A need analysis for the development of augmented reality based-geometry teaching instruments in junior high schools

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Abstract. Previous studies have shown that augmented reality (AR) is an interactive teaching media that can improve students’ learning motivation and spatial ability. Many studies have discussed AR technology and GeoGebra App but there are no previous studies on developing and using GeoGebra AR-based teaching instruments to improve students' spatial abilities in mathematics. The purpose of this study to develop valid and practical GeoGebra AR-based teaching instruments on geometry and used the Plomp model. This paper only reports the findings on the preliminary research. The research participants were three vice-principals of curriculum, three mathematics teachers and six-year 8 students who were randomly selected. The data were collected by administering questionnaires, interviews, and observations, and then analyzed descriptively. The result of this study indicated that the mathematics learning process on geometry topics in years 8 could be improved through GeoGebra AR-based teaching instruments. Moreover, students' abilities were sufficient to use it. In conclusion, students and teachers need GeoGebra AR-based teaching instruments in geometry learning. The results of this study can be used as theoretical and empirical references for the next stage of development.

1. Introduction
Education in the fourth industrial revolution requires teachers to develop more interactive teaching strategies. Integrating technology into the classroom helps teachers design an attractive and interactive lesson plan to increase the learning effectiveness of millennial students [1]. Ministry of Research, Technology and Higher Education of the Republic of Indonesia has actively voiced education policies and programs to deal with the globalization of revolution [2].

Regulation of the Indonesian Ministry of Education and Culture (MoEC) Number 58 of 2014 [3] on junior high school curriculum states that mathematics aims to enable students to: (a) understand concepts and be able to do algorithms in problem solving; (b) use thinking patterns as conjecture and be able to make a generalization based on existing phenomena or data; (c) use reasoning and do mathematical manipulation in mathematics and in other contexts; (d) communicate ideas and reasoning and be able to do mathematical proofs; (e) appreciate the importance of mathematics in everyday life; (f) have attitudes and behaviors in accordance with the values in mathematics and mathematics learning; (g) do motor activities that use mathematical knowledge and (h) use simple manipulatives and technologies to do mathematics activities. To achieve the goals, the mathematics-learning process is designed to be student-centered or known as constructive learning. For this reason, interactive teaching media are needed as instructional tools in the learning process.
Confrey [4], a constructivist, states that she did not teach about the mathematical structure whose objects exist in this world, but taught students how to see the world through existing knowledge and then produce new knowledge from their experience. The statement infers that the main purpose of constructive learning is that students are able to achieve a learning goal by building upon their prior knowledge. The implementation of this theory suggests teachers to act as facilitators in learning; that is, as a provider of interactive teaching media so that it can help the learning occurs constructively.

It is worth noting that teaching media, as a channel for information, can stimulate the attention, interests, thoughts, and feelings of students in learning activities. The classification of teaching media as stated by the Leshin taxonomy [5] consists of: (a) human-based media that transform students' attitudes through interactive learning design, (b) print-based media that attract students to learn through languages, colors, letters, and appealing illustrations, (c) visual-based media that can grow students' interest in learning and help students to connect the content of teaching material to the real world, (d) audio-visual-based media used to learn about teaching material and (e) computer-based media containing the presentation of information about content, practice questions, or both. It would be better and more interesting if these various media can be integrated to address students' different learning abilities [6].

One of the media currently being used in learning is augmented reality (AR). In contrast to virtual reality made to capture a version of reality in human visuals with three-dimensional objects, AR is able to present the design of three-dimensional objects in the midst of real human visual situations. There are three principles of this technology: AR is a combination of real and virtual environments, running in real-time and virtual displays integrated in the real environment [6]. The main purpose of AR can be defined as a real environment to which virtual objects are added so that users feel a created real environment. In other words, users believe there is no difference between what they see and what they feel in the real environment.

