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IMPROVING MATHEMATICAL CRITICAL THINKING ABILITY THROUGH AUGMENTED REALITY-BASED LEARNING

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Abstract

Through Augmented Reality-based learning, this study aims to improve mathematical critical thinking skills. Learning with Augmented Reality-based media in Unity 3D can be used both online and offline. This research is quantitative (quasi-experimental), with 30 students from SMPN 34 Pekanbaru class VII participating in the academic year 2022/2023. The research was conducted on triangle and quadrilateral material. The following methods were used to collect data: (1) a mathematical critical thinking ability test; (2) interviews; and (3) documentation. The test result data was statistically processed, whereas the interview and documentation data were processed descriptively. The findings revealed that students who learned using Augmented Reality media with Unity 3D improved their mathematical critical thinking skills.

Keywords: Augmented reality; critical thinking; unity 3D.

Abstrak

Penelitian ini bertujuan untuk meningkatkan kemampuan berpikir kritis matematis melalui pembelajaran berbasis Augmented Reality. Pembelajaran dengan menggunakan media berbasis Augmented Reality dengan unity 3D dapat digunakan dalam pembelajaran online maupun pembelajaran offline. Penelitian ini merupakan penelitian kuantitatif (kuasi eksperimen), sedangkan subjek penelitian adalah siswa SMPN 34 pekanbaru kelas VII tahun ajaran 2022/2023 sebanyak 30 siswa, penelitian ini dilakukan pada materi segitiga dan segiempat. Metode pengumpulan data yang digunakan meliputi: (1) tes kemampuan berpikir kritis matematis; (2) wawancara; dan (3) dokumentasi. Data hasil tes diolah dengan uji statistik, sedangkan data wawancara dan dokumentasi diolah secara deskriptif. Hasil penelitian menunjukkan bahwa peningkatan kemampuan berpikir kritis matematis siswa yang memperoleh pembelajaran dengan media augmented reality dengan unity 3D lebih baik dibandingkan peningkatan kemampuan berpikir kritis matematis siswa yang memperoleh pembelajaran konvensional secara keseluruhan.

***Kata kunci**: Augmented reality; berpikir kritis; unity 3D.*

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INTRODUCTION

Mathematical critical thinking skills are critical for students to develop when learning mathematics (Cysarah, 2021; Delina et al., 2018; Karim & Normaya, 2015). Educational policies in several countries include mathematical critical thinking skills as one of the learning objectives (Rahayu & Alyani, 2020; Umam & Anti, 2017). As a result, an effort is required to develop these abilities in mathematics learning.

The ability to understand, apply, analyze, synthesize, and evaluate information obtained through experience, observation, reflection, reasoning, and communication is referred to as critical thinking ability (Cysarah, 2021; Delina et al., 2018; Karim & Normaya, 2015; Rahayu & Alyani, 2020; Umam & Anti, 2017). Critical thinking does not develop quickly; it requires habituation and regular practice because critical thinking is a skill, attitude, and commitment to constantly question something.

Interpretation, analysis, evaluation, drawing conclusions, explanations, and independence are all components of critical thinking. In mathematics, critical thinking is the ability to use prior knowledge, mathematical reasoning, and cognitive strategies to effectively generalize, prove, or evaluate unfamiliar mathematical situations (Aulia & Mukhni, 2018; Farib et al., 2019; Fasha et al., 2018; Jumaisyaroh & Hasratuddin, 2016; Nastiti et al., 2020). Someone who thinks critically will become accustomed to asking the right questions, comprehending the information, and analyzing the information in order to effectively and efficiently organize the information into better information.

One of the media that has a significant impact on learning is interactive multimedia (Ilyasa & Dwiningsih, 2020; Mumtaha & Khoiri, 2019; Nazar et al., 2020). Augmented Reality is one type of interactive multimedia-based teaching material that is widely used in mathematics education. AR is defined as a system with three characteristics: (1) combining the real and virtual worlds; (2) being interactive; and (3) utilizing three-dimensional space (Asry, 2019; Bahiyah et al., 2020; Fauziyah et al., 2020; Hamdani & Sumbawati, 2020; Hardiyanti et al., 2020; Mukti, 2019). AR is interactive and can be used in mobile-based learning to provide a better understanding of a concept, to create more real learning, and to provide a higher quality learning experience. Students can interact with 3D objects as virtual objects using augmented reality. Students can understand materials and questions that train mathematical critical thinking skills using AR-based teaching materials in the absence of lecturers in the classroom. AR-based teaching materials are required to train mathematical critical thinking skills, particularly in the material concepts of triangles and quadrilaterals.

