PAPER • OPEN ACCESS

The use of augmented reality to improve mathematics conceptual understanding of pre-service elementary education teachers

To cite this article: N Hendracipta *et al* 2021 *J. Phys.: Conf. Ser.* **1796** 012018

View the article online for updates and enhancements.

The use of augmented reality to improve mathematics conceptual understanding of pre-service elementary education teachers

N Hendracipta[1], I Rafianti[2], H Pujiastuti[2*], R Haryadi[3]

[1]Primary School Teacher Education Department, Universitas Sultan Ageng Tirtayasa, Jl. Raya Jakarta KM. 04 Pakupatan, Serang 42111, Indonesia
[2]Mathematics Education Department, Universitas Sultan Ageng Tirtayasa, Jl. Raya Jakarta KM. 04 Pakupatan, Serang 42111, Indonesia
[3]Physics Education Department, Universitas Sultan Ageng Tirtayasa, Jl. Raya Jakarta KM. 04 Pakupatan, Serang 42111, Indonesia

[*]corresponding author: henipujiastuti@untirta.ac.id

Abstract. The purpose of this study was to determine the understanding of mathematics concepts of pre-service elementary education teachers at Universitas Sultan Ageng Tirtayasa (Sultan Ageng Tirtayasa University) through augmented reality learning media. The method used in this study was a quasi-experiment with the design of one group pre-test and post-test. The instrument used in this study was a test of understanding of mathematics concepts on geometry topic in the form of 10 description tests and tested on 20 pre-service teachers (higher education students). The average result of N-gain in pre-service elementary education teachers was 0.48 in the medium category. Based on the results obtained, the use of augmented reality can be used as a learning medium for mathematical concepts. In the learning process, students can easily understand the material taught. The suggestion in this research is that further development of augmented reality media is needed at all levels of education and it needs to be tested in a larger scale in order to know its effectiveness to be used in all levels of education.

Keyword: Augmented reality, learning media, understanding of mathematics concepts

1. Introduction

Mathematics learning is an activity to acquire knowledge built by students themselves and must be done in such a way as to provide opportunities for students to rediscover mathematical concepts [1]. Mathematics learning should start with contextual or realistic problems of life, be close to students' minds, and be relevant to society to have human values [2]. Thus, learning mathematics in accordance with the characteristics of mathematics itself, namely the existence of logical reasoning flow and has a consistent deductive mindset [3,4].

In general, the aim of learning mathematics is to help students prepare themselves to be able to deal with changing circumstances in life and in an ever-evolving world, through the practice of acting on the basis of logical, rational, and critical thinking and preparing students to be able to use mathematics and mathematical thinking in daily life and in learning various sciences [5,6].

Learning mathematics requires a serious study, the theory taught in mathematics is different from the theory taught in other subjects [7]. Learning mathematics is not needed to memorize definitions but
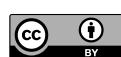
how to get understand the concepts or subjects taught [8]. Learning mathematics requires a lot of practice, for example, solving practice questions, we must be able to master new concepts to solve problems in questions [9]. There are other ways in learning mathematics for students can easily understand the concepts taught by teachers or educators and this is by using learning media to them[10].

Learning media is one of the important components contained in the learning process [11]. The use of instructional media should be part of the preparation of the teacher in learning activities [12,13]. The reason behind when it is less varied and does not use optimal learning media causes a lack of interest in learning among students [14,15]. Unfortunately, this is in contrary to the purpose of learning media because it should serve as a learning aid that is useful for streamlining the learning process [16].

Learning media consists of various types. One type of learning media commonly used in schools is print learning media [17]. The media is widely used because it is considered practical, can adjust based on the ability of students, and easily distributed, but this media has a limitation that is, more likely, unable to display certain objects such as sound, moving images, and three-dimensional objects [18]. Examples of learning that require visualization of three-dimensional objects are wide area polyhedron [19].

