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IMPROVING STUDENTS' MATHEMATICAL REASONING ABILITY THROUGH AUGMENTED REALITY LEARNING MEDIA

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Abstract

This study is prompted by the insufficient mathematical reasoning skills among junior high school students in Pekanbaru. This information is gathered from reports by teachers indicating that students face challenges in adequately solving mathematical reasoning problems. The primary objective of this research is to assess the impact of augmented reality learning media on the mathematical reasoning abilities of students. The study employs an experimental approach with a quasi-experimental design involving random sampling, with randomization conducted at the class level. The research encompasses 60 seventh-grade students from one of the junior high schools in Pekanbaru during the academic year 2022/2023, with a focus on the geometry of flat shapes, particularly triangles and quadrilaterals. The assessment instrument utilized is a mathematical reasoning ability test constructed based on various indicators as per expert recommendations. Data analysis encompasses normality tests, homogeneity tests, and parametric tests. The results of the data analysis reveal a significance value of 0.00, signifying that the enhancement in students' mathematical reasoning abilities is more pronounced when utilizing augmented reality learning media compared to conventional learning methods

Keywords: Augmented Reality; Improvement; Mathematical Reasoning

Abstrak

Penelitian ini dilatarbelakangi oleh rendahnya kemampuan penalaran matematis siswa SMP di Pekanbaru, hal ini diperoleh dari keterangan guru yang mengajar di sekolah bahwa anak-anak masih belum cukup mampu dalam menyelesaikan soal-soal penalaran matematis. Tujuan penelitian ini adalah untuk menganalisis pengaruh penggunaan media pembelajaran augmented reality terhadap kemampuan penalaran matematis siswa. Penelitian ini merupakan penelitian eksperimen dengan desain kuasi-eksperimen yang menggunakan sampel acak, namun pengacakan yang dilakukan adalah acak kelas. Subyek penelitian sebanyak 60 siswa kelas VII di salah satu SMP Pekanbaru tahun pelajaran 2022/2023 pada materi geometri bangun datar, khususnya segitiga dan segiempat. Instrumen yang digunakan adalah tes kemampuan penalaran matematis yang mengacu pada beberapa indikator menurut para ahli. Pengolahan data menggunakan uji normalitas, uji homogenitas, dan uji parametrik. Berdasarkan pengolahan data diperoleh signifikansi sebesar 0,00 yang mengindikasikan bahwa peningkatan kemampuan penalaran matematis siswa yang menggunakan media pembelajaran dengan augmented reality lebih baik daripada siswa yang belajar secara konvensional.

***Kata kunci**:* Augmented Reality*; Penalaran Matematis; Peningkatan*

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INTRODUCTION

The capacity to convey reasons that are necessary for comprehending mathematics is known as mathematical reasoning ability (Kadarisma et al., 2020). One of the subjects of mathematics studied in school is about Geometry. Geometry content frequently incorporates abstract ideas like points, lines, angles, planes, and three-dimensional shapes. Proficiency in detailing, connecting, and comprehending the significance of these ideas demands abstract thought and mathematical reasoning. The content of geometry is interrelated with other mathematical concepts like algebra, trigonometry, and calculus. Proficiency in mathematical reasoning empowers students to recognize the connections among diverse mathematical concepts and apply them in context. The ability to understand students' concepts about flat shapes can be built by familiarizing mathematical reasoning ability, so that students will not experience difficulties in the next stages of the cognitive domain, namely the stages of application, analysis, synthesis and evaluation of flat shape.

Based on observations at school, flat shape subject is still one of the subjects that is considered difficult for students, the teacher informs that during learning on flat shape subject, Abstract subjects make it difficult for students to understand them. This is consistent with studies undertaken by Abidin & Jupri (2017); Fan et al. (2018); and Sandy et al. (2019), that geometry is the most prioritized for the Indonesian state. Difficulties in learning geometry are felt starting from the Elementary School level up to the University level (Hegg et al., 2018; Komatsu et al., 2017; Martinez et al., 2011).