Research on the application of AR media has been carried out by (Hamdani & Sumbawati, 2020; Hardiyanti et al., 2020; Kusmanagara et al., 2018; Oktavia et al., 2019; Rachmanto & Noval, 2018; Renando & Sumarudin, 2015; Rusnandi et al., 2016; Sidik & Vivivanti, 2021; Sirumapea et al., 2017) researchers concentrated on developing augmented reality-based learning media in digital system courses, identifying the application of AR as a media for child health, developing learning media on geometry material, developing learning

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media in learning Cantonese, developing learning media in class V MI, identifying the application of AR for interior design, identifying the application of AR as a learning medium, and identifying the application of AR in computer network installation. Meanwhile, this study investigates the use of augmented reality media to improve students' mathematical critical thinking skills on flat shapes (triangles and quadrilaterals).

Critical thinking skills can be improved through the use of AR media, and AR media can aid in the achievement of learning objectives. The use of AR media in learning is beneficial for delivering knowledge and skills, as well as stimulating students' attention and interest, resulting in more directed and controlled learning (Kayano, 2020; Mustaqim, 2016; Mustaqim & Nanang, 2017; Prasetyo & Sutopo, 2018; Sidik & Vivivanti, 2021; Yang et al., 2018).

Flat shapes, particularly triangles and quadrilaterals, are materials that junior high students must study. This material contains some fundamental mathematical concepts that necessitate higher-order thinking abilities. Triangles and quadrilaterals require advanced mathematical thinking skills, specifically mathematical critical thinking. However, students' mathematical critical thinking skills remain low, particularly in geometry. This is evident from the test scores of students who scored above 50, which included as many as 5 students out of a total of 30 students, while the remainder scored below 50. The goal of this research is to improve mathematical critical thinking skills using augmented reality-based learning with Unity 3D to support online and offline learning.

METHOD

This study was conducted in the 2022/2023 academic year at SMPN 34 Pekanbaru with grade VII students. The subjects of this study were 30 students divided into two groups: experimental and control. The experimental group received learning using AR-based learning media with 3D unity, while the control group received teaching materials in the form of Student Work-sheets (SW). Each teaching material is designed to promote effective learning and help students improve their mathematical critical thinking skills.

This is an experimental research method used to determine the effect of various treatments. This study used a quasi-experimental nonequivalent control group design (pretest-posttest control group design) because the students who participated in this study were not chosen at random, but the researchers randomized the existing classes.

Tests, interviews, and documentation were used to collect research data. The exam consists of questions about mathematical critical thinking skills. The test is administered at the beginning and end of the process, and it is then refined through in-depth interviews and documentation. Experts validated the test first. The data was then analyzed using Anova test. The data were tested for prerequisites prior to the Anova test, in this case to ensure that the data met the normality and homogeneity assumption tests. The Kolmogorov-Smirnov test was used for normality, and the Levene test was used for homogeneity. If the data distribution fails the normality assumption test, the data will be subjected to a non-parametric test. Meanwhile, data from interviews and documentation were processed descriptively.

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RESULTS AND DISCUSSION

The data were analyzed descriptively in order to determine the mean, standard deviation, minimum value, and maximum value of the two groups of students' mathematical critical thinking skills. The summary of the results of the descriptive analysis of students' mathematical critical thinking ability data in the two lessons can be seen in Table 1.

Table 1. Data description of students' mathematical critical thinking ability

Descriptive Statistics	Control	Experiment (AR)
N	15	15
$\bar{X}$	54,53	69,33
Sd	5,20	3,95
Min	15	45
Max	75	95

Table 1 shows that the overall average mathematical critical thinking ability of students who receive learning using augmented reality media with Unity 3D is better than that of students who receive conventional learning.

Before testing the average difference, the data on the mathematical critical thinking ability of students who receive learning using augmented reality media with Unity 3D (experimental class) and conventional learning will be tested for normality and homogeneity of variance (control class). The normality test results of the students' mathematical critical thinking ability data for the two learning groups can be seen in Table 2.