Along with the development of technology, the limitations possessed by print-based learning media can be minimized, one of them is by utilizing augmented reality technology [20]. This technology can combine the virtual world and the real world in real time if supported by technological devices such as computers, tablets, and smartphones [21]. Supported by adequate devices such as smartphones and augmented reality technology, print-based learning media can not only display objects in two dimensions on paper, but also in three dimensions, video and sound [22].

Augmented reality is a technology developed in the world, combining two-dimensional or three-dimensional virtual objects into a real three-dimensional environment and then projecting these virtual objects in real time [23]. Three-dimensional commonly abbreviated as 3D or called space, is a form of objects that have length, width, and height [24]. This term is usually used in the fields of art, animation, computer and mathematics [25]. The application of augmented reality is not like virtual reality which completely replaces reality, but augmented reality only adds or complements reality by using the ARToolkit and Marker Library so images in three-dimensional form will appear on the webcam-assisted computer screen [26 - 28].

Some research results about augmented reality have been widely used in the learning process [29]. Here are some of the uses of augmented reality when it was used to medical students, the results show that students can understand more deeply the anatomy of teeth [30]. Furthermore, through augmented reality, students can overcome cognitive difficulties in the learning process and can visualize the concepts of the material provided [31]. Augmented reality can encourage motivation, and understanding of mathematics concepts in college students [32]. The results also state that the use of augmented reality can improve the ability of the concept of food security in college students [33]. So, understanding concept is one aspect of assessment in learning [34].

Vision of the development of mathematics learning is to meet the needs in the present and that is mathematics learning should be directed to understanding mathematical concepts and principles which are really needed to solve mathematical problems, problems in multidisciplines, and problems in daily life [35]. Furthermore, to measure the ability to understand mathematical concepts, several indicators are needed. The following are indicators of the ability of mathematical concepts, including: 1) Restate a concept, 2) Classify objects according to certain properties, 3) Give examples and non-examples of concepts, 4) Present concepts in various forms of mathematical representation, 5) Developing requirements require a concept, 6) Using, utilizing, and choosing certain procedures or operations, and 7) Applying the concept.

The purpose of this study is to develop an understanding of mathematical concepts for prospective teachers in Sultan Ageng Tirtayasa University through the use of augmented reality learning media. The novelty of this research is the use of augmented reality in the form of cards that can be opened through an android application, so students can learn by accessing various information from the learning process.