Some previous studies conducted in Indonesia investigated the use of AR in mathematics learning. A study that used AR on solid geometry found that students were able to confirm the results of the tasks they do independently [7]. Another study [8] developed AR-based learning media on the volume and surface area of straight-sided three-dimensional objects; the findings showed that students taught using AR-based learning had the mathematics learning outcome above the minimum criteria. A study that examined high school students' perceptions towards AR [9] and the development of learning media using AR had a positive impact on three-dimensional object topic. The learning outcomes of learners who get that media better than the learners who use learning with conventional learning [10]. The international study on the use of AR in education from 2011 to 2016 [11] reported that AR had been present in mathematics learning specifically. Currently, AR is used together with one of the applications commonly used in mathematics, GeoGebra; thus, it becomes GeoGebra AR.

Another study that focused on GeoGebra [12] integrated ICT into mathematics learning that allowed teachers to modify mathematical concepts and constructive ways of teaching. The results showed that the experience of using GeoGebra tended to change geometry learning approach to be visual and to emphasize on the importance of mathematical representations in learning. However, the study applied a classic GeoGebra, not GeoGebra AR. GeoGebra AR is a combination of visual and computer media, and can be further developed with other forms of media into a better learning media. Therefore, the researchers assumed that there have been no previous studies on developing and using a GeoGebra AR-based teaching instrument to improve students' spatial abilities in mathematics.

The researchers view this issue as a potential to integrate teaching media to be an innovative learning tool by introducing the media applet. Developing a teaching instrument should consider the characteristics of teachers and students in the learning process. This process should go through the stages of the needs analysis, which is the basis of a developmental study for learning [13]. The empirical analysis presents in this paper illustrates how the characteristics of teachers, students and GeoGebra AR media can facilitate the design and the implementation of geometry teaching instruments in junior high schools constructively and attractively to improve students' spatial abilities.
Based on the description above, the research questions in this study is to what extent is the need for GeoGebra AR-based teaching instruments in junior high schools to improve students' spatial abilities?

2. Methodology

To achieve the objectives of the study, research was carried out using the research model of the development of Plomp [14] with the stages as in figure 1.

![Figure 1. Stages of research.](image)

As explained earlier, this paper reports the results of the preliminary stage of this present study. At the preliminary stage, aims to find information including problems, potentials and facilities that can be developed in this study. The information was obtained by employing research instruments that consisted of curriculum analysis, concept analysis, student characteristics analysis, literature and sources analysis, and media analysis.

This research was conducted in junior high school. The schools involved in this study were selected based on the category of the national exam scores: above average, average and below average. The participants at this preliminary stage involved mathematics teachers and eighth-grade students, randomly selected from public junior high schools in Banda Aceh. They were three vice-principals of curriculum, three mathematics teachers and six students. Three vice-principals of curriculum can give information about the achievement of curriculum standards in mathematics learning in each school. Three mathematics teachers can provide information about the achievement of implementation of standards mathematics learning in each school. Two students from each school can give their views on the mathematics learning experienced from the media that has been used.

To collect the data, this study employed several instruments: (1) Closed and open-ended questionnaires were administered to teachers and students in an attempt to learn the characteristics of students and teaching media used by teachers and students in mathematics learning. The questionnaires were self-administered by teachers and students; (2) In-depth interviews with mathematics teachers and students. In-depth interviews were conducted after distributing the questionnaires. The researchers used the participants’ responses to the questionnaires to delve more information from them during the interview session. The interviews were conducted to obtain data on the implementation of mathematics learning at schools; (3) Classroom observations were carried out to find data on the types of teaching media used by teachers and students in mathematics learning, and to observe student learning activities; and (4) Data documentation was gathered to get curriculum documents, syllabus, and lesson plans designed by junior high school mathematics teachers, as well as students’ responses to the GeoGebra AR demonstration. The instruments used had been validated by the experts in mathematics learning and technology, and the experts in learning design.

