Can augmented reality improve problem-solving and spatial skill?

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Abstract. Spatial and problem-solving skill are two essential skills that are needed by students to deal with the industrial revolution 4.0. Spatial and problem-solving skills certainly are not genetically obtained but are the result of a long learning process. Augmented reality technology is one of the solutions to improve problem-solving and spatial skills. The purpose of this study is to explain why AR can improve problem-solving and spatial skills based on the study of theory and results from previous research. The method used is a literature review. Data was obtained from scientific journals and books that have been published in reputable publishers. The results show that augmented reality can improve problem-solving and spatial skill because there are interrelated relationships between these two skills and augmented reality which is a technology that combines the real world and cyberspace that has been tested in several studies which can improve both of these skills.

1. Introduction
Technology has a very significant impact and influence on human life. Current technological developments change our habits as humans to do many things ranging from social interaction to find the latest information. The education which is the foundation to educate the nation's generation is demanded to follow the development of science and technology especially with the 4.0 industrial revolution which has now begun to spread in every country. Along with the rapid development of the technology, there have been many educators and prospective educators who use technology as teaching material. According to Setyaningrum [1] the use of technology in the classroom can improve students' interest and involvement with the material that they are learning. One of the technology used as a teaching material is augmented reality. Augmented reality itself is a technology that combines two-dimensional virtual objects into a real three-dimensional environment and then projects virtual objects into the real world [2].

According to NCTM [3] one of the skills that students must achieve in learning mathematics is problem-solving and mathematical representation. The importance of problem-solving skills by students in mathematics is also emphasized by Krulik & Robert E. Reys [4], mathematics does not only exist in the classroom but also in daily life, giving challenges to students to think and find their own ideas. This is reinforced by Adams & Hamm [5] people who have the skill to solve problems will
be able to ask questions that are meaningful to solve the problem. This results make students becoming motivated to be creative and innovative when facing problems.

The skill of mathematical representation is very closely related to spatial skill. Sarama & Clements [6] explains that "spatial skill is an essential human skill that contributes to mathematical skills". so both problem-solving and spatial skill are important skills for students to learn. The focus in this study is to explain why AR can improve spatial and problem-solving skill based on theoretical studies and research results from previous researchers.

2. Method
This research was used a literature review method regarding knowledge, ideas, or findings contained in the literature. It can provide theoretical and scientific information relating to why augmented reality can increase the skills of problem-solving and spatial. Data is collected and analyzed in the form of literature. The data analysis technique is carried out in several steps.

The first step is collected literature on AR, problem-solving skills, and spatial skills. Data is obtained through a search on Google Scholar using “AR problem-solving” keywords which is obtained 268000 articles. Then using “spatial AR” keyword which is obtained 209000 articles. The second step is to reduce existing data because not all articles discuss in depth about the using of AR in improving problem-solving and spatial skills only 40 articles that are used. The third step, the authors identify the use of AR in improving problem-solving and spatial skills. After seeing the relationship between AR and its role in improving problem-solving and spatial skills. Finally, the final step is the authors conclude that problem-solving and spatial skill can be enhanced by augmented reality.

3. Result and discussion
3.1. Augmented Reality
Augmented Reality (AR) is an application of computer technology that combines 3D graphic data with the real world or in other words reality is added to a media. This media can be in the form of paper, a marker or a marker through certain input devices [7]. In AR technology there are three characteristics that become the basis of which are a combination of the real and virtual world, interactions that run in real time and the shape of objects in the form of 3-dimensional or 3D models [8]. Three Dimensional Modeling (3D) –3D modeling or also known as meshing– is the process of making a mathematical representation of a three-dimensional surface of an object with certain software. Product of the modeling results are called 3D models. The 3D model can be displayed as a two-dimensional image through a process called 3D rendering. 3D models are represented from a collection of points in 3D, connected by various kinds of geometric entities, such as triangles, lines, curved surfaces, etc[9].

AR has several advantages which is, AR can show the parts of a plane or build space in a vertical or horizontal position, AR can show the changes in the shape or position of an object, AR can show the changes in the shape of a flat or built space based on the direction of rotation, AR can show the form of a space or relationship between parts of a building, AR can show determine the shape of a building. Some of the components needed in making and developing augmented reality applications consist of software and hardware. The minimum hardware needed to implement this augmented reality technology is a camera, display, and processor. The camera is tasked to capture the real world which will then be processed by the processor. The processor is tasked to add virtual objects into real world video that has been captured by the camera. Results from the previous stage are then displayed via the display. Display can be a smartphone screen or a laptop screen. In general, the algorithm for adding virtual objects to augmented reality technology begins with the detection of interest points on the image captured by the camera, which is commonly called a marker. From these interest points, the coordinates will be used to adjust the position and rotation when adding virtual objects. The position of the virtual object will lie perpendicular to the marker. The virtual object will stand in line with the Z axis and perpendicular to the X axis (right or left) and Y axis (front or back) of the virtual marker coordinates. This process is shown in Figure 1.
3.2. Problem-solving skill

