Designing augmented reality-based teaching resource of three dimensional geometry

Mailizar¹, Rahmah Johar² and Lainufar³

¹,²Mathematics Education Department, Universitas Syiah Kuala, Banda Aceh, 23111
³Master Program of Mathematics Education, Universitas Syiah Kuala, Banda Aceh, 23111

Email: mailizar@unsyiah.ac.id

Abstract. Indonesia, like many other countries, sees Information and Communication Technology (ICT) as a potential tool for enhancing education and the country is keen to integrate this digital technology in the classroom classrooms. Therefore, since 2004 Indonesian Ministry Education and Culture has stipulated a regulation on the implementing the technology in teaching and learning process. Furthermore, since 2013 Indonesian government implemented a new curriculum emphasizing the use of ICT in the classroom. Recently, Augmented Reality (AR) is one of digital technologies that has received increasing attention for teaching and learning of mathematics. However, lack of research has been devoted to design and develop Augmented Reality-Based teaching resources for secondary school mathematics. This study aimed at designing and developing Augmented Reality - based teaching resources (e.g., lesson plans, student worksheets and Augmented Reality Applets) for teaching Geometry in senior secondary schools. In order to achieve the aim, in this study, we employed a design research model proposed by Plomp and Nieveen. This model consists of three phases that are preliminary phase, prototyping phase and assessment phase. It is important to note that this paper reports results from preliminary. In the preliminary phase we distributed questionnaires to teachers and students which were then followed by interviews. The findings revealed that teachers and students were keen to integrate Augmented Reality technology in teaching and learning mathematics. Furthermore, the teachers expected to be equipped with ICT-based learning resources that support discovery and project based teaching approach. Based on the findings, we designed and developed Augmented Reality applet, lesson plan and student worksheet for teaching three dimensional geometry in senior secondary schools with a project based-teaching approach.

Keyword: Augmented Reality, Teaching Resources, Three Dimensional Geometry, ICT in Mathematics Education

1. Introduction

Technology has been introduced and integrated into education in various countries since the mid-80s. The use of ICT (Communication and Information Technology) in learning has attracted the interest of many countries including Indonesia. Based on UNESCO, the Indonesian Ministry of Education and Culture has since 2004 issued a policy that allows the use of ICT as part of the curriculum in schools and universities in Indonesia (1). One School One Computer Laboratory) and WANkota (City Network Schools) (1). Furthermore, in 2007, the Indonesian government also passed Ministerial Regulation No. 24 regarding school infrastructure standards. The regulation regulates schools to be equipped with
hardware and software related to access to ICT to support learning (Kemdikbud, 2007). In 2016, the Indonesian Government through the Ministry of Education and Culture issued the Number 22 Ministerial Regulation concerning the standard of the education process, one of which was the use of ICT in learning.

Researchers believe that the integration of ICT in learning will improve student learning outcomes in Indonesia. Previous research (e.g., (2), (3), (4), and (24)) showed positive impact of using ICT to teach mathematics in Indonesia. For example, Al Jupri (2) considers that ICT integration is not the only solution to mathematics education problems, but it is expected to improve the quality of mathematics learning so that it can improve student achievement.

However, the Mailizar (5) shows that high school mathematics teachers in Aceh province use ICT in teaching limited numbers of mathematics lessons. The teachers did not use ICT to change teaching and learning to be more constructive. Based on this study (5), one of the challenges of teachers in the use of ICT in a constructive way is teachers have lack of knowledge in the use of ICT and they have difficulty to develop ICT-based learning materials.

One of the technologies used in mathematics learning is Augmented Reality (AR). AR is a technology that combines two-dimensional and or three-dimensional virtual objects into a real three-dimensional environment. The availability of smartphones and tablets with the power and speed of high processors allows this technology to be used with these tools.

Previous studies showed that Augmented Reality help to improve students’ motivation in learning (11, 12). In addition, the previous study also revealed that AR support teacher centred approach (11) and learning by doing (13). Furthermore, Van Krevelen (15) argued that AR technology can enhance students’ spatial ability. However, the previous studies did not look at the improvement of students’ spatial ability in learning geometry assisted with GeoGebra Augmented Reality. Furthermore, one of the challenges in learning mathematics using ICT, especially Augmented Reality is that teachers have difficulty designing teaching resources that are ready to be implemented in the classroom. Furthermore, the teaching resources, as mentioned previously, are not widely available so that teachers have lack of the learning resources they can be used. Therefore, it is necessary to design and develop mathematical Augmented Reality-based geometry teaching resources.

