Assessing the Potential of Augmented Reality in Education

Muhamad Ikhsan Sahal Guntur
Mathematics Education Study Program,
Graduate School Program, Universitas Negeri Yogyakarta, Indonesia
+6285273037488)
muhamadikhsan.2018@student.uny.ac.id

Wahyu Setyaningrum
Mathematics Education
Universitas Negeri Yogyakarta, Ind (Indonesia)
wahyu_setyaningrum@uny.ac.id

Heri Retnawati
Mathematics Education,
Universitas Negeri Yogyakarta, Indonesia
+628122774435
heri_retnawati@uny.ac.id

M. Marsigit
Mathematics Education,
Universitas Negeri Yogyakarta, Indonesia
+6281578708917
marsigit@uny.ac.id

ABSTRACT
Augmented Reality (AR) is a technology that combines three-dimensional virtual objects (3D) into a real three-dimensional environment. The 3-dimensional model is commonly used as a teaching material aid to make students better understand the knowledge provided. AR technology has been applied in various diverse fields, including in education. The purpose of this study is to look at the potential of AR in the world of Education using the scoping review method. Using this method, 10 articles were obtained from the results of a quasi-experiment study. The results showed that AR can improve spatial abilities, problem-solving and student motivation.

CCS Concepts
• **General and reference → Document types → General conference proceedings**

Keywords
Potential, Augmented Reality (AR), Scoping review.

1. INTRODUCTION
Today, information and communication technology has increasingly developed in the field of learning, for example, the use of Microsoft PowerPoint in the classroom has become commonplace in classroom teaching. But this technology only puts students as passive elements in the learning process. Therefore, we need more advanced technology to produce an interactive learning process. One technology that is able to present a three-dimensional display of two-dimensional objects is Augmented Reality (AR) technology. According to Chou "Augmented Reality (AR) is a variation of VR (Virtual Reality). VR is a technology that really immerses its users in an artificial environment, and users cannot see the real world around them. In contrast, AR allows users to see the real world, with virtual objects superimposed on real objects"[1]. AR basically presents a new reality (augmented) that overwrites reality that is witnessed through the sense of sight or heard through the senses of the listener. According to Azuma "AR combines two-dimensional or three-dimensional virtual objects into a real environment and then projects these virtual objects in real-time" [2].

AR technology has been developed in various fields such as military, medicine, education, engineering, industry to entertainment. This is caused by the superiority of AR technology that allows users to interact using their natural body movements. The camera as the 'eye' of AR technology takes pictures of these markers on an ongoing basis, processes and then produces virtual interactions that appear on the real-world display both on the layer and head-mounted display (HMD). The combination of virtual and real-world is expected to bring a more effective and efficient learning process. Hannes Kaufman [3] from the Vienna Institute of Technology Austria's Institute of Software Technology and Interactive Systems supports this in his paper entitled "Collaborative Augmented reality in Education". In the paper, Hannes revealed that because of the progress in the development of pedagogical concepts, applications and technology, and the reduction in the cost of purchasing hardware, the use of augmented reality technology in the world of education has become very possible in this decade (assuming sustainable development at the same level). However, the potential of this technology requires careful attention in order to truly be utilized to improve educational success [3].

The purpose of this study is to see the potential of AR in the world of education by analyzing the results of research on AR using the quasi-experiment or mix method.

2. RESEARCH METHOD
This is a scoping review study in which Arksey and O'Malley's [4] five-stage framework is utilized. The five stages of Arksey and O'Malley's framework "first identifying research questions, second identifying relevant studies, third study selection, fourth charting the data, fifth summarizing and reporting the results were utilized in this review of the use of AR in education".

IC4E 2020, January 10–12, 2020, Osaka, Japan

ACM ISBN 978-1-4503-7294-7/20/01…$15.00
DOI: https://doi.org/10.1145/3377571.3377621

Data was obtained through a search on Google Scholar using the keyword augmented reality The reason for choosing 'augmented reality' as a search keyword without applying other filtering options is to reach a very diverse study. From the search results using Google Scholar found 13 million articles which were then reduced to 10 articles. Criteria for selecting data as follows.

