness criteria value and the average value of students' mathematical creative thinking skills. In other words, it can be concluded that the multimedia learning is effective in improving students' creative thinking skills [50]. Multimedia can facilitate students in learning mathematical objects which are marked by the development of mathematical creative thinking skills [51, 52]. Abstract mathematical objects such as geometry can be visualized with multimedia, making it easier for the students to understand the learning materials [53–55]. In addition, the animation provided can help students to construct the geometry concepts being learned. When students' reasoning is trained to construct a concept, their creativity will also be trained [56–59]. In other words, discovery learning will train students to construct a mathematical concept, so that their creative thinking skills will also develop [60].

V. CONCLUSION

Students' difficulties in understanding geometry are caused by abstract geometric objects. Students need to be taught to learn mathematics by constructing the concepts learned. With this, students' reasoning will be trained so that they are able to stimulate mathematical thinking skills. Therefore, this multimedia was developed to make it easier for the students to learn geometry and to guide them to learn to construct the geometry concepts being studied. The results showed that the android-based AR multimedia with ethnomathematical content developed in the current study has met the criteria of being very valid, practical, and effective in improving mathematical creative thinking skills. Therefore, the multimedia developed is expected to be implemented more widely.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Rino Richardo carried out needs analysis, developed material topic designs, storyboards, and collected data on validity, practicality and article writing. Ahmad Anis Abdullah carried out product effectiveness data collection and data analysis. Tri Rochmadi, Astri Widi Astuti and Khasanah Nur Hidayah contributed to developing AR applications. Ariyadi Wijaya and Nurkhamid provided input and suggestions as a whole from the research process.

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