Before using AR media, students have already utilized various learning media, one of which is the use of PowerPoint and Quizizz. However, the use of both has not yielded maximum effectiveness. The used of augmented reality-based digital teaching subjects is a solution that can be used to make it easier for students to learn geometry, especially flat shape subject. The usage of augmented reality media in the classroom and beyond may aid learning activities and provide additional context to information (Ahmad & Junaini, 2020; Ambarwulan & Muliyati, 2016; Buchner & Kerres, 2021; Gargrish et al., 2021; Ismail et al., 2021; Kristian et al., 2020). Student-centered learning and making students understand the content well can be created with AR media.

Several previous research results have revealed some results from the used of augmented reality. Research by Blattgerste et al. (2017); Buchner et al. (2022); Cuendet et al. (2013); Dunleavy (2014); and Estapa & Nadolny (2015) explained that augmented reality makes it easier for students to understand math subject and improves student motivation in learning mathematics.

The primary concern addressed in this study is the insufficient mathematical reasoning skills of students. Previous research has shown that traditional teaching methods, especially those employing PowerPoint media, do not yield optimal results in enhancing students' mathematical reasoning capabilities. This creates a disparity between the potential offered by advanced learning technologies, such as augmented reality (AR), and the existing instructional approaches. Students' logical reasoning in mathematics is currently confined to the pattern recognition stage, with limited evidence of abstraction and algorithmic thinking skills. This underscores a gap in the

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progression of students' mathematical reasoning abilities that could be bridged through more innovative educational media. The present study aims to address this gap by incorporating AR technology as a learning tool. Given the advancements in technology, there is an opportunity to revolutionize the way students learn and refine their mathematical reasoning skills. The uniqueness of this research lies in the integration of AR technology as an educational medium to enhance students' mathematical reasoning capabilities. This investigation holds promise for introducing fresh perspectives and inventive solutions to tackle the challenge of insufficient mathematical reasoning skills among students through the application of AR technology. Based on this description, the purpose of this research is to improve students' mathematical reasoning ability through augmented reality media.

METHOD

The research is focused on improving students' mathematical reasoning skills through the use of augmented reality learning media, with the expectation of achieving superior effectiveness compared to conventional learning (power point media). The study employs an experimental approach with a quasi-experimental design involving random sampling, with randomization conducted at the class level**.** The two groups in this research were designated as "experimental" and "control.". The experimental class receives learning using augmented reality media, whereas the control class receives conventional learning (power point media).

The research encompasses 60 seventh-grade students from one of the junior high schools in Pekanbaru during the academic year 2022/2023, with a focus on the geometry of flat shapes, particularly triangles and quadrilaterals. Thirty students participated in the experiment, while the remaining 30 served as a control group. Validity testing has been successfully completed on the mathematical reasoning test that is employed as the study instrument. Students were given an initial test of their mathematical prowess to help determine the criterion for equivalency. Data analysis encompasses normality tests (Kolmogorov-Smirnov), homogeneity tests (Levene-test), and parametric tests (t-test and Anova-test).

The researcher first examined the classes that would serve as research samples to classify students' initial mathematical ability according to research needs, using the results of students' initial mathematical ability tests from the previous subject to determine which sample members had low, medium, and high ability. Table 1 explains how teachers classify children into the high, middle, and poor categories based on their basic mathematical abilities.

Table 1. Initial mathematical ability category

Score	Category
$X < 30\%$	Low
$30\% \leq X < 70\%$	Medium
$X \geq 70\%$	High

Gain data analysis uses parametric test (2 ways Anova) and homogeneity and reliability assumption tests. Then the gain data is classified into 3 categories in the Table 2.

Table 2. Normalized Gain Classification

Score	Category
$g < 0.3$	Low
$0.3 \leq g < 0.7$	Medium
$g \geq 0.7$	High

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RESULTS

Initial Mathematical Ability (IMA) is categorized into three levels: high, medium, and poor. Before conducting this study, data were collected and evaluated from a pre-test to measure students' baseline mathematical competence. The results of the pre-test served as the first data on mathematical ability, which was then classified as high, medium, or low. Table 3 is the distribution of study samples.