Table 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Time period	The last 10 years (2009-2019)	Studies outside these dates or time period
Study focus	Education	Research other than the realm of Education is not used
Research method	Quasi-experiment, Mixmetode	Qualitative, RnD, Development, Survei
Sample	Student	The general public who have completed education

3. RESULTS AND DISCUSSIONS

Summaries are developed for each article with respect to numerous dimensions, such as the author, year, subject, method, instrument, country, dependent variable, results, and suggestions. A detailed summary of those variables that are concluded from the included studies are illustrated in table 2 and table 3

Table 2. Studies Included into scoping review

Researcher	Manuel Contero et al	Tosti H. C. Chiang et-al	Cheng-ping Chen and Chang-Hwa Wang	Jorge Martín-Gutiérreza, Manuel Conterob, Mariano Alcañizb	Chien-Hsu Chen, Yin-Yu Chou, Chun-Yen Huang
Year	2012	2014	2015	2015	2016
Title	" Development of an Augmented Reality Based Remedial Course to Improve the Spatial Ability of Engineering Students". [5]	"An Augmented Reality-based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities." [6]	"Employing Augmented-Reality Embedded Instruction to Disperse the Imparities of Individual Differences in Earth Science Learning." [7]	"Augmented reality to training spatial skills."[8]	"An Augmented-Reality-Based Concept Map to Support Mobile Learning for Science."[9]
Subjek	42 Engineering Students	57 fourth graders	144 eighth-grade student junior high school	49 Engineering Students	71 fifth-grade
Country	Spain	Taiwan	New Taipei	Spain	Taiwan
Method	Experiment	Experiment	Mixed-Method	Experiment	Mix Method
Instrument	Tests	Tests	Pre-tests dan post-test and interview.	Tests and questionnaire	Tests and interview
Dependent variable	Spatial ability	Motivation, Learning achievement	Learning achievement	Spatial abilities	Learning motivation, learning attitude
Result	"Augmented reality-based training for the development of spatial skills is a feasible approach that provides good results and offers an attractive stimulus to students to enroll in elective activities" [5]	"The students who learned with the augmented reality-based mobile learning approach showed significantly higher motivations in the attention, confidence, and relevance dimensions than those who learned with the conventional" [6]	"The results of data analyses showed that overall learning achievement was significant and most students were in favor of learning with AR" [7]	"a covariance analysis (ANCOVA) shows that the experimental group significantly improved its spatial skills after performing this training compared to the control group that had not undergone any spatial skills training."[8]	" Students were able to engage in learning activities that efficaciously increased their motivation to learn and improved their attitude about learning."[9]
Suggestions	". The wide adoption of augmented reality requires authoring environments oriented to provide support to the teacher with a creative and active attitude towards the new technologies. However, current authoring tools are programmer oriented and require a big effort to create didactic contents." [5]	"Try to apply this approach to other mobile learning applications, including the natural science courses and local culture courses of elementary and high schools" [6]	"for future studies, we suggest that larger sample sizes and extensive subject matters need to be concerned. " [7]	"Augmented reality is a cost-effective technology for providing students with attractive contents with respect to paper books, giving new life to classic pen and paper exercises."[8]	-