2. Method

This type of research is a quasi-experimental research with one group pre-test-post-test design. This study does not use a comparison class but has used a preliminary test so that the magnitude of the effect of using augmented reality learning media can be known with certainty. In this study, the research subjects were first given a preliminary test to diagnose the students' initial abilities before being given mathematics learning by using augmented reality learning media. After given a preliminary test, then the students were given a treatment called mathematics learning using augmented reality learning media. After completing mathematics learning with augmented reality learning media, then all students were given a final test to find out to what extent of the effect of learning mathematics using augmented reality learning media had added on the understanding of mathematics concepts of pre-service elementary education teachers of Sultan Ageng Tirtayasa University. Furthermore, the research design used can be seen in Figure 1.
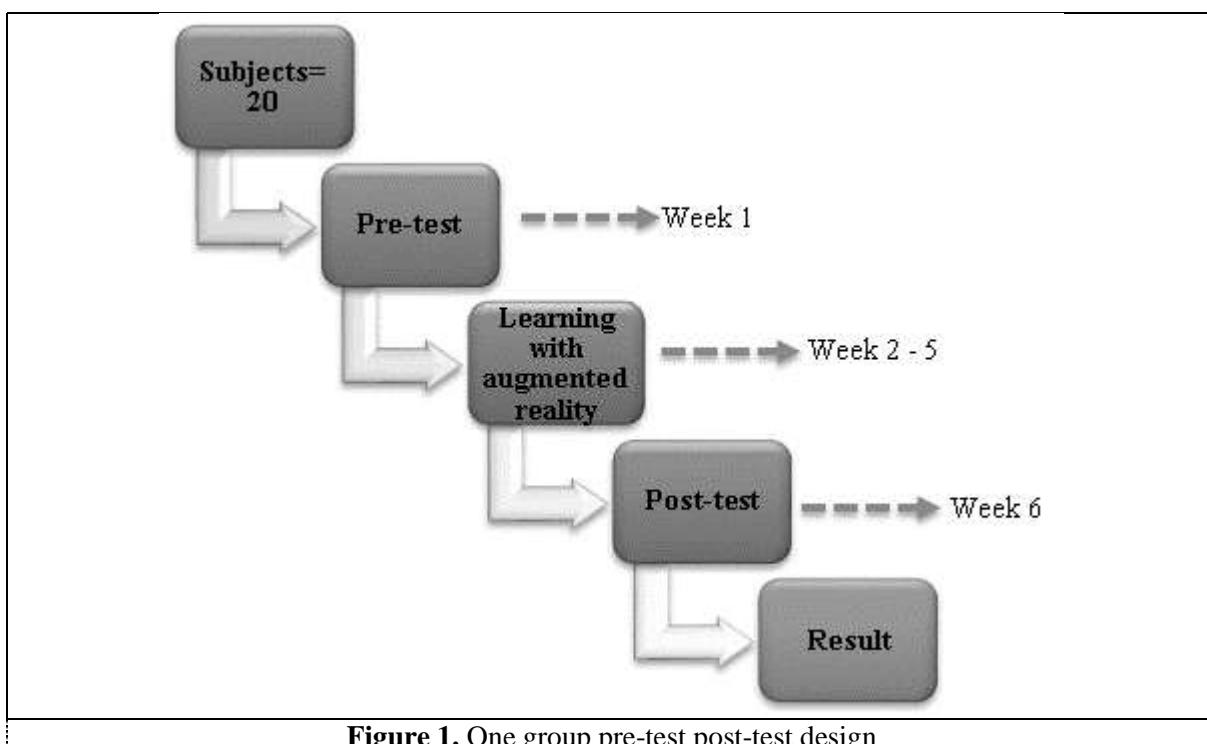

Figure 1. One group pre-test post-test design

The subjects of this study were pre-service elementary education teachers of Sultan Ageng Tirtayasa University. There were 20 students and all of them had heterogeneous characteristics. The instrument used in this study was a test of mathematical concept ability. This research used a test instrument in the form of essay questions. The instrument was given twice, namely the pre-test and post-test. Essay questions made were 10.

After obtaining the results of the pre-test and post-test results, then using the normalized gain score formula (N-Gain) with the aim to find out the improvement of understanding mathematical concepts. With the existence of score N-Gain it provides an overview of the improvement of students' understanding of mathematics concepts between before and after treatment. The formula used can be seen below [36].

$$N - Gain = \frac{Post-test\ score\ -\ Pre-test\ Score}{Maximum\ score\ -\ Pre-test\ Score}$$

Then, to determine the criteria for increasing understanding of mathematics concepts before and after learning mathematics using augmented reality learning media can be seen in Table 1.

Table 1. Classification of N-Gain [36]

N-Gain	Improvement Classification
$g > 0{,}70$	High
$0{,}30 < g \leq 0{,}70$	Medium
$g \leq 0{,}30$	Low

