Augmented Reality to Improve Self-Regulated Learning and Spatial Ability

**PS Pambudi1, W Setyaningrum2, H Retnawati3 and Marsigit4**

1Graduate Program of Mathematics Education, Yogyakarta State University, 1 Colombo Street, Yogyakarta, Indonesia

2Graduate Program of Mathematics Education, Yogyakarta State University, 1 Colombo Street, Yogyakarta, Indonesia

2Graduate Program of Mathematics Education, Yogyakarta State University, 1 Colombo Street, Yogyakarta, Indonesia

4Graduate Program of Mathematics Education, Yogyakarta State University, 1 Colombo Street, Yogyakarta, Indonesia

1puguhsri.2018@student.uny.ac.id

2wahyu\_setyaningrum@uny.ac.id

3heri\_retnawati@uny.ac.id

4marsigit@uny.ac.id

**Abstract**. Spatial ability and self-regulated learning are important aspects in human life. Besides, Augmented Reality (AR) nowadays becomes technology which steals the world's attention to be developed in many fields, including in education. This study aims to explain "can Augmented reality improve spatial abilities and self-regulated learning?". The method used is a literature review. Data was obtained from scientific journals and books that have been published in a place that is reputable. The results showed that AR can improve spatial ability and self-regulated learning of student. AR can improve spatial abilities based on a lot of scientific research and from the aspect of spatial abilities which basically can be improved by using AR. Meanwhile, AR is said to be able to improve SRL based on the SRL aspect which is in accordance with the advantages of AR technology which can be applied in the form of learning media based on Android smartphone software.

1. Introduction

Self-regulated learning (SRL) is one of the important topics in education including mathematics education [1]. With SRL students will master their own learning process [2]. Woolfolk [3] said that students with SRL have the characteristics of continuing to expand knowledge and maintain motivation, periodically monitoring their learning progress, adjusting or improving strategies based on the progress they have made, and evaluating possible obstacles then making the necessary adaptations. So that in primary and further education, SRL is very important. SRL involves the ability to manage experiences more effectively in a variety of cognitive, emotional, physiological and behavioral areas [4]. SRL is important for mathematics learning achievement because it is a factor that makes the learning process more effective, students who have high SRL tend to have high motivation and achievement. [5][6].

Besides self-regulated learning, it is also important for students to have spatial abilities in learning mathematics. Much evidence has shown that, spatial ability has a significant positive relationship with math ability [7]–[11]. Spatial abilities are not abilities that cannot be trained at all. Spatial abilities can be trained to improve student achievement [9], [12], [13].

On the other hand, technology is developing very rapidly in the world of education [14]. The technology that is being developed and discussed in mathematics learning, especially geometry, is Augmented Reality (AR) [15]. Augmented reality is a technology that inserts digital objects into the real world and then displays them using a specific screen. By adding digital objects to the real world, AR allows students to see the spatial relationship of 3-dimensional geometric objects with the real world that cannot be facilitated with just a textbook. [15]. At this time, AR technology has been developed in the form of Android applications [16]. By being developed into an android application, AR can be used by students studying outside of school.

1. Method

This article uses a literature review method of knowledge, ideas, or findings contained in the literature. So that it can provide theoretical and scientific information related to Can Augmented Reality improve Self-Regulated Learning and Spatial Ability. Data were collected and analyzed in the form of literature. And finally the data analysis technique is carried out in several steps.

The first step is to collect literature on augmented reality, self-regulated learning, and spatial abilities. The data were obtained through a search on Google Scholar using the keyword augmented reality self-regulated learning and obtained 63,100 articles. Then using the keyword augmented reality spatial and obtained 435,000 articles. The second step is to reduce the existing data because not all articles discuss the use of augmented reality in increasing self-regulated learning and spatial ability. The third step, the authors identified the use of augmented reality to improve self-regulated learning and spatial abilities. After looking at the relationship between augmented reality and its role in increasing self-regulated learning and spatial ability, the final step is the authors conclude that self-regulated learning and spatial ability can be improved by augmented reality.

