Designing augmented reality-based mathematics mobile apps for outdoor mathematics learning

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M G K Ahsan[1], Miftahudin[2], A N Cahyono[1,*]

[1]Department of Mathematics, Universitas Negeri Semarang, Indonesia
[2]SMP Negeri 10 Semarang, Indonesia

[*]Corresponding author: adinurcahyono@mail.unnes.ac.id

Abstract. Augmented reality, one of the current technologies, can make a virtual object on the real-life environment, and it is suitable for the space geometry learning. The purpose of this research is to design an Augmented Reality-based mathematics mobile phone application for outdoor mathematics learning about space geometry. This study used a design research method consisting of the design and implementation stages. The focus of this paper was on the designing stage. The Preliminary analysis in school showed that mathematics learning used instructional media frequently, and the school environment had some real-life objects similar to the space geometry objects. The app design of the user interface was made in order to make it easy to use, the 3D model was designed according to the scientific learning to help students to illustrate mathematically the real problems faced. The outdoor mathematics learning was designed by making some exercises that used the objects around the school. The results of the feasibility test of the product indicated that the application was suitable for the use in outdoor mathematics learning in schools.

1. Introduction

The smarter technology creates the concept of "learning anywhere and anytime" to be more comfortable. Industrial Revolution 4.0 has encouraged the birth of network-based education, digital content and strengthened the need for innovation in the field of education using Information Technology and communication better known as education 4.0 [1]. Teachers are required to be familiar with learning using technology assistance. This is done so that teachers can adjust to the times and also the character of students now who are familiar with the technology that might be even more proficient than teachers.

The main target of the next generation of the learning systems is to use the current and modern technologies to provide new techniques of learning, training, and education that will be easily accessed and available for all who wish to be part of it[2]. One of which is Mobile Learning. Mobile Learning is a learning model that utilizes information and communication technology [3]. In this learning concept, Mobile Learning brings the benefits of the teaching materials availability that can be accessed anytime and the visualization of the interesting material. Indeed, the learning process will become suboptimal when the smartphone device is very useful, easy to use, and easy to learn [4].

The Organization for Economic Co-operation and Development (OECD) conducted a PISA study, which was a three-year assessment of literacy achievement in reading, mathematics, and science of 15-year-old school students. Indonesia's participation in the PISA study since 2000 shows that the achievements of Indonesian students have not been encouraging in the number of reports issued by

PISA. In 2015 PISA, Indonesia received a score of 386, far below the OECD average score of 490 and ranked 62nd out of 70 participating countries.

One reason for Indonesia's low PISA score is the lack of student literacy skills. Mathematical literacy ability is the ability of the individuals to formulate, apply, and interpret mathematics in various contexts [5]. This includes mathematical reasoning and the use of concepts, procedures, facts, and mathematical tools to describe, explain, and predict a phenomenon or event. Someone who is literate (literate) in mathematics does not only understand mathematics but also able to use it in solving everyday problems [6].

Besides the low mathematical ability of the students also caused many students afraid of mathematics and math phobias. They tend to skip math lessons and are happy when the mathematics teacher cannot attend the class [7]. This results in the low quality of mathematics learning and also the lack of student achievement in mathematics has an impact on the student literacy skills. Mathematics learning in the classroom did not explore the students' mathematics literacy skills but only the transfer of knowledge [8]. The need to apply mathematics learning that is not boring, one of them by learning mathematics outside the classroom. This learning model is known as an outdoor mathematics learning. This learning model is suitable to be applied so that students are accustomed to the real objects in mathematics learning [9], and they can also apply mathematics directly in real life. The outdoor learning encourages sharing experience as a medium of teaching and learning process[10]. It is necessary to explore the potential of mobile technology for the use of outdoors mathematics learning, and in doing so, to engage students, as trails walkers, in meaningful mathematical outdoor activities [11].

In this research, application development based on augmented reality will be applied in outdoor learning models. Augmented Reality uses a system integrated into a smartphone or other gadgets. This is intended to help the perception and interaction with the real world. Augmented Reality uses a marker to show the virtual object [12, 13]. The outdoor learning is assisted by using augmented reality-based applications to make the interaction between users and real-world subjects more interactive because something that cannot be visualized in the real world can be visualized in the digital in augmented reality applications. Therefore, the importance of improving students' mathematical abilities can be developed by interesting media, one of which is augmented reality for learning mathematics outdoors. As an initial stage of the development, an augmented reality-based smartphone application was designed.