The skill to solve problems is the skill to think at a high level to find various ways of solving problems in a problem and find one that is appropriate so as to achieve the goals to be achieved [10]. A person who has the skill to solve problems will be able to identify problems, what are the difficulties in solving problems, and what is the possible solutions[10]. In addition, Mourtos, Okamoto, & Rhee, [11] stated that the skill of problem-solving is a process to get the best answer or subject to decisions on several obstacles. Krulik & Robert E. Reys, [4] states that the skill to solve problems is the process of someone using experience, skills and knowledge to respond in unexpected situations. Then, Adam and Hamm [5] state that the skill to solve problems as a mathematical application, which is to calculate, define, implement, and pay attention to the area of the solution. Students who have good problem-solving skills will be able to understand problems, represent problems, choose appropriate strategies for problem-solving, implement strategies, and evaluate solutions Bruning, Schraw, & Norby, [12]. In addition, mathematics and natural science learning achievement is strongly influenced by this skill [13].

Based on some of the above opinions, the problem-solving skill can be defined as the skill to use the knowledge that has been obtained in one or more higher-levels thought processes to be applied in understanding, choosing an appropriate strategy, evaluating the solution of the problem obtained. The problem given is a non-routine problems. Bransford and Stein [10] differentiate problem-solving skills in five stages, namely 1 (problem identification), D (defining the problem), E (explore looking for various possible strategies), A (act / doing strategy), L (look back / look back and evaluate activities). De Bono [12] states that there are five skills that become aspects of problem-solving skills, namely planning, bringing up alternatives, analyzing, comparing, choosing, and evaluating. Meanwhile, polya [14] states that the skill to solve problems has four aspects, namely understanding the problem, making plans to do the plan, and checking back each previous stage.

3.3. Spatial skill

Spatial skill is defined by expert, such as Linn & Petersen [15] explaining that "spatial skill refers to skills in representing, transforming, generating, and recalling symbolic, non-linguistic information". In line with previous opinions Van de Walle, Karen, & Bay-Williams [16] states that "spatial sense can be defined as an intuition about shapes and relationships between shapes". Mulligan [17] also states that "spatial reasoning for spatial skill, spatial intelligence, or spatially refers to the skill to recognize..."
and manipulate the spatial properties of objects and the spatial relations between objects." In line with that, Sera & colleagues Bosnyak & Kondor [18] stated that, "spatial skill is the skill of solving spatial problems by using the perception of two and three dimensional shapes and the understanding of the perceived information and relations".

The opinion of Sera and colleagues can be interpreted that spatial skill is related to three-dimensional and two-dimensional objects. So the students who have understood the shape of objects and can take advantage of information and relationships between objects when he views these objects, the spatial problems being faced can be solved easily. In addition, Clements & Battista [19] states that "spatial reasoning, on the other hand, consists of the set of cognitive processes by mental representations for spatial objects, relationships, and transformations are constructed and manipulated". Furthermore May & Smith [20] define "spatial skills - a collective term for a wide range of acquired skills, all of which use basic memory for shape and position". Gardner [21] add one more spatial skill called spatial intelligence that refers to “the skill of forming a mental model of the spatial world and working with this model".

Based on the spatial theories put forward by these experts, it can be concluded that spatial reasoning is a series of cognitive processes that utilize basic knowledge of the shapes, positions and transformations of three-dimensional and two-dimensional objects, able to find the relationships of these objects and manipulate visible information to solve related issues. Summarizing from Maier, [22] spatial reasoning skills include five elements: 1) spatial perception is the skill of students to know the parts of a plane or build space in a vertical or horizontal position; 2) spatial visualization is the skill of students to know changes in the shape or position of an object: 3) mental rotation is the skill of students to know the changes in the shape of a flat or built space based on the direction of rotation; 4) spatial relationship is the skill of students to know the form of a space or relationship between parts of a building; 5) spatial orientation is the skill of students to think and determine the shape of a building.

3.4. Why AR can improve problem-solving and spatial skill

Augmented reality has a very strong relationship with student’s spatial and problem-solving skills, this is based on the results of the previous research which tried to use augmented reality to improve students' spatial and problem-solving skills. Research that discusses AR and spatial skill is conducted by Quintero, Salinas, González-Mendivil, & Ramírez [23], it found that “spatial skill is not a static trait but instead of a dynamic process which can be fostered through interaction of real and virtual objects. This skill could be enriched with the development of new technologies such as AR”. Kaufmann, Steinbügl, Dünser, & Glück [24] is conducted research focusing on students aged 17-19 years found that to improve students' spatial skills can be done by using AR both male and female students. This opinion is also supported by Kaufmann & Meyer [25] in their research that focuses on using AR in learning to explain that “AR is best suited for simulating and solving inherent three-dimensional problems that are hard to do in real life”.