1. Results and discussion

## Spatial ability

Spatial ability is an ability that students must master in mathematics [17]. Spatial abilities are related to geometry in mathematics [18]. According to Carroll [18] In general, spatial ability is related to the "individual" ability to understand, shape, and manipulate the visual plane, shape, and position of objects as they are perceived visually. Spatial ability refers to skills in representing, transforming, producing, and remembering, symbolic non-linguistic information [19]. McGee dalam Linn [19] divides spatial ability into two main factors: spatial visualization and spatial orientation. Spatial visualization is the ability to imagine, manipulate, rotate, rotate, or flip objects without referring to a person. Meanwhile, spatial orientation is considered as one's ability to imagine the appearance of objects from various points of view*.* According to Sera in Bosnyak [20], Spatial ability is the ability to solve problems using two- and three-dimensional shape perceptions and an understanding of information and perceived relationships*.*

Based on the theories about spatial abilities by the experts above, it can be concluded that spatial ability is a cognitive process that utilizes basic knowledge about the shape, position and transformation of two and three dimensional objects, is able to find the relationships of these objects and manipulate the visible information. to solve related problems. Maier in Bosnyak [20] distinguishing spatial abilities into 5 branches, namely: Spatial Perception, Spatial Visualization, Mental Rotation, Spatial Relations, and Spatial Orientation*.*

## Self-regulated learning

Self-regulated learning is a process by which students are metacognitive, motivated, and proactive to learn [21]. With self-regulated learning, students tend to be able to choose their own way of learning in order to achieve certain learning objectives.

According to Shih and colleagues [22] SRL system with scaffolding support can be used to develop students' independent learning ability. SRL involves self-initiated metacognitive, motivational, and behavioral aspects, such as goal setting, planning, learning strategies, self-strengthening, self-recording, and self-regulation in order to acquire knowledge and skills [2]. Meanwhile, according to Walid and Hartono [23], SRL is a self-regulation strategy that includes executive, cognitive, and evaluation strategy factors.

SRL is a self-regulation strategy that includes executive, cognitive, and evaluation strategy factors [24]. SRL is part of self-regulation, so in general the SRL process is the same as a self-regulation process.

* + 1. Self-regulated learning factors.

The factors that affect the students 'SRL need to be known by the teacher, so that teachers can design learning activities that can increase students' SRL so that mathematics learning achievement can also increase. Research that has been conducted by previous researchers has revealed the factors that influence a person's SRL. The factors that influence SRL include family, peers, school environment, and personal characteristics [25].

Conditioning schools or student learning methods can also be used to improve SRL, for example by using the blended learning approach conducted by Setyaningrum [1]. The use of multimedia learning in teaching mathematics has also been shown to increase SRL [26].

* + 1. Mathematics and Self-Regulated Learning

Mathematics is generally considered a difficult subject by students [27]. Students who find it difficult to accept mathematics learning tend not to be interested in learning material so they don't pay attention to the teacher. From a mental perspective, students who have low self-confidence tend to be passive during lessons and do not have the courage to ask questions during lessons. To overcome this problem, students who have good self-regulated learning will seek other learning outside of school in the form of the internet, multimedia, videos, and other learning media or it can be said that students can learn informally. According to Kurniawati [28], Students who are active and independent (have good self-regulated learning) can understand the lesson well so that students can solve math problems correctly.

## Augmented reality

Azuma in Koutromanos [16] states that Augmented reality (AR) is a technology that basically has three uses: a) Combining virtual and real objects; b) Allows for interaction in real time; and c) Accurately displaying virtual objects added to real-world objects. In simple terms, AR is a technology that combines two-dimensional or three-dimensional virtual objects into a real environment and then projects these virtual objects directly / real time. In other words, Augmented reality is a technology for adding virtual objects to the real world, where virtual objects appear triggered by certain triggers in the form of markers (bar code, QR code, image), and without markers (GPS coordinates, flat object), face tracking, motion tracking and others) [29].

In AR technology, there are 3 main elements, namely a combination / combination of the real and virtual worlds, interactions that run in real-time, and objects in the form of 3D or three-dimensional models [30]. Three-dimensional modeling (3D) is a three-dimensional representation process of a three-dimensional object using certain software. The product of this representation is called a 3D model. The 3D model is then displayed in a two-dimensional image on a certain layer through a process called 3D rendering. The 3D model is represented by a collection of points in 3D, connected by being basic geometric objects, such as triangles, lines, curved surfaces, and others [31].