2. Related Literature

In mathematics education, the role of ICT to improve learning has received attention from researchers and educators. For example, ICT has become an interesting theme in an event organized by the international Congress of Mathematics Education (ICME). In addition, other organizations such as The National Council of Teachers of Mathematics (NCTCM) are also very concerned about the use of ICT as stated in one of its standard, namely "technology is very important in teaching and learning mathematics and influencing mathematics taught and improving student learning" (6). More specifically, NCTM (6) state that: "With the guidance of an effective math teacher, students at different levels can use these tools to support and expand mathematical reasoning and reasoning, gain access to mathematical content and the context of problem solving, and improve computing competency". In addition, technology has the potential to create dynamic mathematical representations, to support the exploration of student assignments and to explore mathematical content.

In addition, it is also believed that ICT have other benefits in mathematics education such as providing rapid feedback that encourages students to continue to explore (7), allowing students to focus on strategies and encourage the trial and error (8), and allowing students to view graphics, images and text simultaneously (8). Furthermore, the availability of special software for learning mathematics such as Dynamic Geometry Software (DGS) enables students to do deductive reasoning and proof (9).

Augmented Reality (AR) is a technology that combines real and virtual objects in a real environment and runs interactively in real time. Although this technology has long been used in other fields, but in the field of education its use has only begun in recent years (10).

The use of augmented reality in the classroom is in line with effective instructional practices in the following aspects: engagement in learning (20), immersion and presence in content (21), situate learning
to a location or context (22), authenticate the content (10) and build community (23). Moreover, this technology has various advantages to be used in learning, including it can attract students’ interest and attention to the lesson and increase their motivation to increase ((11), (12)). In addition, AR has features that enable student-centered learning (11) and learning by doing (13). Specifically, AR technology presents 3D virtual objects and combines these virtual objects with the real world.

Within mathematics education research, the use of AR in the classroom is in its early stages, but shows powerful results (25). Demitriado et al (26) argue that augmented reality displays potential for educational activities in mathematics. For instance, Estapa and Nadolny (25) conducted a study to assess student motivation and achievement during an augmented reality mathematics activity. This study revealed that the use of Augmented Reality increases students’ achievement, enhances students; motivation to learn mathematics. Moreover, previous study indicates that AR environment can help learners develop skills and knowledge in a more effective way (17). Therefore, implementation of AR within mathematics instruction has the potential to enhance both kinds of mathematical activity, technical and conceptual, along with student motivation (25).

However, existing research on the integration of AR in teaching mathematics has primarily conceptualized manipulative (18), basic computation (19). The use AR in geometry has the greatest potential to enhance student learning (25). However, less attention has been given to study the use of AR in teaching geometry to improve spatial ability which is one of the important components of human intelligence. The terms spatial ability include five components, spatial perception, spatial visualization, mental rotation, spatial relations and spatial orientation (14). Generally, the main purpose of geometry education is to improve this spatial skill. Various other studies have concluded that spatial abilities can be enhanced by AR technology (15). AR aims to improve better understanding of the spatial side of mathematical objects and help connect real-world reality with mathematics.

3. Aim and Research Question
The aim of this study was to develop upper secondary school mathematics Augmented Reality-based teaching resources. The resources that are GeoGebra applets augmented reality, lesson plans, and student worksheets. As mentioned earlier, this paper reports the preliminary phase of this study. Therefore, the research question examined in this paper is what are teachers and students’ view of the development and potential use of Augmented Reality based resource for teaching and learning Mathematics?

4. Research Method
This is a developmental research project employing Plomp and Nieveen’s model (16). The model consists of three phases, namely: (a) preliminary phase; (b) prototyping phase; and (c) assessment phase. The steps of the Plomp and Nieveen development model are as follows:

- Preliminary Phase
- Prototyping Phase
- Assessment Phase

![Figure 1. Plomp and Nieveen’s (2013) Model of Developmental Research](image)

As mentioned earlier, this paper report results from preliminary phase of this study. Therefore, in the following paragraph, we explain method and data collection process of this phase.
At the preliminary phase, a needs analysis is carried out to explore students and teacher’s view of the need of Augmented Reality-based teaching and learning resources. The collect the data, we distributed questionnaires and interviewed teachers and students from three upper secondary schools in Banda Aceh, Indonesia. The schools were randomly selected. In total, 6 teachers and 12 students participated in this phase. Data were analyzed through quantitative and qualitative descriptive analysis.

5. Result and Discussion
Result from questionnaires and interview show that all of the teacher participants were aware that the current curriculum (2013 Curriculum) emphasizes on constructivist based-approach. Moreover, the teachers were also aware that they need to use scientific based- teaching and learning approach such as inquiry based learning and project based learning. Furthermore, all the teachers were also understand that the current Indonesian curriculum requires the teachers to integrate technology in the teaching and learning. However, when we asked the teacher about what kind of technology and how they use it in mathematics teaching, most of the teacher said they do not take it seriously in the use of ICT in the classroom. For example, of the teacher said that: “I did not take into account about the use of ICT, and some teachers use of ICT out of the teaching context”.