Thornton, Ernst, & Clark [26] explain that AR can bring classroom learning to life while increasing students' spatial skills. This statement is also supported by Tsai [27] who explains that “students' spatial skills, practical skills, and conceptual understanding are often afforded by image-based AR”. Do & Lee [28] said that “With multiple levels, the AR provides a tool to improve spatial skills for a wide range of ages. Through the AR, users can practice many spatial skills such as analyzing a 3D model's structure, figuring out what to do to make a primitive geometry become a component of a 3D model, assembling components to create a complex model”. It is also supported by Martín-Gutiérrez, Contero, & Alcañiz [29]. The research show that “the experimental group significantly improved its spatial skills after performing this training with AR”. This study was also supported by Gün & Atasoy [30] The results indicate that “a significant increase was observed in the spatial skill between the posttest spatial skill mean scores of the experimental and control groups”.

Martín-Gutiérrez, Contero, & Alcañiz, [29] said that "An AR-based application has been developed with a view to improve spatial skills among engineering students, thus enabling them to gain a better understanding of engineering graphics subjects". In line with the research Subagyō [31] also
conducted research on PGSD students in Madison. The results of the study showed that AR really helped students improve their spatial skills, and stimulated students to be more enthusiastic in participating in learning, this was also reinforced by research Coimbra, [32] which shows that the use of AR at Portuguese universities greatly assisted engineering students in understanding geometrical material spatially.

Based on the results of research above on how AR can improve spatial skill, it is certainly not too much to say that AR can improve spatial skill. According to Liao [33] “AR allows students to view the spatial relationships of real world objects that is impossible to implement in traditional textbooks. It also provides students a more intuitive way to manipulate virtual objects and when viewed from aspects of spatial skill ranging from spatial perception, spatial visualization, mental rotation, spatial relations, spatial orientation can all be facilitated by and developed in AR-based learning”.

Several other studies that discuss AR and problem-solving skills are carried out by Muwahiddah, Asikin, & Mariani [34] Their research focuses on the use of AR based on ethnomathematics to improve students' problem-solving skills. his research showed positive results namely the problem-solving skill of experimental class students better than the control class. Further research was Jaya & Mantasia, [35] which developed AR technology as a reinforcement and support of learning methods in junior high school in order to facilitate the skill to solve the problems demanded in the model curriculum learning models also demonstrate the effectiveness of the practicality and validity of the media that they develop. In line with previous research Hodhod, Fleenor, & Nabi, [36] tried to develop AR in the form of games to improve problem-solving skills and they explained that "AR is one technology that can provide fun, safe environments in which students can practice and develop problems. solving and computational thinking".

According to Wasko [37] states that "Student participants have reported an increased interest in the settings of the experiences and have expressed a positive attitude towards this innovative form of instructional delivery to collaborate with each other in order to solve an ill-defined problem". From the results of this study it can be explained that AR-based learning stimulates students to be more interested in solving non-routine problems. Eh Phon, Ali, & Halim [38] explained that AR can improve students' thinking skills such as problem-solving, communications, and thinking. The work of Eh Phon, Ali, & Halim [38] is in line with that of Ke & Hsu [39] who also used AR in their classrooms, AR can improve students' problem-solving and discussion skills. Muwahiddah (2018).

Fleck, Hachet, & Christian Bastien [40] in their study explained that 93.1% of the 126 students who took the research sample chose to use AR to solve problems that required problem-solving skills. Dunleavy et al [41] in their research using AR in class learning explained that AR has a unique skill to create a conducive learning environment, thus facilitating the development of process skills such as critical thinking, problem-solving and mathematical communication. The work of Eh Phon, Dunleavy et al [41] is in line with that of Karagözlu. Karagözlu [42] conducted a study of 147 seventh grade students. The results of the posttest in the experimental class showed an increase in students' problem-solving skill from the results of the previous pretest. when comparing the results of the posttest between the control class and the experimental class the experimental class using AR shows a better value than the control class.

Interestingly, there is an interrelated relationship between problem-solving and spatial skill. Where spatial skill can facilitate problem-solving skills to develop [4]. This is because spatial skill will stimulate students' skill to solve problems because aspects of problem-solving and spatial skill are interconnected. The relationship between AR, spatial, problem-solving and how AR can improve that skill can be seen in Figure 2.
Figure 2. The relationship between AR, spatial and problem-solving skill

4. Conclusion

Problem-solving and spatial skills are skills that are needed by students to deal with the industrial revolution 4.0. Augmented reality technology is an answer to improve problem-solving and spatial skills. Evidenced by the many researches that use AR to improve these skills. Based on expert opinion it was also found that the spatial and the problem-solving skills are interrelated when the spatial skill is enhanced through the use of AR, the problem-solving skill will also be facilitated and vice versa. Some suggestions in the development of augmented reality applications are, add material features that are more and more varied, both in terms of material and problems. In addition, other researchers are expected to develop similar learning media that will be operated on device with other operating systems and different materials.

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