2. Method

The research design paradigm was used to design this application. The method used was ADDIE. The Development steps are as follows:

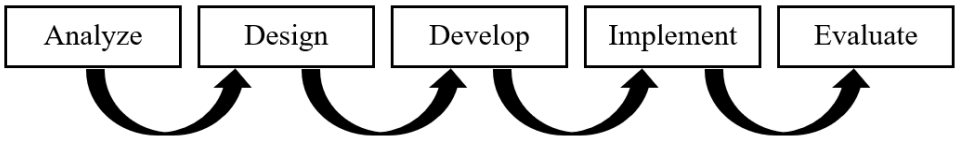

Figure 1. ADDIE Steps [14]

This research focused on the design of the augmented reality mobile applications before being implemented in schools. The stages comprise analyzing, designing, and developing. These three steps were performed because the design result was the initial product that was ready to be implemented. The participants of this study were students from Junior High School 10 Semarang (JHS 10 Semarang). The analysis phase included problem analysis, analysis of learning components, and analysis of media development. The design phase included determining the name and design of the application. The last stage was the development including assessment by experts, teachers, and some students. After that, The final design of the application may apply at school. The product assessment

criteria on augmented reality-based android applications refer to Bokhove [15] by modifying algebraic criteria into mathematical criteria.

3. Results and Discussion

3.1. Analyzing of research equipment

In the analysis phase, several results were obtained. In problem analysis, it was found that students were more enthusiast about learning mathematics on a project basis during the class hours. this is evidenced by the students being more active when learning Project Based Learning models in Flat Space Geometry where students could be free to create shapes to build space rather than only being given class material. In the analysis of the learning component, it was obtained several places in JHS 10 Semarang that represented the building space, so students could learn to build a space outside the room. In the analysis of media development, it was found that students were also more interested in using smartphones for learning. From the results of the analysis, it was found that the use of smartphones for outdoor learning was suitable for SMP N 10 Semarang. However, some considerations were decided that there should be still a learning in the classroom to supply the concept of the Flat Space Geometry strengthening the concept by working on the questions outside the room.

3.2. Designing of the application

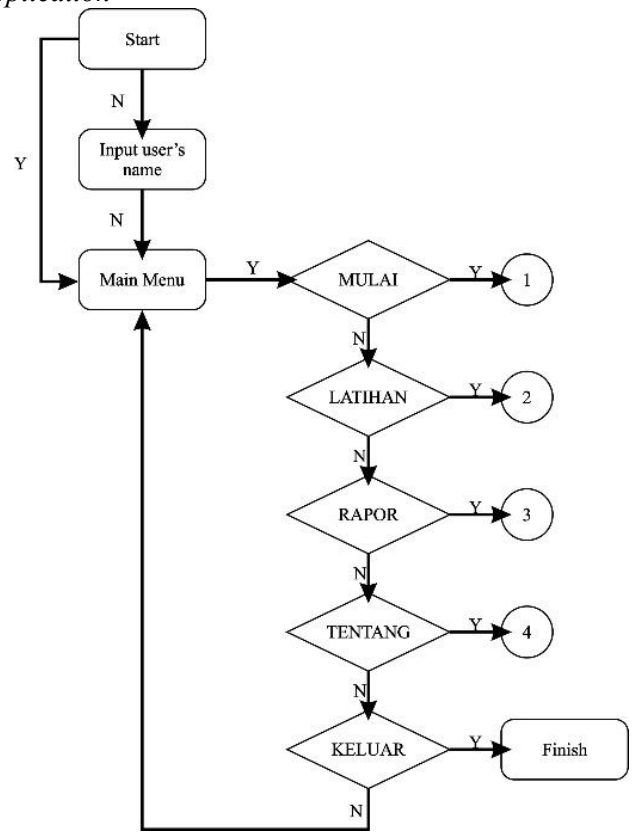

Figure 2. Main Menu Flow Chart

This application is named Mathinact. It has a main menu consisting of MULAI, LATIHAN, RAPOR, and TENTANG. The main menu flow diagram is shown in Figure 2. The menu starts to be intended for activities in the classroom as the first conceptual giving of the material about building space. The Start Menu contains 4 building spaces namely cubes, cuboids, prisms, and pyramid. Each space menu consists of 4 materials, namely elements, nets, surface area, and volume. The LATIHAN menu is a

guide for students to work on questions outside the room. The LATIHAN menu at this Development stage was made for JHS 10 Semarang.