3. Result and Discussion

3.1 Understanding of mathematics concepts
The results of understanding of mathematics concepts for pre-service elementary education teachers can see in Figure 2 below.
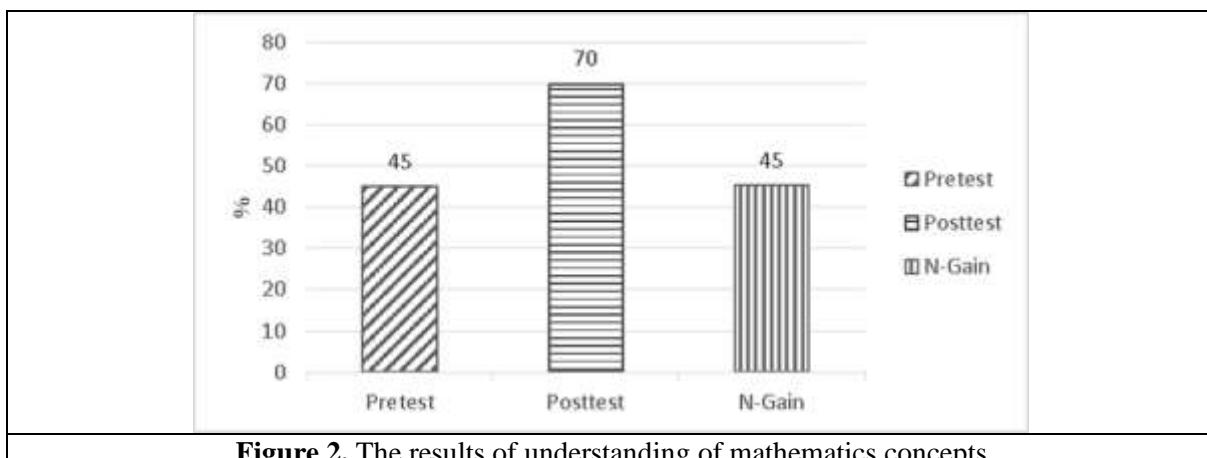

Figure 2. The results of understanding of mathematics concepts

In Figure 2, we can see that the N-Gain results from understanding of mathematics concepts by 45% or equal to 0.45. This shows that the ability of students' mathematical concepts that treated learning mathematics by using augmented reality learning media is in the medium category. Based on the results of the N-Gain, that learning by using augmented reality learning media is quite effective to improve understanding of mathematics concepts.

Furthermore, the results of each aspect of understanding mathematical concepts can see in Table 2 below.

Table 2. Results of each indicator of understanding mathematical concepts

Indicator understanding of mathematical concepts	Pre-test	Post-test	N-Gain
Restate a concept	50	80	0.60
Classifying objects according to certain properties	45	70	0.45
Give examples and non-examples of concepts	50	65	0.30
Presenting concepts in various forms of mathematical representation	40	70	0.50
Developing requirements requires a concept	45	70	0.45
Using, utilizing, and choosing certain procedures or operations	45	70	0.45
Apply the concept	40	65	0.42
Average	45	70	0.45

From Table 2, the process of learning mathematics by using augmented reality learning media can improve students' understanding of mathematical concepts. In the restate a concept stage, students experience an increase from 50% to 80%. N-gain obtained is 60% or 0.60. Based on the results of N-gain obtained, then the restate a concept aspect of 0.60 is included in medium category. The first indicator used in this study is an indicator of understanding mathematical concepts that measure students' ability to restate a concept with their own language, which means the ability of students to restate the concept of geometry is effective with their own language.

Furthermore, the results of classifying objects according to certain properties obtained from 45% to 70%. N-gain obtained is 45% or 0.45. These results indicate that the ability of classifying objects according to certain properties belongs to medium category. Classifying objects according to certain properties to the concept is the second indicator of understanding mathematical concepts, one of which measured in this study is the ability of students to classify a problem based on the properties possessed contained in geometry material.

Then in the Give examples and non-examples of concepts stages, it obtained from 50% to 65%. Then, the N-gain obtained is 30% or 0.30. From the results of the N-gain, the ability to give examples and non-examples of concepts is included in medium categories. The third indicator in this study is an indicator that measures the ability of students to distinguish which are the examples and not examples of geometry concepts.

In the presenting concepts stage, various forms of mathematical representation obtained from 40% to 70%. Then, the N-gain obtained is 50% or 0.50. From the results of the N-gain, the ability of presenting concepts in various forms of mathematical representation is included in medium categories. The fourth indicator used in this study is to present concepts in various mathematical representations, specifically indicators that measure the ability of students to present geometry concepts into the form of images or symbols in a mathematical sequence.

Furthermore, at the developing requirements requires a concept stage, it is obtained from 45% to 70%. Then, the N-gain obtained is 45% or 0.45. From the results of the N-gain, that the ability of developing requirements requires a concept is included in medium categories. Developing the necessary or sufficient requirements of a concept is the fifth indicator in this study, which measures the ability of students to solve problems according to procedures based on sufficient known requirements.