Table 3. Distribution of research sample

IMA	Control	Experiment	Sum
High	10	10	20
Medium	10	10	20
Low	10	10	20
Total	30	30	60

Description:
Experiment = Augmented Reality;
Control = Conventional Learning

Descriptive statistics, the Kolmogorov-Smirnov normality test, the Levene homogeneity test, the t-test, and the two-way Anova test are all part of SPSS software's reasoning ability test analysis. The data must be checked for normality and the variance must be homogeneous before any statistical tests can be performed. Pre- and post-test results served as the data source for this investigation. The pre-test score is used to assess students' abilities before they get treatment, and the post-test score is compared to the ideal score of students' mathematical reasoning ability, represented in the normalized gain score, to measure the degree of improvement. This section contains tabular descriptive statistics of pre- and post-test scores as well as normalized gain (g) scores.

Table 4. Descriptive statistics mathematical reasoning ability scores

	N	Min	Max	Mean
Pretest (E)	30	0.00	5.00	3.21
Posttest (E)	30	6.00	12.00	10.59
Gain (E)	30	0.30	1.00	0.86
Pretest (C)	30	0.00	7.00	3.26
Posttest (C)	30	3.00	8.00	7.18
Gain (C)	30	0.20	0.60	0.49

Description:
E : Experiment Class
C : Control Class

In the table 4, experimental class students had a lower average mathematical reasoning ability score before learning than control class students; the experimental class average is 3.21 and the control class average is 3.26. The mean of the two groups differed by 0.05, this shows that the difference is very small. Whereas after learning was carried out the average score of the experimental class' mathematical reasoning ability was 10.59. Whereas in the control class, after learning the average was 7.18.

In addition, a similarity test of the average pre-test results was conducted to determine that there was no significant difference between the experimental class and the control class in terms of initial ability. The steps that must be taken to carry out the average similarity test first are to test the normality of the data distribution and the homogeneity of the variance. If the data meets the normality and homogeneity requirements, test the average similarity t-test. The results of the calculation of the pre-test normality test for mathematical reasoning ability can be seen in the Table 5.

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Table 5. Normality test of pretest scores of students' mathematical reasoning ability

Kolmogorov-Smirnov	Control	Experiment
N	30	30
Sig.	0.15	0.16

Based on the data in Table 5, H_0 is acceptable since the p-value for the experimental group is more than 0.05 and less than 0.2. To sum up, we may say that at the = 0.05 level of significance (normal distribution). Testing the homogeneity of the pre-test data of students' mathematical reasoning ability as a whole was carried out using the Levene test. The results of the calculation of the homogeneity test can be seen in the Table 6.

Table 6. Homogeneity test of variance pretest scores of students' mathematical reasoning ability

Levene-test	Data	Criteria
N	60	H_0 accepted
Sig.	0.90	

From the table 6, it can be seen that the significance value is 0.90. As the significance threshold is larger than = 0.05, we may infer that H_0 is accepted. In other words, there is no statistically significant difference in the variance between the two groups of learners. Because the two sample groups met the assumption of normality of the data and met the assumption of homogeneity of variance, then the equality of the initial mathematical ability data would be tested using the t-test. The table 7 presents the results of the average pre-test similarity test of students' mathematical reasoning ability.

Table 7. T-test of pretest score of students' mathematical reasoning ability

t-test	Data	Criteria
N	60	H_0 accepted
Sig. (2-tailed)	0.89	

Based on the table 7, it can be seen that the significance is 0.89 > from $\alpha = 0.05$. So that H_0 is accepted, which means that the average initial mathematical reasoning ability of students who received AR learning is the same as the average initial mathematical reasoning ability of students who receive Conventional Learning (CL).

The normalized gain data of students who got AR learning and students who received traditional learning were compared to determine the increase in mathematical reasoning abilities between the two groups. Below are descriptive statistics of gain data standardized by learning and student ability classes for experimental and control courses.

With the use of SPSS, the descriptive statistics and normalized growth of students' mathematical reasoning abilities are in the Table 8.