The information that had been collected was then analyzed and the descriptive analysis results were taken into consideration in developing teaching instruments. Closed and open-ended questionnaires were explained in an inductive descriptive with taxonomy analysis. Analysis of the interview data is carried out with the data classification stage, data tabulation, calculation of the percentage of
respondents' answers and interpretation of the percentage. Then it will be explained in narrative description. Classroom observation and data documentation explained in narrative description.

3. Results and discussion

The document analysis on Regulation of the Indonesian MoEC Number 22 of 2016 [15] shows that the current curriculum standards in Indonesia are Curriculum 2013 with constructivism learning principles. The Curriculum 2013 applies a scientific approach, discovery/inquiry learning (DL), and project-based learning (PjBL). Based on the information from the vice principals of curriculum in the three schools, each of these schools enacted the Curriculum 2013. The teaching instruments used by the teachers had been supervised by the curriculum coordinator and satisfied the standards of the Regulation of the Indonesian MoEC. The main mathematics topics taught in grade 8 includes number patterns, Cartesian coordinates, relations and functions, linear equations, systems of linear equations with two variables, Pythagorean theorem, circles, straight-sided three-dimensional objects, statistics and probability.

Straight-sided three-dimensional object as the main focus on geometry requires students to master several basic competencies. The first competency is that students should be able to generate the formula of the surface area and volume of straight-sided three-dimensional objects (i.e., cubes, cuboid, prisms, and pyramids). Second, students should be able to explain the relationship between space diagonal, face diagonal, and diagonal plane of straight-sided three-dimensional objects. Third, students should be able to solve problems related to the surface area and volume of straight-sided three-dimensional objects and their combination. Last, students should be able to solve problems related to straight-sided three-dimensional objects using the concepts of diagonal space, face diagonal, and diagonal plane. The essential concepts can be seen on the concept map in figure 2.

![Figure 2. Mind map of straight-sided three-dimensional object.](image)

The classroom observation results in the schools indicated that the topics were presented in order and under the demands of the curriculum content standards.

The teachers informed the age of students ranges from 13 to 15 year old. Students in this age range experience the developmental stages of concrete thinking levels into spatial mathematics. Students are required to be able to reason by using abstract concepts and are able to master verbal symbols and abstract ideas. By understanding the characteristics of the development of this group of students, teachers can design learning strategies that can help the students' progress optimally.

The analysis on the teacher and student questionnaires found that students faced difficulties in learning and understanding straight-sided three-dimensional objects. Based on the responses of two out of three teachers, this issue resulted from having difficulties to imagine the logic and processes that occurred. While another teacher believed that the difficulties happened since the students were unwilling to learn. The same result was obtained from student questionnaires that showed that five out of six students occasionally encountered difficulties due to the factors mentioned above. In addition to
those factors, limited variety of the three-dimensional shapes displayed by teachers made students difficult to imagine the similar but different shapes that were then found in the textbook or practice questions. Surprisingly, almost all students felt the topic was important to study, simply because it would be tested in the exam. Therefore, it is essential to provide teaching media that can display interesting various shapes.

Regarding teaching media used in the learning, two out of three teachers used teaching media and assumed students got interested. Later on, the researchers found information that the media used were projectors, which are technology-based teaching media. However, the teachers never asked students to use technology to solve problems given in the worksheet. On the other hand, another teacher used non-technology-based teaching media and was aware that the students were not interested. Student questionnaires reported that the six students were interested in the teaching media the teachers used. Yet, they needed more interesting novel mathematics teaching media. Furthermore, the students expected the new teaching media could present interesting straight-sided three-dimensional shapes that could facilitate students in understanding the topic. In regard to responses to the development of teaching media on geometry, all of the teachers agreed that teaching media innovation was crucial to improve the quality of teaching and to update teaching media for teacher use.