Table 3. Studies Included into scoping review

Researcher	Ezgi Tosik Gün, Bilal Atasoy	Damla Karagozlu	Hafizul Fahri Hanafi et al	Ángela Di Serio et al	Anne Estapa and Larysa Nadolny
Year	2017	2018	2017	2013	2015
Title	"The Effects of Augmented Reality on Elementary School Students Spatial Ability and Academic Achievement." [10]	"Determination of the impact of augmented reality application on the success and problem-solving skills of students" [11]	"Improving Students' Motivation in Learning ICT Course With the Use of A Mobile Augmented Reality Learning Environment." [12]	"Impact of an augmented reality system on students' motivation for a visual art course." [13]	"The Effect of an Augmented Reality Enhanced Mathematics Lesson on Student Achievement and Motivation." [14]
Subjek	88 sixth grade students	147 seventh grade students	120 non-technical undergraduates	96 middle-school students	61 students
Country	Turkey	Turkey	Malaysia	Venezuela	USA
Method	Mix Method	Quasi-experimental	Quasi-experimental	Mix Method	Quasi-experimental
Instrument	tests and interview	Pre- test/post-test	Pre- test/post-test	IMMS questionnaire and test	IMMS Survey, pre-test, post-test, and achievement tests
Dependent variable	Spatial ability and academic achievement	Problem-solving skills	Motivation	Motivation	Student achievement, student motivation
Result	"The results indicate that though a significant increase was observed in the spatial ability groups, In addition to the spatial ability results, the students' academic achievement scores in the experimental group significantly increased, but the small increase in the control group students' scores was not significant." [10]	"It is concluded that AR application increased student achievement, Problem-solving skill and also ensured that the self-control level of students is increased" [11]	"This finding showed male students were more motivated than their opposite counterparts. In contrast, no such main effect attributed to the learning method was observed, as evidenced from the mean scores of 4.08 and 4.07 of the experimental group and control group respectively for the measured construct, suggesting both methods were both equally effective." [12]	"The quantitative results of this research study showed that the use of augmented reality technology in learning environments had a positive effect on the motivation of middle-school students. These results were supported by a qualitative study where students claimed that an AR learning environment was more appealing and easy to understand than the slide-based course." [13]	" Findings support claims that technology use within a mathematics lesson increases student achievement, and augmented reality enhances student motivation to learn mathematics" [14]
Suggestions	"The teacher yielded valuable information that may assist researchers who attempt to integrate augmented reality in education." [10]	-	"Arguably, such a mobile learning tool can be used to help non-technical undergraduates learn with greater motivation, but its success will rely on proper planning and implementation by considering students' demographic background." [12]	"The usability study showed that although this technology is not mature enough to be used massively in education, the enthusiasm of middle-school students diminished most of the barriers found. " [13]	"The need for continued exploration to determine the impact of technology use not only on overall mathematical achievement but also on the specific type of mathematical activity, technical or conceptual." [14]

AR is a technology that began to be used and developed in education [15]. This can be seen from the many studies that use this technology to improve the cognitive and affective aspects of students[15].

Based on research by Tosti H. C. Chiang et-al explains that AR can improve student motivation. Subjects tested were 57 4th grade elementary school students in Taiwan and used experimental research [6]. This is also supported by Chien-Hsu Chen, Yin-Yu Chou, Chun-Yen Huang who examined 71 5th grade students in different countries resulting in a significant improvement in student motivation [9]. Experimental-based research conducted by Hafizul Fahri Hanafi of 120 non-technical undergraduates in Malaysia also concluded that AR can improve student motivation[12]. The improvement of problem-solving skills in learning is caused by the interesting use of AR in learning. according to Hamzah B Uno suggested that the factors that influence extrinsic motivation include the appreciation of learning, the existence of interesting activities in learning, and the existence of a conducive learning environment[16]. So if you see one of the factors that affect students' extrinsic motivation is the existence of interesting activities, AR is able to do that [11].

Based on research conducted by Manuel Contero in 2012 who tried to develop AR to improve spatial abilities 42 Engineering Students showed a significant increase in experimental class in the spatial abilities and student learning outcomes [5]. This is also supported by further research conducted by Jorge Martín-Gutiérreza, Manuel Conterob, Mariano Alcañizb in 2015 who tried to use AR to improve spatial abilities 49 Engineering Students showed a significant improvement in spatial abilities in the experimental class [8]. Another study conducted by Ezgi Tosik Gün, Bilal Atasoy at a different level from the subjects of 88 sixth grade students also showed an increase in spatial abilities and student learning outcomes [10].

Based on the results of how AR can improve spatial skill, it is certainly not too much to say that AR can improve spatial skill. According to Liao "AR allows students to view the spatial relationships of real-world objects that are 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" [17].