Table 8. Descriptive statistics normalized gain of students' mathematical reasoning ability

Learning	Reasoning Ability	Mean of Gain	N
AR	High	0.95	10
AR	Medium	0.86	10
AR	Low	0.76	10
CL	High	0.59	10
CL	Medium	0.49	10
CL	Low	0.40	10

Based on the table 8 can be described students' mathematical reasoning ability as follows. First, the average boost in mathematical

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reasoning ability for children with high ability who receive AR is 0.95. While the average increase in mathematical reasoning skill improvement for kids who get CL is 0.59. Therefore, it may be stated that the average growth in mathematical reasoning ability of high-ability students who get AR is greater than that of those who receive CL.

The average improvement in mathematical reasoning ability for children with average ability who get AR is 0.86. While the average improvement in mathematical reasoning ability among CL students is 0.49 points. Therefore, it can be stated that the average growth in mathematical reasonning ability of students with medium ability who receive AR is greater than that of students who obtain CL.

The average boost in mathematical reasoning ability for low-ability pupils who achieve AR is 0.76 points. While the average improvement in mathematical reasoning skills among CL students is 0.40 points. This indicates that the average growth in mathematical reasoning ability for low-ability kids who get AR is greater than the average gain for children who receive CL.

To determine the importance of the aforementioned findings' veracity, it is required to compute the two-way Anova test. Previously, tests for normalcy and homogeneity were conducted on the gain of the two data groups. The summary of normality test calculations is presented in the Table 9.

Table 9. Normalized gain test of mathematical reasoning ability

Kolmogorov -Smirnov	**Control**	**Experiment**
N	30	30
Sig.	0.10	0.65

It can be seen from the table 9 that the p-value (Asymp Sig) for the experimental group is more than 0.05 (0.65) and less than 0.05 (0.10), indicating that H_0 is true. Students' mathematical reasoning skills who were given AR and students' mathematical reasoning skills who were given CL were normally distributed at the = 0.05 significant level after the data gain normalization procedure was used. The homogeneity of variance test (Levene Statistics) was performed to examine whether or not the variances of the experimental class and control class data gain groups were similar.

Table 10. Homogeneity test of normalized gain score of mathematical reasoning ability

Levene-test	**Data**	**Criteria**
N	60	H_0 accepted
Sig.	0.60	

Based on the Table 10, hence the null hypothesis that the population variance of the two data groups is equal is accepted. This indicates that the variance of the two sets of normalized gain score data for students' mathematical reasoning ability is identical.

In addition, a two-way analysis of variance (Anova) was performed to determine the significance of the difference in mean differences between the two groups, given that both the experimental class and the control class normalized data gain groups had homogeneous variances and were normally distributed. This investigation was undertaken to determine the direct impact of two distinct treatments on the mathematical reasoning abilities of students based on learning mediua. The results of the SPSS analysis of variance test computation are provided in the Table 11.

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Table 11. Normalized gain analysis of variance of mathematical reasoning ability

	Sum of Square	F	Sig.
Learning	1.986	112.16	0.00
Error	0.797		
Total	21.17		

This study's hypothesis is that the increase in mathematical reasoning ability of students who got AR learning is greater than the improvement in mathematical reasoning ability of students who received conventional learning. After calculating the two-ways Anova. Sig (1-tailed) = 0.00 < α = 0.05. Therefore, the results of the null hypothesis are rejected, Students' gains in mathematical reasoning after receiving AR instruction were greater than those of students who had received conventional instruction.

The used of learning media AR can facilitate the role of the instructor in explaining subject, shorten the duration of time needed by the teacher and can create a more interactive learning. The advantage of this media is that it has high interactivity, namely the existence of AR virtual objects that can interact directly with the user. Augmented reality is a visual media that merges virtual world items with views of the actual world in real time. Using augmented reality and an Android smartphone, geometric objects may be represented concretely via three-dimensional virtual modeling that resembles the actual thing directly on top of a flat paper figure. Android-based applications by utilizing augmented reality as a media for learning geometric mathematics can be an alternative to assist students in understanding various geometric objects concretely.

