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Research Article

Improving critical thinking skills through a Problem Based Learning (PBL) Approach based on Augmented Reality (AR) at SMAN 1 Seunuddon

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ABSTRACT

This research aims to explore improving students' critical thinking skills through the application of the Problem Based Learning (PBL) learning model assisted by Augmented Reality (AR) technology. The research method used was an experiment with a quasi-experimental design, involving two sample groups, namely the experimental group that applied the AR-assisted PBL model and the control group that followed conventional learning methods. This research sample consisted of 60 high school students who were selected purposively. The instrument used in this research is a critical thinking skills test which has been tested for validity and reliability. The results of the validity test show that all question items are valid with a coefficient above 0.6, while the reliability test shows a Cronbach's Alpha value of 0.87, which indicates high reliability. The results of the question difficulty level test show that the questions used are in the moderate category, and the question discrimination power test shows that there is good variation in differentiating students based on their ability level. The data normality test showed that the two groups (experimental and control) were not normally distributed, so data analysis continued using the Mann-Whitney non-parametric test. The results of this statistical test show a significance value of 0.00, which means there is a significant difference between the experimental group and the control group in improving critical thinking skills. This research concludes that the application of the Problem Based Learning learning model assisted by Augmented Reality (AR) can significantly improve students' critical thinking skills.

Keywords: Problem Based Learning; Augmented Reality; Critical Thinking Skills

1. INTRODUCTION

In the era of industrial revolution 4.0, Indonesia experienced an increase in technology and human resource skills through education by producing young analysts for the advancement of education in Indonesia (Muliana. et al., 2024). Educational progress has a very important role in human life skills so that it influences Human Resources (HR) in all aspects of personality and life (Napitupulu et al., 2023). Therefore, quality education has a big influence on improving human life skills. This aims to create superior human resources that are able to survive in the face of changing times. Currently is an era known as the era of developing science, one of which is technology and information which is developing rapidly in all aspects of life (Mardhiyah et al., 2021). This does not escape the world of education. Therefore, in preparing students who are able to keep up with the times, students are equipped with the 4C skills, namely creative thinking skills, critical thinking and problem solving, communication and collaboration. (Redhana, 2019) and (Yochebed, 2019). Jobs in the future will not only require technical skills, but also the ability to solve problems, think critically, and innovate to remain relevant and competitive (Muliana and Hayatun Nufus, 2020).

Based on the results of observations and interviews at SMA 1 Seunuddon, North Aceh, information was obtained that the critical thinking skills of students at this school were still not optimal. Other information obtained is that there are still many teachers who use conventional learning models which focus on the lecture method in learning, so that students are less active and get bored easily during the learning process. This conventional learning model also causes a lack of use and utilization of technology by teachers during the learning process. The results of these observations and interviews require creative and innovative solutions because currently learning does not only teach routine and monotonous things, but what is needed is a complex of communication, collaboration, innovation, and solving problems (Widodo, 2020). Furthermore, in current learning activities, teachers are expected to be able to collaborate technology in the learning process (Handayani et

al., 2022). the application of critical thinking modules that are integrated with students' local culture is considered very important in the learning process (Muliana et al., 2023). Therefore, one solution to this problem is to provide a learning approach that suits students' needs and also collaborates with technology in the learning process. The learning approach used is the Problem Based Learning (PBL) approach or better known as the problem solving based approach. By using this model, students are more actively involved in the thinking process and learning activities, students can exchange ideas to understand subject concepts, and student learning outcomes increase (Muliana et al., 2022).

Problem Based Learning (PBL) is a learning approach that prioritizes solving real problems as a means for learning (Isfayani & Muliana, 2024). Problem Based Learning is a form of learning that is based on the constructivist paradigm, which is oriented towards the student learning process (student-centered learning) (Mayasari et al., 2022). Problem Based Learning focuses on presenting a problem (real or simulated) to students, then students are asked to find a solution through a series of research and investigations based on theories and principle concepts they have learned from various sciences. Problems as a focus, stimulus and guide to the learning process. The characteristics of PBL according to (Arifudin, 2020) are as follows: 1). Learning is student-centered, namely the PBL learning process focuses more on students as learning people. 2) Authentic problems form the focus of organizing for learning, namely the problems presented to students are authentic problems. 3) New information is acquired through self-directed learning, namely students try to find information through sources, whether from books or other information. 4) Learning occurs in small groups, namely carried out in small groups. 5) Teachers act as facilitators, namely teachers only act as facilitators.