Some of the components needed in making and developing augmented reality applications consist of software and hardware. In general, the hardware used in implementing augmented reality technology is the camera, display and processor. The camera is used to take real-world pictures / videos including makers or other triggers to make out objects in augmented reality. And then the image will be processed by the processor. The processor is in charge of adding and rendering virtual objects into real-world video that has been captured by the camera. The results from the previous stage are then displayed on the display. The display can be a smartphone screen or a laptop screen [32].

In simple terms, the way Augmented Reality technology works to add virtual objects to the real world is started by detecting markers contained in the image or video captured by the camera. In this marker, the coordinates will be used to adjust the position of the virtual object. The position of the virtual object will be perpendicular to the marker.

## Discussion

*3.4.1 Augmented Reality Improves Spatial Ability*

Augmented reality can improve students' spatial abilities, this is shown from the results of several studies. In research by Contero[33], concluded that developing Augmented reality-based learning media can improve students' spatial abilities. Quintero [34] in his research states that spatial abilities can be enriched by the development of new technologies such as Augmented Reality. Liao [15] in his research also states that AR can improve spatial abilities, geometry learning achievement, and learning attitudes.

Kaufmann [35] also conducted research which states that the spatial abilities of male and female students can be improved using augmented reality. Further research by Thornton [37] stated that AR can be used in an effort to increase students 'enthusiasm for learning in class and also to improve students' spatial abilities. The results of this study were also supported by Tsai [38] which states that students' spatial abilities, practical skills, and conceptual understanding can be supported by AR media.

Martín-Gutiérrez [39] dan Gün [40] in his research also stated that the use of AR can significantly improve the spatial skills of the experimental group in the study when compared to the control group.

Based on some of the research results previously mentioned, it can be said that Augmented Reality can increase spatial abilities. Judging from the aspects of spatial abilities, namely Spatial Perception, Spatial Visualization, Mental Rotation, Spatial Relations, and Spatial Orientation, all can be facilitated and developed in AR-based learning [41].

*3.4.1 Augmented Reality Improved Self-Regulated Learning*

Self-regulated learning is needed by students. Students who have good self-regulated learning will always be able to learn better when compared to students who have poor self-regulated learning. From several studies, self-regulated learning can be improved by using multimedia that can be carried and used outside the classroom [42]. By using technology in learning, students can determine for themselves when and where they will learn. In line with the results of previous research, Aadzar [26] also revealed that the use of multimedia learning can strengthen students' independent learning experiences.

Refer to multimedia more specifically, in Sujatmiko's research [43] Android media is appropriate if it is chosen as a medium for enhancing self-regulated learning. The study obtained positive results, namely that android media can be used to improve self-regulated learning. In line with previous research, Supriyadi [44] develop Android-based learning media to improve SRL*.* Hendikawati[45] also said that SRL can be improved by using Android-based learning media, because the media is mobile and can be used wherever students feel comfortable learning.

In the development of Augmented Reality technology for learning, learning media that apply AR technology are more in the form of mobile applications (Andoid). In research and development by Mustaqim [46] AR technology is embedded in Android to create learning media for engineering education students. Besides that, Rochmah [47] also develops learning media for elementary students in the form of an AR-based android application. In line with de Ravé's previous research [48] and Cerqueira [49] also developing learning media in the form of an AR-based Android application to teach mathematical geometry to students. Apart from geometry, Herrera [50] also developed an AR-based Android application for calculus. Lubis [51] and Stefan [52] also developed an AR-based Android application in the form of a picture book that is displayed in three dimensions. The form of Android was chosen in development because of the facts in the field that many students and teachers have used Android, besides that the use of Android requires less funds compared to developing AR technology in the form of PC software.

By looking at the fact that SRL can be improved with Android-based learning media and Augmented Reality technology can be developed into an Android application, we can conclude that Augmented reality-based learning media has a great opportunity to increase Self-regulated Learning, which is when it is developed into Android-shaped media.

1. Conclusion

Spatial abilities and Self-Regulated learning are abilities that students really need to face the industrial revolution 4.0. Spatial ability and self-regulated learning, of course, are not only acquired genetically but can be obtained from long studies. Augmented Reality technology is an answer as a way to increase spatial ability and self-regulated learning. This is proven by the number of studies that use augmented reality to improve spatial abilities. AR technology can also be used to improve self-regulated learning by developing it in the form of Android software.

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