The findings demonstrated that the increase in students' mathematical reasoning skills utilizing augmented reality media was much greater than the improvement using traditional learning methods. Students who learn to use augmented reality media carry out learning activities that are the same as students who learn with conventional learning, which starts with an introduction, core activities and closing. What distinguishes the two classes is the media used, the experimental class uses AR media, AR in appearance has high interactivity, AR virtual objects can interact directly with users. Whereas students who study conventionally received subject through power points which also help make learning more interesting, but the level of interactivity is lower. Here's what AR media looks like in Picture 1.

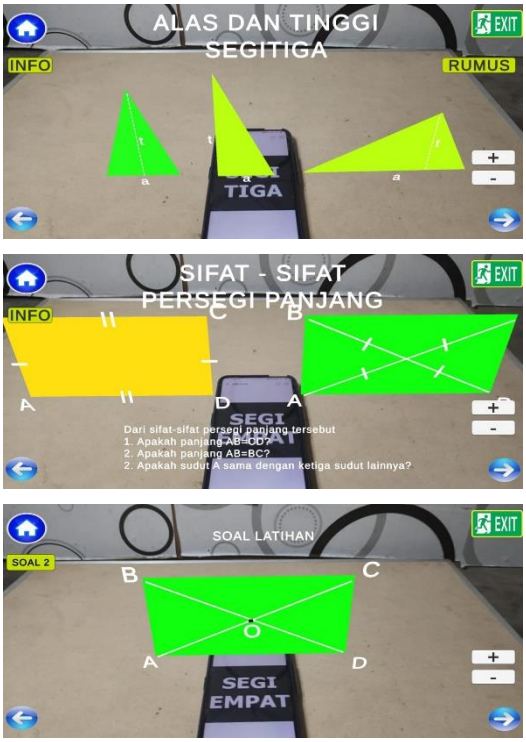

Figure 1. Augmented reality media display

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To run interactive multimedia-based learning media on the subject "triangle and quadrilateral". The steps that students must take are (1) The teacher distributes the application of the subject "triangle and quadrilateral". This application can be sent via WhatsApp or Telegram and can be saved on Google Drive and then shared via e-mail; (2) Then students can directly install the application on the Android device; (3) Then students can follow the steps by allowing the operation of the application on Android; (4) The learning application "triangle and quadrilateral" is ready to use. After the learning application is ready to use, students can start learning with an interactive multimedia-based learning application on the subject "triangle and quadrilateral".

The primary distinction in these findings lies in the utilization of augmented reality (AR) media compared to traditional learning approaches employing PowerPoint. Within the realm of learning theories, interactivity is acknowledged as a catalyst for improving comprehension and fostering student engagement in the learning process. The incorporation of AR media elevates interactivity levels, given that virtual AR objects have the capability to directly engage with users. This engenders a more dynamic and immediate learning experience, enabling students to actively participate in the learning process (Abdinejad et al., 2021; Arici et al., 2019; Challenor & Ma, 2019; Deli, 2020; Elmqaddem, 2019; Fakhrudin et al., 2019; Farsi et al., 2021; Garcia, 2020; Wahyudi & Arwansyah, 2019).

Constructivism theory underscores the significance of learning that involves students in the construction of knowledge through direct experiences. Through AR media, students can take a more proactive role in constructing their own knowledge. They are not merely passive recipients of information but are actively engaged in a tangible and pertinent learning experience. These findings can also be scrutinized from the vantage point of motivation theory in learning. The utilization of AR media has the potential to heighten students' interest and motivation to learn by offering an innovative and captivating learning experience. The elevated interactivity in AR also injects an element of enjoyment into learning, which can serve as a motivational catalyst for students to participate more actively (Garzón et al., 2019; Georgiou & Kyza, 2021; Sulaksono, 2021). This theory underscores that the effective incorporation of technology can augment the efficacy of learning. In this context, AR media serves as a potent tool for enhancing the comprehension of mathematical concepts owing to its capacity to vividly visualize intricate ideas. Through the integration of AR media, this research illustrates that learning technology can play a pivotal role in boosting student engagement and improving learning outcomes, particularly concerning the enhancement of mathematical reasoning abilities.