Table 2. Normality test of mathematical critical thinking ability (Kolmogorov Smirnov)

	Control	Experiment (AR)
N	15	15
Sig.	0,08	0,20
Information	H_0 accepted	H_0 accepted

The Table 2 shows that the significance value of the two learning groups' mathematical critical thinking ability is greater than 0.05. This implies that the null hypothesis is correct. That is, the data on students' mathematical critical thinking skills is normally distributed in both the control and experimental classes. Furthermore, Levene's test will be used to assess the homogeneity of the variance in critical thinking skills between the two sample groups. The test criteria are as follows: if the probability value (sig.) is greater than = 0.05, H_0 is accepted; otherwise, H_0 is rejected. The results of the data variance homogeneity test of students' mathematical critical thinking abilities in the two learning groups can be seen in Table 3.

Table 3. Homogeneity Test

Test-Levene	**df1**	**df2**	**Sig.**
2,09	5	24	0,10

From the Table 3, It can be seen that the significant value of the homogeneity of the data variance of students who received learning using augmented reality media with Unity 3D (experimental class) and conventional learning (control class) was greater than 0.05. This implies that the null hypothesis is correct. Because the data on the two learning groups' mathematical critical thinking abilities meet the assumptions of data normality and variance homogeneity, the next step is to see if there is a significant difference in the average mathematical critical thinking skills of students who receive learning using augmented reality media with Unity 3D (experimental class) and students who receive conventional learning (control class). The calculation results are presented in Table 4.

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Table 4. Anova Test

	Sum Of Squares	Dk	Average Square	F	Sig.	H_0
Pembelajaran	1642,80	1	1642,80	54,69	0,00	Ditolak
Kesalahan	720,80	24	30,03			
Total	125678,00	30				

From the table 4, It is clear that the learning factors employed by each learning group have a significant impact on students' mathematical critical thinking abilities. This is demonstrated by the significance value obtained at 0.00, which is less than 0.05. This means that there is a significant difference in the average mathematical critical thinking skills of students who are taught using augmented reality media with Unity 3D (experimental class) and students who are taught using traditional methods (control class).

Researchers are concerned about several aspects of students' mathematical critical thinking skills at each stage of learning using AR during the learning process. Students looked closely at AR applications during the introduction stage. The AR application introduction stage introduces an overview of the application to be used as well as an explanation of how to use AR applications and the concepts to be studied. Students' roles in this stage are to observe, directly practice the application, and analyze the concept to be studied, AR media display can be seen in Figure 1.