Teachers act as facilitators, that is, teachers only act as facilitators. According to Eni Wulandari in (Agustina, 2018), the PBL approach can develop creative thinking skills and critical thinking skills, apart from that, this approach also provides opportunities for students to apply knowledge to the real world. Furthermore, it is hoped that current learning can be collaborated with technology, one of which is Augmented Reality (AR). Augmented Reality (AR) is a technology that can be applied in the world of education which can stimulate students' mindsets in thinking critically about problems and events that occur in the environment or everyday life (Aditama et al., 2021). Therefore, it is hoped that the PBL approach based on Augmented Reality (AR) can be a solution that can improve students' 4C skills which are not yet optimal. AR, when used in problem-based learning, provides opportunities for students to apply the knowledge they learn in more dynamic and contextual situations (Phasa, 2020). The use of AR in a PBL context allows students to visualize problems more clearly and in depth, so that students can more easily formulate solutions and think critically. AR can accelerate the development of critical thinking skills if used in a problem-based learning approach (Masrinah et al., 2019). The application of PBL in education has been proven to provide various benefits, such as increasing student learning motivation, developing critical thinking skills, and better ability to apply knowledge in real situations (Muliana et al., 2024). The use of AR in problem-based learning situations not only increases understanding of concepts, but also supports the development of critical thinking skills, because students are encouraged to evaluate and reflect on the solutions that students find (Rahmatia, 2020). Based on the background above, a research will be carried out with the title "Improving critical thinking skills through a problem based learning approach based on Augmented Reality (AR) at SMA 1 Seunuddon.

2. RESEARCH METHOD

The model used in this research is experimental research. According to (Sugiyono, 2019), experimental research is a method used to find the effect of certain treatments on results under controlled conditions. The parameters measured in this research are: Increased Critical Thinking skills. The research place is the location where research takes place and where research data is obtained. The location of this research will be SMA 1 Seunuddon, North Aceh district. For sampel 60 Student. Sampling using purposive sampling. The research design used in this research is Quasi experimental in the type of Nonequivalent control group design in the form of a Posttest Only Control Design. According to (Sugiyono, 2019) Quasi experimental is a type of experimental research, but in its implementation it does not use random assignment but instead uses pre-existing groups. In this research, a Critical Thinking skills test will be given at the beginning (pretest) after the treatment (posttest) in order to compare and see improvements between groups that were given learning treatment using the Problem Based Learning approach based on Augmented Reality (AR) and those given conventional learning treatment. The following is presented the design used in this research (Sugiyono, 2019):

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experiment	O_1	X_1	O_3
Control	O_2	X_2	O_4

Information:

X1 = Learning uses a Problem Based Learning approach based on Augmented Reality (AR)

X2 = Learning using the Conventional model

O1 = Results of the experimental group's critical thinking skills pretest

O2 = Control group critical thinking skills pretest results

O3 = Posttest results of critical thinking skills of the experimental group

O4 = Control group critical thinking skills posttest results

2.1 Data Collection Techniques

According to Sugiyono (2019) the collection technique aims to obtain data for research. The data collection technique used in this research was a written test. The research instrument is a tool used to measure research variables Sugiyono (2019). The instruments used in this research consisted of instruments, namely critical thinking skills instruments.This instrument will be used in accordance with the indicators in mathematics subject matter. The instrument analysis used is the validity test, reliability test, and difficulty level test and different power test.

2.1.1 Validity Test

Validity test is a test used to show the validity or validity of a research instrument (Arikunto, 2020). In this research, the validity test will be carried out on the numeracy literacy ability test items. The validity test will be carried out using the SPSS version 26 software computer program. Modification (Arikunto, 2020) The criteria used to determine the validity of the question items in **Table 2**.

Table 2. Validity Criteria of the Question Item

Correlation Coefficient	Criteria
$0,80 \leq r_{xy} \leq 1,00$	Very high
$0,60 \leq r_{xy} < 0,80$	High
$0,40 \leq r_{xy} < 0,60$	Enough
$0,20 \leq r_{xy} < 0,40$	Low
$0,00 \leq r_{xy} < 0,20$	Very Low
$r_{xy} < 0,00$	Invalid

2.1.2 Reliability Test

Question reliability is related to a set of questions if tested on the same subject repeatedly, showing the stability of the results. Reliability shows that a research instrument is trustworthy enough to be used as a data collection tool (Arikunto, 2020). The reliability test will be carried out using the SPSS version 26 software computer program. The criteria used to determine the reliability of the question items are as **Table 3**.