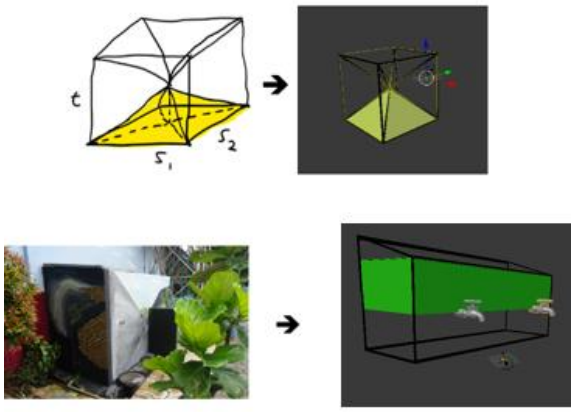

Figure 3. 3D Concept Realization

The first process of making 3-D objects was using 3D blender software. The 3D objects created were designed based on the scientific approach. Figure 3 represents the model to find the volume of the pyramid formula. It is for indoor learning in the classroom, and this is a Trapezoid Pond, and the 3D model shows the model of the pondand also shows the hint of the concept/ formula uses. Moreover, the Marker design will be made for each building. However, the questions outside the room use a marker around the object to be done. This is useful to improve students' insights related to the marker to be scanned.

3.3. The Development of the learning instrument

A preliminary product is the result of the design made. The software used to develop the application is Unity 3D. Figure 4 shows the main menu, augmented reality features, and the map of SMP N 10 Semarang.

Figure 4. Application Display

In addition, this application is also assisted by student worksheets. The student worksheet serves to write down the results of student observations of the 3D object seen. The application trial was conducted at JHS 10 Semarang by taking a sample from 4 students in the 8A class.

Figure 5 showed an example of an indoor task, students were asked to learn the concept of cuboid surface area. They opened the level 2 of the cuboid menu, there was a net of the cuboid. Based on the augmented reality apps display, students made their own net that was different from apps display. After that, students were guided to the level 3 of the cuboid. The apps showed the model of the cuboid which surface was red, green, and blue, like thenet. Students connected the concept of the net to find the surface area of a cuboid.