Then in the using, utilizing, and choosing certain procedures or operations stages, it obtained from 45% to 70%. Then, the N-gain obtained is 45% or 0.45. From the results of the N-gain, the ability of using, utilizing, and choosing certain procedures or operations, is included in medium categories. Using, utilizing and choosing certain procedures or operations are the abilities of students to solve problems by choosing and utilizing established procedures, and this concept is the sixth indicator in this study.

Finally, apply the concept stage improved from 40% to 65%. Then, the N-gain obtained is 42% or 0.42. From the results of the N-gain, the ability to apply the concept is included in medium categories. Applying concepts to problem solving is the seventh indicator of understanding mathematical concepts that measure students' ability to apply a concept in problem solving based on the correct steps.

4. Conclusion

Based on the results on the analysis of the research data, this study extrapolates that learning mathematics by using augmented reality learning media can improve understanding mathematical concepts for pre-service elementary education teachers on the concept of geometry. This can be seen from the results of each aspect or indicator achieved from understanding mathematical concepts. It also showed by the average N-gain of each aspect of understanding mathematics concepts which described that the category was sufficient at 45% or 0.45. This shows that learning mathematics by using augmented reality learning media can improve understanding of mathematical concepts, particularly on the concept of geometry.

References
[1] Knuth E, Zaslavsky O and Ellis A 2019 The role and use of examples in learning to prove *J. Math. Behav.* **53** 256–62
[2] Zaslavsky O 2019 There is more to examples than meets the eye : Thinking with and through mathematical examples in different settings *J. Math. Behav.* **53** 245–55
[3] Mason J 2019 Relationships between proof and examples : Comments arising from the papers in this issue *J. Math. Behav.* **53** 339–47
[4] Young H, Moore K C and Ibrahim H 2019 Reasoning within quantitative frames of reference : The case of *J. Math. Behav.* **53** 81–95
[5] Wessman-enzinger N M 2019 Grade 5 children ' s drawings for integer addition and subtraction open number sentences *J. Math. Behav.* **53** 105–28
[6] Ozgur Z, Ellis A B, Vinsonhaler R, Fatih M and Knuth E 2019 The Journal of Mathematical Behavior From examples to proof : Purposes , strategies , and affordances of example use *J. Math. Behav.* **53** 284–303
[7] Pujiastuti H, Suviati D, Haryadi R and Marethi I 2020 Development of mathmodule based on local wisdom and 21 st century skills : linear equation system *J. Phys. Conf. Ser.*
[8] Simon M A 2018 An emerging methodology for studying mathematics concept learning and instructional design *J. Math. Behav.* **52** 113–21
[9] Shepherd M D and van de Sande C C 2014 Reading mathematics for understanding-From novice to expert *J. Math. Behav.* **35** 74–86
[10] Pujiastuti H, Utami R and Haryadi R 2020 The development of interactive mathematics learning media based on local wisdom and 21st century skills : social arithmetic *J. Phys. Conf. Ser.*
[11] Grabusts P, Musatovs J and Golenkov V 2019 The application of simulated annealing method for optimal route The application of simulated annealing method for optimal route detection between objects detection between objects *Procedia Comput. Sci.* **149** 95–101
[12] Butko T 2019 Organization of railway freight short-haul transportation on the basis of logistic approaches Organization of railway freight basis of logistic approaches *Procedia Comput. Sci.* **149** 102–9
[13] Magoev K, Krzhizhanovskaya V, Kovalchuk S V and Magoev K 2018 Application of clustering methods for detecting critical acute coronary methods syndrome patients Application of clustering for detecting critical acute coronary syndrome patients *Procedia Comput. Sci.* **136** 370–9
[14] Pontevedra V, Helming S, Ungermann F, Hierath N, Stricker N, Lanza G, Helming S, Ungermann F, Hierath N, Stricker N and Lanza G 2019 Development of a training concept for leadership 4 . 0 in production Development of a training concept for leadership 4 . 0 in production environments Costing models for capacity optimization in Industry 9th Conference on Learning Factories 2019 *Procedia Manuf.* **31** 38–44
[15] Rau P L P, Zheng J, Guo Z and Li J 2018 Speed reading on virtual reality and augmented reality *Comput. Educ.* **125** 240–5
[16] Pujiastuti H and Fitriah F 2019 Design of interactive teaching materials based on a scientific approach to support junior high school students' learning: Line and angles *J. Phys. Conf. Ser.* **1157**
[17] International S, Oestreich H, Torben T and Wrede S 2019 Interactive Interactive Learning Learning of of Assembly Assembly Processes Processes using Digital Assistance *Procedia Manuf.*
[18] Haryadi R and Pujiastuti H 2020 PhET simulation software-based learning to improve science process skills *J. Phys. Conf. Ser.*
[19] Suarsana I M, Widiasih N P S and Suparta I N 2017 The Effect of Brain Based Learning on Second Grade Junior Students' Mathematics Conceptual Understanding on Polyhedron *J. Math. Educ.* **9** 145–56
[20] Lindner C, Rienow A and Jürgens C 2019 Augmented Reality applications as digital experiments for education – An example in the Earth-Moon System *Acta Astronaut.* **161** 66–74