Moreover, teachers and students’ responses to the teaching media that lead to knowledge formation were then analyzed. The analysis illustrated that two of three teachers had already known about GeoGebra. The finding is in line with Mailizar and Fan’s Study [16]. Furthermore, about one of three teachers knew about AR and no teacher knew about the application of GeoGebra AR. The teachers used teaching media that were manually made using tools such as paper and scissors. Even by simply using the PowerPoint slides, the teachers assumed that they had integrated technology into their teaching. Whereas, the slides presented were not constructive at all. Based on the questionnaires, interviews and documentation, the findings indicated that the learning had not met the high standards of the learning process as stated in the Regulation of the Indonesian MoEC Number 22 of 2016 [15].

Teachers and students have computers, either in the form of laptops or androids. Three out of six students used them very often (more than 4 hours) to study or to search for learning materials for school. Other students used them for games, listening to songs, and watching. That information implies that students are familiar with computers. The researchers even highly appreciate those who use their computers to look for learning references about straight-sided three-dimensional objects. It gave the researchers greater opportunities to integrate technology into mathematics learning. The researchers demonstrated the draft of GeoGebra AR media applet design to the participants before they filled out the questionnaires related to the analysis of the potential of the design in learning. The draft is presented in figure 3.

![Figure 3(a)](image1.png) **Figure 3(a).** The projection of the rectangular cube design at GeoGebra AR as an illustration from the box.

![Figure 3(b)](image2.png) **Figure 3(b).** Display of exploration of rectangular cube nets at GeoGebra AR.
The results of the questionnaires and interviews as well as demonstrations of GeoGebra AR related to the development of teaching instruments brought out various responses from the teachers and students. One of them is that the teachers need teaching media and learning tools in teaching mathematics at junior high school level. Others stated that learning experiences to train students' mathematical process skills need to be designed and applied to students. They also suggested that DL using GeoGebra AR is a possible learning model implemented in the classroom. Last, they believed that teaching media encouraging students to learn and practice mathematical skills constructively need to be well designed. The design is tailored to the needs of students [6], teachers and students strongly agreed on the development of GeoGebra AR-based teaching media on geometry.

The results of this study align with the results of previous studies [12]. That is, integrating ICT into mathematics learning enables teachers to modify mathematical concepts and constructive ways of teaching. The findings also indicated that students were more enthusiastic about AR digital teaching media. These findings support the previous study [10] that brought positive impacts of the development of mathematics learning using AR. The questionnaire results showed that the use of geometric teaching media in the learning process did not encourage students to think. This assumption is also supported by the fact that most of the teaching media teachers used were designed for students with low cognitive level. It means that teachers’ skills to use teaching media in mathematics were still limited.

Based on the findings, the Curriculum 2013 as a current national curriculum in Indonesia requires constructive learning by integrating technology-based teaching media. Most studies suggest that AR has a positive impact on mathematics learning. The results of the needs analysis showed that junior high school mathematics teachers responded positively to the development of GeoGebra AR-based learning media. These responses arose because they believed that GeoGebra AR, as one of the teaching media and learning tools, benefits students in motivating themselves to learn independently [7]. Then, appropriate learning activities can be designed to help students carry out project-based learning so that they will develop better mathematical process skills and conceptual understanding.

4. Conclusion

Based on the results of this preliminary research, the researchers draw some conclusions as follows. First, the current curriculum implemented at schools is the Curriculum 2013 and it has been supervised by curriculum coordinators and met the curriculum content standards; mathematics concepts, specifically straight-sided three-dimensional objects, were adequate and in order. Second, the characteristics of the junior high school students allowed Discovery Learning, Project Based Learning and AR-based learning to be implemented in the mathematics classroom. Third, teaching media used by teachers were more passive and not constructive for students; the challenges faced by teachers were a limited understanding of the roles and types of mathematics teaching media and lack of ability to create interesting teaching media; and the teachers argued that it was necessary to develop GeoGebra AR-based teaching media on geometry. Teaching media to assist teachers and students in mathematics learning need to be designed and developed to improve students' conceptual understanding and mathematical process skills. It is also a need to provide teachers with training to prepare them with skills in using the teaching media.

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