Research conducted by Karagozlu who tried to see the use of AR in improving the ability of problem-solving 147 seventh grade students. The results of the posttest in the experimental class showed an improvement in students' problem-solving skills from the results of the previous pretest. when comparing the results of the posttest between the control class and the experimental class using AR shows a better value than the control class [11]. This is also supported by Matt Dunleavy's research which concluded that AR can improve problem-solving abilities. He believed that AR has a unique ability to improve problem-solving skills [18]. Why this can occur because of the aspects of problem-solving proposed by Polya namely understanding the problem, making plans to do the plan, and checking back each previous stage can be facilitated using AR[19].

Research conducted by Cheng-ping Chen and Chang-Hwa Wang on 144 eighth-grade junior high school students in New Taipei shows a significant increase in learning achievement [7] as well as research conducted by Anne Estapa and Larysa Nadolny to 96 middle- school students in Venezuela also showed an increase in Learning achievement using AR in their learning activities [14].

Research conducted by Ezgi Tosik Gün, Bilal Atasoy in 2017 showed an increase in not only Spatial ability but also academic achievement [10]. In addition, research conducted by Tosti also concluded that AR not only increases motivation but also increases learning achievement [6]. This can occur because of the increase in students' affective and cognitive aspects such as motivation, problem-solving abilities and spatial abilities of students will also improve student learning outcomes [20].

The use of AR applications has a lot of mathematical abilities that can be facilitated improvement such as critical thinking, High order thinking skills, Problem-Solving and communication [18]. But in reality, students are still having trouble to solve problems that require these abilities [21]. AR is a solution in this case especially for applying mathematics learning in other subjects such as physics [22]. Things that need to be considered in the use of AR in the classroom is the preparation of a good learning trajectory so that it will help to learn in the classroom [23].

Based on the above research it can also be concluded that the use of AR has grown in several countries such as Spain, Taiwan, New Taipei, Turkey, Malaysia, Venezuela, USA [5] [6] [7] [10] [12] [13] [14].

4. CONCLUSION

The research results selected in this article aim to look at the effects of using AR in the classroom. Education level subjects studied ranging from elementary school to college. The research methods used are a quasi-experiment, experiment, and mixed methods. The instrument used in this study used a survey, IMMS questionnaire, open statements. pre-test and post-test interviews. All studies report improvements in spatial abilities, problem-solving abilities, and student motivation.

Based on the results of the study above, research aimed at looking at student learning outcomes as measured by pre-test and post-test scores reported improvement compared to the control group, where the AR application was not used. The questions in the open interview revealed the students' perspectives regarding the use of the AR application in classroom learning, the results of the interview showed the students were more motivated and enthusiastic in participating in-class learning.

Most of the research results in this study reveal the fact that, although the use of AR technology in-class learning has the potential to improve learning outcomes of spatial abilities, student motivation, problem-solving abilities, and student achievement there are still many other potentials that can be searched to developed. Like the use of AR in other learning materials and methods.

What needs to be done in future research is the development of numerous and varied AR so the teachers can have many choices when teaching in class. Finally, there is a need for research aimed to develop and use AR in developing countries, including Indonesia.

5. ACKNOWLEDGMENTS

The researcher's thanks LPDP as a related party for research funding. Thank you to Yogyakarta State University.

6. REFERENCES

[1] T. Chou and L. Chanlin, "Augmented reality smartphone environment orientation application : a case study of the Fu-Jen University mobile campus touring system," in *Procedia - Social and Behavioral Sciences*, 2012, vol. 46, pp. 410–416.

[2] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier, and B. MacIntyre, "Recent advances in augmented reality," *IEEE Comput. Graph. Appl.*, 2001.

[3] H. Kaufmann, "Construct3D: an augmented reality application for mathematics and geometry education," in *MULTIMEDIA '02 Proceedings of the tenth ACM international conference on Multimedia*, 2002, pp. 656–657.

[4] L. Arksey, H., & O'Malley, "Scoping studies: towards a methodological framework," *Int. J. Soc. Res. Methodol.*, vol. 8, no. 1, pp. 19–32, 2005.

[5] M. Contero, J. M. Gomis, F. Naya, F. Albert, and J. Martin-Gutierrez, "Development of an augmented reality based remedial course to improve the spatial ability of engineering students," *Proc. - Front. Educ. Conf. FIE*, 2012.