[21] Lee C and Wong G K C 2019 Virtual reality and augmented reality in the management of intracranial tumors: A review *J. Clin. Neurosci.* **62** 14–20

[22] Stief P, Dantan J, Etienne A and Siadat A 2018 General Requirements for Industrial Augmented Reality France Applications *Procedia CIRP* **72** 1130–5

[23] Huang T K, Yang C H, Hsieh Y H, Wang J C and Hung C C 2018 Augmented reality (AR) and virtual reality (VR) applied in dentistry *Kaohsiung J. Med. Sci.* **34** 243–8

[24] Cabero-Almenara J, Fernández-Batanero J M and Barroso-Osuna J 2019 Adoption of augmented reality technology by university students *Heliyon* **5**

[25] Mahony S O 2015 A Proposed Model for the Approach to Augmented Reality Deployment in Marketing Communications *Procedia - Soc. Behav. Sci.* **175** 227–35

[26] Wang Y Y, Liu H P, Hsiao F L and Kumar A 2019 Augmented reality for temporomandibular joint arthrocentesis: a cadaver study *Int. J. Oral Maxillofac. Surg.* 10–3

[27] Palmarini R, Erkoyuncu J A and Roy R 2017 An Innovative Process to Select Augmented Reality (AR) Technology for Maintenance *Procedia CIRP* **59** 23–8

[28] Yip J, Wong S, Yick K, Chan K and Wong K 2019 Improving quality of teaching and learning in classes by using augmented reality video *Comput. Educ.* **128** 88–101

[29] Nincarean D, Bilal M, Dayana N, Halim A and Abdul H 2013 Mobile Augmented Reality : the potential for education *Procedia - Soc. Behav. Sci.* **103** 657–64

[30] Iftene A and Trandabăt D 2018 Enhancing the Attractiveness of Learning through Augmented Reality *Procedia Comput. Sci.* **126** 166–75

[31] Akçayır M and Akçayır G 2017 Advantages and challenges associated with augmented reality for education: A systematic review of the literature *Educ. Res. Rev.* **20** 1–11

[32] Coimbra M T, Cardoso T and Mateus A 2015 Augmented Reality: An Enhancer for Higher Education Students in Math's Learning? *Procedia Comput. Sci.* **67** 332–9

[33] Pujiastuti H and Haryadi R 2020 The Use of Augmented Reality Blended Learning for Improving Understanding of Food Security in Universitas Sultan Ageng Tirtayasa: A Case Study *J. Pendidik. IPA Indones. T* **9**

[34] Robinson K M, Dubé A K and Beatch J A 2017 Children's understanding of additive concepts *J. Exp. Child Psychol.* **156** 16–28

[35] Magombedze G and Marino S 2018 Mathematical and computational approaches in understanding the immunobiology of granulomatous diseases *Curr. Opin. Syst. Biol.* **12** 1–11

[36] Hake R R 1998 Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses *Am. J. Phys.* **66** 64–74