We further investigated teachers’ awareness of the available ICT resource for teaching and learning mathematics, particularly GeoGebra and Augmented Reality. The findings suggest that about 80% of the participants knew about Geogebra, 30% of them were aware about Augmented Reality. However, there was no participants who were aware that there is GeoGebra Augmented Reality that are available for free and can be employed for teaching and learning mathematics at upper secondary schools.

In order to understand teachers and students’ need of instructional media, we asked the participants about this aspect. The finding showed that the majority of the teachers and students need instructional media that contain illustrations, explanations, and examples of objects in everyday life. They also need instructional media that has interesting animation and is flexible to adjust. On the teacher revealed that:

“I need an instruction media that contain an object, explanation about the object, it relates to real-life environment and it also has problems for practices. I believe would be easy for students to learn through an instructional media that has an object”

Another important point, the participants revealed that they need media that easy and freely accessible. Participants also raised another critical point regarding instructional media is that they need media that facilitate discussion and support students’ mathematical activities. These aspects in line with augmented reality as described by Peddie (17) and Gonzales (18). The participants also need an instructional media that authenticate the contents as described by Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C (10).

In order to introduce Augmented Reality to participants, we showed them example of GeoGebra Augmented Reality before we interviewed them. The sample is shown in Figure 2.
Teacher and students’ responses to the development of Augmented Reality-based teacher and learning resources show that they need the resource for teaching and learning of mathematics. Teacher believe that student need to experience learning with augmented reality technology in order to improve their mathematical skills. The teachers also suggested that discovery learning model can be employed with Geogebra AR. The teaching and learning resources need to be designed based on the students’ need. Finally, the teachers strongly support the developing of GeoGebra Augmented Reality based teaching and learning resources. One of the teachers said that:

“I hope Augmented Reality-Based teaching resources will be available soon. I will help me to integrate the technology in my classroom, and I hope many teachers would use these resources in their classroom when they teach mathematics”

We also asked the teachers what mathematics topics that they need to teach with ICT. The majority of the participant revealed that they really need ICT for teaching graphic functions and geometry. For instance, one of the participants revealed that:

“Graphic functions, really need ICT for that topic. For other topic, teaching Geometry requires ICT, I think that all. In teaching Geometry, since Geometry has many picture, it is easier if I use ICT. It is like Trigonometry, it is easier to teach with ICT when I need to show trigonometry graphics, for instance I can plot graph of Sinus and make animation”

The results revealed that the students and teachers were very enthusiastic with the potential use of Augmented Reality technology in teaching and learning mathematics. This findings is in line with previous findings such as (18) and (12). It can be conclude that upper secondary school mathematics teachers have positive perspective and opinion on the development and use of Augmented Reality-based teaching and learning resources. This is because it is believed that AR is one of the teaching media that has advantages in motivating students to learn independently (18). As a result, it is hoped that they students can develop better mathematical skills and conceptual understanding.

Regarding the finding from the preliminary phase of the study we conclude that appropriate learning activities need to be designed so that students can make use of this technology in problem based or project-based learning activities. For the sake of this, in the next phase of this research project, we design and assess learning activities involving GeoGebra augmented reality through a project based learning. We will focus on topic of three dimensional geometry, particularly in sub-topic of angle between a line and a plane, distance between two lines, distance of a point from a plane and angle between two planes. Learning activities will be featured through lesson plans and students worksheet. We will also design
assessment items for assessing the effectiveness of the learning activities. Some augmented reality applets are presented below:

**Figure 3:** Augmented reality applets of cube and tetrahedron

**Figure 4:** Augmented reality applets of prism and pyramid

Figure 3 shows two examples of augmented reality applet designing to help students in learning distance between a point to a line in a cube and tetrahedron. Moreover, Figure 4 shows sample of augmented
realistic applets of prism and pyramid designing for teaching and learning distance between a point to a line and/or to an object in prism and pyramid. Teachers and students will use these applets along with lesson plans and student worksheets that will be designed and developed in the next phase of this research.

6. Conclusion
Based on the results from preliminary phase of this research project, we can draw the following conclusion. First, upper secondary school mathematics teachers in Banda Aceh were aware of the implementing the current curriculum with emphasis on students centered learning and integration of ICT. Furthermore, the finding show that teachers and students expressed their need on augmented reality-based teaching and learning resources for mathematics, particularly geometry. The participants strongly support this development. Finally, based on the finding, in the next phase, we are going to complete the designing of Augmented Reality-based teaching and learning resources (Applets, Lesson Plan, and Students’ worksheet) for Project-based learning activities.

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