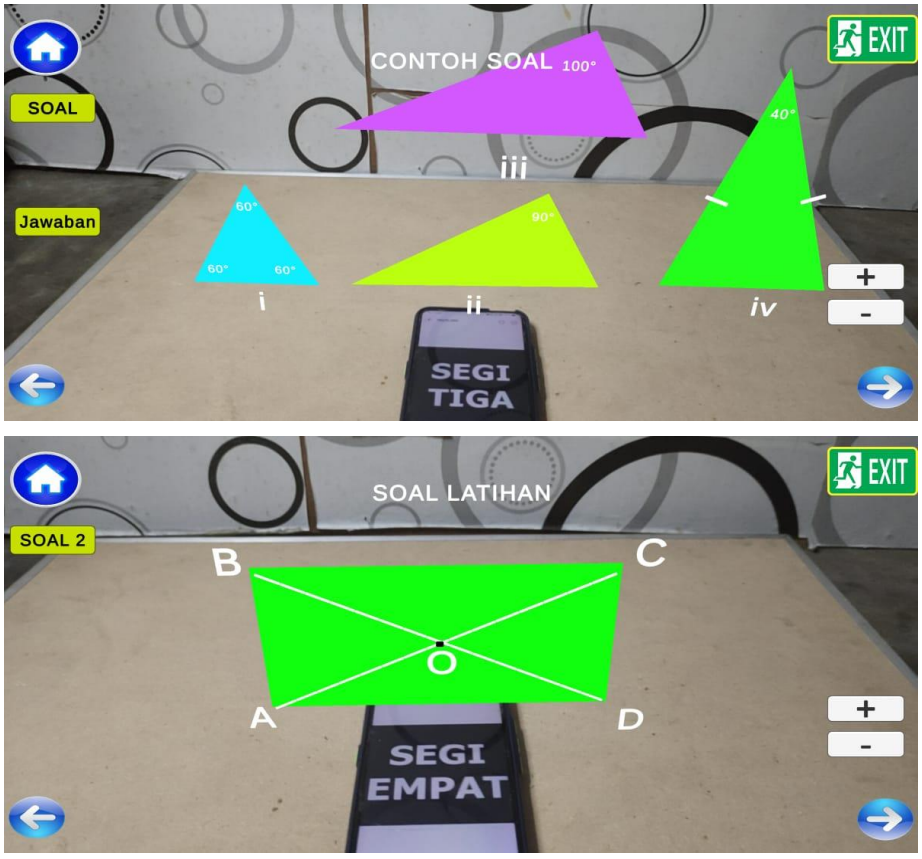

Figure 1. Tampilan *augmented reality* pada materi segitiga dan segi empat

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During the concept introduction stage of the AR application, student activities include discussing with friends nearby. Students are asked to discuss the characteristics of the concepts studied in order to identify them, and then to find concepts based on the characteristics they have discovered. The teacher's role here is to provide stimuli so that they can discover concepts on their own through interactive AR applications.

Furthermore, during the thinking strategies stage, students are asked to express the reasons for formulating the concept in their own words and write down the concept. Following the discussion, the teacher confirms the accuracy of the concepts being studied, so that students who are less precise in the process of finding their concepts through the AR application receive feedback on the errors they make. Documentation of the implementation of learning in the experimental class can be seen in Figure 2.

Figure 2. Implementation of learning in the experimental class

The main discussion in the learning process at the first meeting was about the types of triangles; on this subject, several groups were formed so that students could exchange opinions about the types of triangles. The main topic of discussion at the second meeting was rectangle types, more controlled learning, and the use of AR applications, which went better than at the first meeting. The learning progressed more quickly in subsequent sessions. The difficulties encountered are more in the course of working on the exercises. Many students who learn with augmented reality media in Unity 3D can answer the evaluation questions in the AR application.

Several issues concerning students' mathematical critical thinking skills are of concern to researchers during the learning process. The main topic of discussion at the first meeting was the different types of triangles; the students eagerly listened to the teacher's explanation. The topic of discussion at the second meeting was the different types of quadrilaterals, and the students'

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eagerness to learn was palpable. This is demonstrated by their discussion activities in response to some of the teacher's questions. Learning progressed more quickly in subsequent meetings. Documentation of the implementation of learning in the control class can be seen in Figure 3.

Figure 3. Implementation of learning in the control class

The constraints that students who are given conventional learning face are more about the perception process. When students who had received conventional learning were asked about the different types of triangles and quadrilaterals, they couldn't answer because they had forgotten. When the teacher asked about the different types of triangles and quadrilaterals, the experimental class responded quickly and precisely. This demonstrates that each individual's concept construction process can help students remember the material better than the teacher's explanation.

Based on the results of the students' mathematical critical thinking ability test, it was discovered that some errors were made by students with low and moderate KAM who received learning using augmented reality media with Unity 3D, despite the fact that the teacher always corrects the mistakes students make during learning. This is evident when students answer questions about mathematical critical thinking skills on the final exam. An example of experimental class mathematical critical thinking test answers with errors in the critical thinking ability test. can be seen in Figure 4.

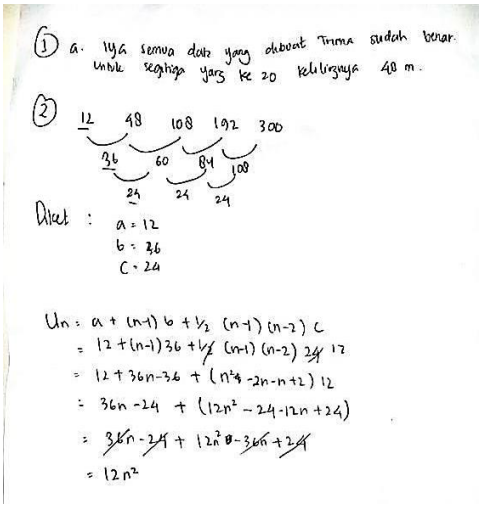

Figure 4. Experimental class critical thinking test answer results

The following indicators of critical thinking skills were used in this study: (1) the ability to identify relevance, in which students collect information that is known and asked, and (2) the ability to identify keywords