Table 3. Reliability Criteria of the Item Problem

Reliability index	Reliability Criteria
$0,90 \leq r11 \leq 1,00$	**Very high**
$0,70 \leq r11 < 0,90$	**High**
$0,40 \leq r11 < 0,70$	**Enough**
$0,20 \leq r11 < 0,40$	**Low**
$0,00 \leq r11 < 0,20$	**Very Low**

2.1.3 Difficulty Level Test

The difficulty level of a question is a tool that determines whether a question item is classified as easy, medium or difficult. The difficulty level test will be carried out using the SPSS Software version 26 computer program. Modification (Arikunto, 2020) The criteria used to determine the difficulty level of the questions in **Table 4**.

Table 4. Difficulty level

Index of Difficulty	Question category
$TK \leq 0,30$	Difficult
$0,31 \leq TK < 0,70$	Currently
$TK \geq 0.71$	Very Low

2.1.4 Different Power Test

Discriminating power is a measurement of the extent to which a question item can differentiate students who have mastered the competency from students who have not mastered the competency. The differential power test was carried

out using the SPSS version 26 software computer program. Modification (Arikunto, 2020) The criteria used to determine the differential power of question items are in the **Table 5**.

Table 5. Differentiating Power Criteria

Different Power of Question Items	Criteria
DP ≤ 0,20	Low
0,21 ≤ DP ≤ 0,40	Fair/Moderate
0,41 ≤ DP ≤ 0,70	Good
0,71≤ DP ≤ 1,00	Very well

2.1 Data analysis

2.2.1 N-gain test

To see an increase in critical thinking skills through the Problem Based Learning approach based on Augmented Reality (AR), you can use the normality gain test with the N-gain score formula. The formula for the N-gain test is as follows

$$\text{N} - \text{gain} = \frac{\text{Skor Posstest} - \text{skor pretest}}{\text{skor ideal} - \text{skor pretest}}$$

The N-gain score category can be determined from the N-gain value or from the N-gain value in the form of a percentage (%). (Hake, 1999) The division of N-gain value acquisition categories is as follows:

Table 6. N-Gain Value

N-gain value	Category
$\boldsymbol{g > 0,7}$	**High**
$\boldsymbol{0,3 \leq g \geq 0,7}$	**Middle**
$\boldsymbol{g < 0,3}$	**Law**

2.2.2 Normality Test

The normality test is used to test whether data is normal or not in a normal distribution. This research uses SPSS software version 26 to test the normality of the data obtained. The provisions for the significant value of the normality test used in this research are as follows:

If the value is significant or sig ≥ 0.05, then H1 is accepted (data is normally distributed).

If the value is significant or sig < 0.05, then H0 is accepted (data is not normally distributed).

2.2.3 Homogeneity Test

The homogeneity test is used to test whether the data is homogeneous or not. If the data is homogeneous then the next stage of data analysis will be carried out. The homogeneity test will be carried out using SPSS software version 26. The provisions for the significance level of the homogeneity test used in this research are as follows.

If the value is significant or sig ≥ 0.05, then the data has the same variance or is homogeneous.

If the value is significant or sig < 0.05 then the data does not have the same variance or is not homogeneous.

2.2.4 Non-parametric Test

Non-parametric tests are used to test statistical data if the data is not normally distributed or homogeneous. The non-parametric test used in this research is the Mann-Whitney U Test.

2.3 Hypothesis Testing

Hypothesis testing in the research was carried out on the experimental class and control class groups. The technique that will be used to test the hypothesis of the parametric statistical formula with a t-test based on the normality test and homogeneity test is by using the equality of two means test to compare the two average values of the initial test value with the final test in each group. This hypothesis testing can be done using SPSS version 26 for Windows software. With the following test criteria:

If the p-value (Sig. 2-tailed) > 0.05, H0 is accepted and H1 is rejected

If the p-value (Sig. 2-tailed) ≤ 0.05, H0 is rejected and H1 is accepted

The formulation of the statistical hypothesis in this research which is based on the results of the t test on the posttest value is as follows:

Information:

$$H_1 : \mu_1 > \mu_2$$

$$H_0 : \mu_1 \leq \mu_2$$

H_0: There is no increase in critical thinking skills through the Problem Based approach Learning based on Augmented Reality (AR) SMA 1 Seunuddon.