Augmented reality is an innovation in multimedia that is currently experiencing development. Currently, augmented reality is widely implemented in many fields such as visualization, navigation, maintenance, medicine, games, and in education. Several previous research results have revealed some results from the use of augmented reality. Research Blattgerste et al. (2017); Buchner et al. (2022); Cuendet et al. (2013); Dunleavy (2014); and Estapa & Nadolny (2015) explains that augmented reality makes it easier

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for students to understand math subject and improves student motivation in learning mathematics. According to Bravo & Maier (2020); Doukianou et al. (2021); and Yanuarto & Iqbal (2022), AR is becoming a trend in the field of education, AR makes explanations more effective and communicative when applied in learning.

Some of the obstacles found during the research were: (1) The use of learning media using android smartphones in schools was still lacking, so that before the research was carried out, the teacher conducted socialization about the use of learning media using AR-based android smartphones; (2) The menu display in the application does not look good because the application interface is still focused on the AR display; (3) on some smartphones, when the camera is pointed at the marker but the object does not appear, this may be due to a lack of light around the marker; (4) on some student devices, the application runs slowly because the Geometry application consumes quite a lot of CPU and memory when it is run.

Augmented reality is an interactive technology that can be developed for learning media on other geometry subjects. This study concluded that students' mathematical reasoning ability improved better in flat subject with 3D illustrations presented in AR, and recorded a difference of 15 minutes between learning using the application and learning classes that did not use the application. If possible, databases and application content that use augmented reality can be stored in the cloud (online). So that it is possible to reduce excessive memory and CPU consumption.

Based on the recognized challenges, the following recommendations are proposed for future research: (a) Enhance awareness and comprehension of AR-based educational media among teachers and students. Conduct more comprehensive awareness sessions before implementing the research to introduce the technology. (b) Enhance the application interface to ensure a more visually appealing and user-friendly menu display. This can improve the overall user experience and interaction with the AR application. (c) Investigate and resolve technical issues associated with AR applications, such as challenges in object visibility due to inadequate lighting around markers or sluggish application performance on certain student devices. This may involve refining the technical specifications of the application.(d) Explore the possibility of cloud-based storage for the application's database and content. Storing augmented reality content online can alleviate the strain on device memory and CPU, thereby enhancing application efficiency. (e) Explore the integration of augmented reality into learning materials for other geometry subjects. Assess the effectiveness of AR in improving understanding and engagement across various mathematical topics within the geometry curriculum. (f) Conduct more thorough comparative research to analyze the influence of augmented reality on students' mathematical reasoning skills across diverse subjects and age groups. This can offer insights into the generalizability of the findings. (g) Consider conducting additional research to assess the long-term effects of augmented reality on students' mathematical reasoning skills. Monitoring progress over an extended period can reveal sustained benefits and areas requiring improvement. (h)

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Increase the sample size to ensure a more representative research population. A larger sample can enhance the external validity of the study and yield more robust findings. (i) Implement feedback mechanisms for continual improvement. Regularly gather input from teachers, students, and other stakeholders to pinpoint areas needing refinement and ensure ongoing enhancements in the augmented reality learning experience.

CONCLUSIONS

The results of the data analysis reveal a significance value of 0.00, signifying that the improvement of mathematical reasoning ability of students who used learning media with augmented reality is better than students who studied conventionally. Augmented reality as a learning media can be used as a modeling tool for geometric flat shapes that are displayed visually in three dimensions. Augmented reality which is capable of processing data quickly and a very simple display makes it easy for students to understand. ar media is also very interactive in displaying its three-dimensional objects, this will certainly be beneficial for the suitability of ar in this application. Subject on modeling special flats at the junior high school level is designed by 3D visuals that utilize the sophistication of augmented reality technology to contribute to the world of education, namely that it can be used as a learning media.

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