[6] T. H. C. Chiang, S. J. H. Yang, and G. J. Hwang, "Students' online interactive patterns in augmented reality-based inquiry activities," *Comput. Educ.*, vol. 78, pp. 97–108, 2014.

[7] C. ping Chen and C. H. Wang, "Employing augmented-reality-embedded instruction to disperse the imparities of individual differences in earth science learning," *J. Sci. Educ. Technol.*, vol. 24, no. 6, pp. 835–847, 2015.

[8] J. Martín-Gutiérrez, M. Contero, and M. Alcañiz, "Augmented Reality to Training Spatial Skills," *Procedia Comput. Sci.*, vol. 77, pp. 33–39, 2015.

[9] C. H. Chen, Y. Y. Chou, and C. Y. Huang, "An Augmented-Reality-Based Concept Map to Support Mobile Learning for Science," *Asia-Pacific Educ. Res.*, vol. 25, no. 4, pp. 567–578, 2016.

[10] E. T. Gün and B. Atasoy, "The effects of augmented reality on elementary school students' spatial ability and academic

achievement," *Egit. ve Bilim*, vol. 42, no. 191, pp. 31–51, 2017.

[11] D. Karagozlu, "Determination of the impact of augmented reality application on the success and problem-solving skills of students," *Qual. Quant.*, vol. 52, no. 5, pp. 2393–2402, 2018.

[12] H. F. Hanafi, C. S. Said, M. H. Wahab, and K. Samsuddin, "Improving Students' Motivation in Learning ICT Course with the Use of A Mobile Augmented Reality Learning Environment," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 226, no. 1, 2017.

[13] Á. Di Serio, M. B. Ibáñez, and C. D. Kloos, "Impact of an augmented reality system on students' motivation for a visual art course," *Comput. Educ.*, vol. 68, pp. 586–596, 2013.

[14] A. Estapa and L. Nadolny, "The Effect of an Augmented Reality Enhanced Mathematics Lesson on Student Achievement and Motivation," *J. STEM Educ.*, vol. 16, no. 3, pp. 40–49, 2015.

[15] D. Yu, J. S. Jin, S. Luo, and W. Lai, "A Useful Visualization Technique: A Literature Review for Augmented Reality and its Application, limitation & future direction," *Vis. Inf. Commun.*, no. March 1999, pp. 311–337, 2010.

[16] Hamzah B. Uno, *Motivation theory and its measurement*. Jakarta: Aksara, 2012.

[17] Y. T. Liao, C. H. Yu, and C. C. Wu, "Learning geometry with augmented reality to enhance spatial ability," *Proc. - 2015 Int. Conf. Learn. Teach. Comput. Eng. LaTiCE 2015*, pp. 221–222, 2015.

[18] M. Dunleavy, C. Dede, and R. Mitchell, "Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning," *J. Sci. Educ. Technol.*, vol. 18, no. 1, pp. 7–22, 2009.

[19] G. Polya, *How to Solve It:A new aspect of mathematical methods*. USA: Princeton University Press, 2004.

[20] L. W. Anderson *et al.*, *A taxonomy for learning*, teaching, *and assessing: A revision of Bloom's taxonomy of educational objectives*. Newyork: Longman, 2001.

[21] S. Hadi, H. Retnawati, S. Munadi, E. Apino, and N. F. Wulandari, "The Difficulties Of High School Students In Solving Higher-Order Thinking Skills Problems," *Probl. Educ. 21st Century*, vol. 76, no. 4, p. 520, 2018.

[22] Heri Retnawati, J. Arlinwibowo, N. F. Wulandari, and R. G. Pradani, "Teachers' Difficulties and Strategies in Physics Teaching and Learning That Applying Mathematics," *J. Balt. Sci. Educ.*, vol. 17, no. 1, pp. 120–135, 2018.

[23] H. Retnawati, "Learning trajectory of item response theory course using multiple softwares," *Olympiads in Informatics*, vol. 11, pp. 123–142, 2017.