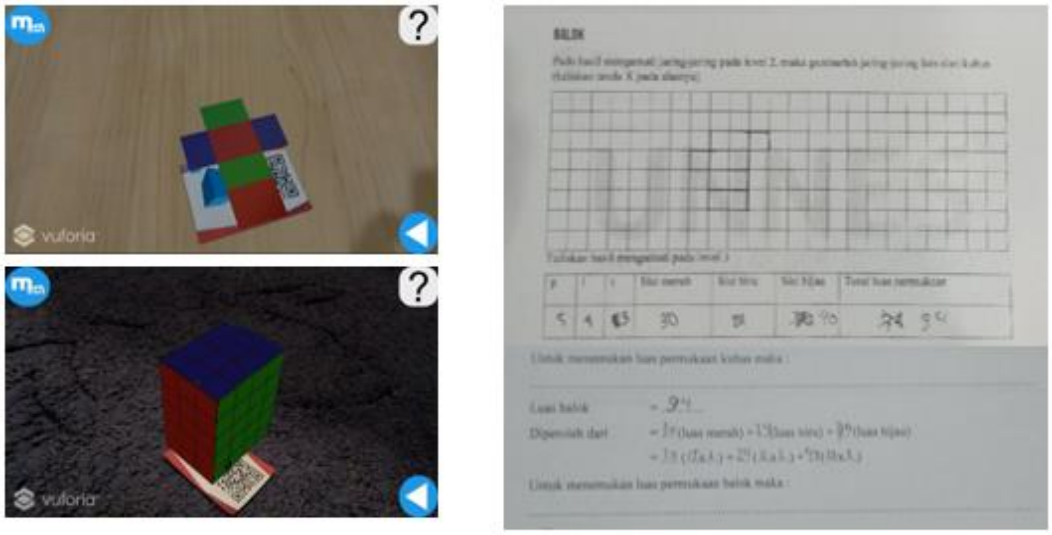

Figure 5 Indoor Task

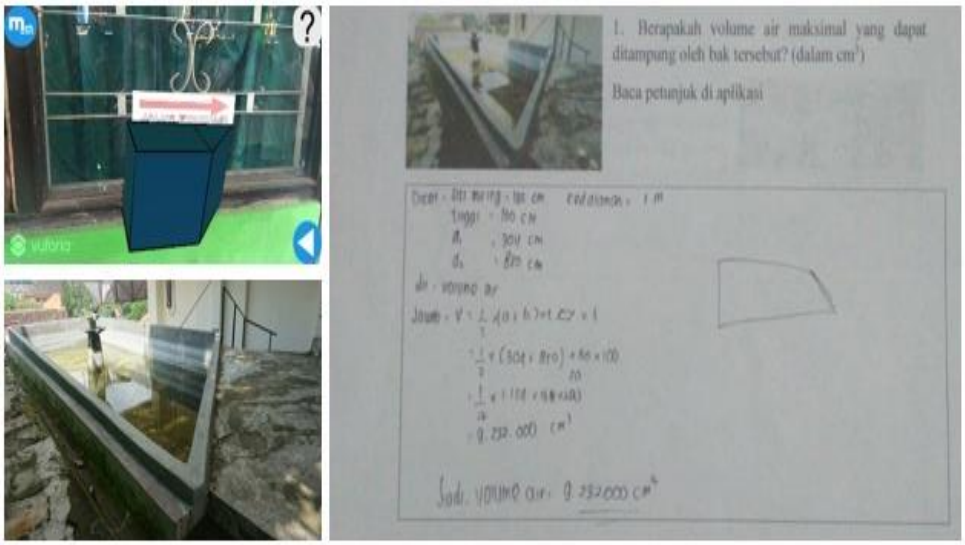

Figure 6. Outdoor Task

Figure 6 showed an example of an outdoor task. This problem was to find the maximum volume of the trapezoid pond. The 3D object showed that the object cwere divided into 2 objects, they were cuboid and triangle prism, but the students did this task of a trapezoid prism concept. This finding showed that students already understood the concept of the prism. Moreover, students filled out the application assessment sheet to find out their views about learning by using the application both inside and outside the room.

Assessments were carried out by mathematics experts, media experts, teachers, and 4 students obtained grades for all criteria. Recap of the assessment of all respondents are as follows.

Table 1 Assessment

No	Criteria	Score	Category
1	Mathematics	4.16	Good
2	Tools	4.22	Very Good
3	Assessment	4.08	Good
4	General	4.40	Very Good

The mathematical criteria obtains 4.16 which means it has a good rating. The applications combined with worksheets allow the students to write the steps of reasoning to find the concepts or do the assignments. The tool criteria obtains 4.22 which means it has a very good rating. This application is easily accessed by the students anytime and anywhere with clear instructions. The assessment criteria obtains 4.08, which means having a good rating. The application contains the students' grades based on the understanding the material and answering many questions.

From the results of the four responses review, it was found that 3D objects had to be able to be manipulated. The 3D objects might be enlarged, moved or rotated. Besides, the main menu display was made more interesting. This application could run smoothly on smartphones with 1 GB minimum of RAM with a minimum Operating System Android Jellybean 4.1.

4. Conclusion

As shown on the results and discussion above, it can be concluded that the application of augmented reality can be the alternative learning media for students to learn about flat side space geometry. The outdoor learning combined with an augmented reality application can improve student interest in learning mathematics. Besides for outdoors, this application can also be used for indoors for learning mathematics as usual. Students become more enthusiastic about learning both indoors outdoors.

From the results of this design, this application can already be implemented in the school learning activities. However, before being implemented, this application must be revised according to the advice of respondents. This research is expected to continue the application of different mathematical abilities and learning models.

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