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contained in mathematical problems. This means that students' ability to recognize relevance is good; (2) students' ability to formulate problems into mathematical models is good; in this ability, students identify the relationship between parts of the problem by linking related information; and students also link problems with other materials that will be used in solving. Students understand when substituting numbers into the formula they use when using the general formula for the multilevel number U n pattern to answer questions. Students think creatively to solve the mathematical problems contained in the problem; (3) the ability to deduce using principles, demonstrating that students met the critical thinking indicators. However, students are careless in their conclusion because they forget to write down the information beginning with how many. However, students can respond to it when interviewed.

This is evident from the overall average acquisition of mathematical critical thinking skills obtained by the experimental class, which is 69.33, indicating that the average critical thinking ability in the experimental class is higher than the average critical thinking ability in the control class, while the b. One of the examples of control class mathematical critical thinking test answers can be seen in Figure 5.

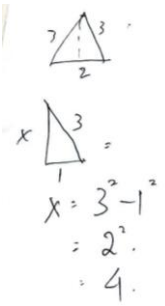

Figure 5. Control class critical thinking test answer results

According to the answers above, students did not meet the critical thinking skills indicators used in this study: (1) the ability to identify relevance, in which students collect information that is known and asked, but students cannot identify keywords contained in mathematical problems. Students do not understand what is being asked in the question, implying that students' ability to identify the relevance of the question is poor; (2) students' ability to formulate problems into mathematical models is poor; in this ability, students identify the relationship between the parts of the problem by linking interconnected information, and students also relate the problem to the material that will be used in solving. Based on the interviews, students knew that the question required them to find the area of a triangle and that they had previously looked for the height of a triangle, but they were incorrect when using the Pythagorean formula and the formula for the area of a triangle. Students are also aware that the questions make use of mathematical logic concepts, but they do not understand these concepts, so their answers are incorrect. (3) the ability to deduce using principles; students do not meet the critical thinking indicators on questions in this ability because they do not understand the concepts of mathematical logic, so they are incorrect in compiling the steps they use in solving problems and drawing inappropriate conclusions.

Critical thinking skills can be improved through the use of AR media, and AR media can aid in the achievement of learning objectives. The use of AR media in learning is beneficial for delivering knowledge and skills, as well as stimulating students' attention and interest, resulting in more

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directed and controlled learning (Kayano, 2020; Mustaqim, 2016; Mustaqim & Nanang, 2017; Prasetyo & Sutopo, 2018; Sidik & Vivivanti, 2021; Yang et al., 2018). Augmented Reality (AR) is a technology that integrates two-dimensional or three-dimensional virtual objects into real-world settings and then projects these virtual objects in real time (Mahendra, 2016; Muntahanah et al., 2017; Nurhasanah & Putri, 2020; Rachmanto & Noval, 2018; Rusnandi et al., 2016). AR operates on three principles: it is a merger of the real and virtual worlds, it is interactive and real-time, and it integrates objects in three dimensions, namely virtual objects that are integrated in the real world. The principles of augmented reality (AR) greatly aid the learning process, which aids in the development of students' critical thinking skills, particularly in flat shapes (triangles and quadrilaterals).

CONCLUSIONS & RECOMMENDATIONS

Based on the results of data processing, analysis, and discussion presented in the previous chapter, the following conclusions are reached: Increasing students' mathematical critical thinking skills through augmented reality media with Unity 3D is superior to increasing students' mathematical critical thinking skills through conventional learning overall. Furthermore, the effect of the interaction between the learning used and early mathematical abilities in each learning group on students' mathematical critical thinking ability must be examined.

During the learning process, the researchers saw that male students were more enthusiastic about using AR media; their enthusiasm was evident from: 1) their being more active in asking questions; 2) their being more enthusiastic about going forward to explain the results of solving the questions given; and 3) their being more enthusiastic about moving AR applications. This is the researcher's thought: that it is necessary to pay attention to the gender factor in the implementation of learning using AR media, especially to improve students' critical thinking skills. This is also in line with the theory that gender factors also influence student learning outcomes.

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