H_1: There is an increase in critical thinking skills through the Problem Based Learning approach based on Augmented Reality (AR) SMA 1 Seunuddon.

2 RESULTS AND DISCUSSION

The results of validity testing show that all question items used in this research have adequate validity values, with a validity coefficient greater than 0.6. This indicates that each question can measure what it should measure accurately. In addition, the reliability test shows that the test instrument has a very good level of consistency, with a Cronbach's Alpha value of 0.87, which shows that this test is very reliable for use in research. When testing the difficulty level of the questions, the results showed that most of the questions were in the moderate difficulty category, which means the questions were quite challenging but could still be answered by the majority of students. Meanwhile, the results of the test on the discriminating power of the questions show that the test instrument has good variations in differentiating students' abilities, where the questions are effective in identifying differences in the level of critical thinking abilities between students.

This research aims to find out whether improving students' critical thinking skills through the Problem Based Learning approach based on Augmented Reality (AR) is better than students who use conventional learning models. This research was conducted at Seunuddon 1 Public High School, North Aceh Regency in the odd semester of the 2024/2025 academic year. This research was conducted in class X of SMA Negeri 1 Seunuddon involving two classes, namely class control) with a total of 30 students used as a class where the conventional learning model was applied. In this research, the material used is spatial construction material. The research was conducted by giving a pretest of critical thinking skills to students, with the aim of finding out students' initial critical thinking skills. The pretest is given by giving a written test in the form of a critical thinking ability test. The test instrument used in the pretest was an instrument modified from several related previous research sources. Next, after giving the pretest, it continues with the application of the learning model in accordance with the research design. Then proceed with giving a critical thinking skills posttest. The test instruments used in the posttest are the same as those used in the pretest. Furthermore, the pretest and posttest results obtained research data in the form of quantitative data which will then be processed using SPSS version 26 to determine the results of the hypothesis in this research.

3.1 N-Gain Data Hypothesis Testing Students' critical thinking skills

To determine the improvement in students' critical thinking skills when applying the Problem Based Learning approach based on Augmented Reality (AR) and using conventional learning models, hypothesis testing is required. Hypothesis testing includes prerequisite testing which is then continued to hypothesis testing, namely as follows:

3.1.1 N-Gain Data Normality Test

The normality test is carried out to determine whether the N-Gain data obtained is normally distributed or not. Based on the N-Gain data for critical thinking skills that have been calculated previously, the following are the results of the N-Gain data normality test carried out.

Table 7. N-Gain Data Normality Test

	Class	Df	Statistic	Sig
N-Gain Results of Students' Critical Thinking skills	Experimental class	30	0,104	0,200
	Counter class	30	0,175	0,020

Based on **Table 7**, the normality test results obtained for the critical thinking experimental class of students in the experimental class were normally distributed, while the N-Gain data for critical thinking skills of control class students was not normally distributed.

3.1.2 N-Gain Data Hypothesis Testing

After testing the prerequisite hypotheses, it was found that the normality of the control class N-Gain data was not normally distributed. Therefore, hypothesis testing was continued using non-parametric hypothesis testing in the form of the Mann Whitney U test. The following are the results of the Mann Whitney U test hypothesis which was carried out on

N-Gain data on students' critical thinking skills.

Table 8. Hypothesis Testing N-Gain Data for Students' Critical Thinking Skills

N-Gain results of students' critical thinking skills	Mann-Whitney U test	Asymp Sig. 2-tailed
	22.0	**0,00**

Based on Table 8, the results obtained from the Mann-Whitney U test calculation of N-Gain data on students' critical thinking skills, with Asymp Sig. 2-tailed of 0.00. In accordance with the hypothesis testing criteria, where if Asymp Sig. 2-tailed ≤0.05 then H1 is accepted. Based on these criteria, it can be concluded that improving the critical thinking skills of students who use the Problem Based Learning approach based on Augmented Reality (AR) is better than the critical thinking skills of students who use conventional learning approaches.

3.2 AR-assisted Problem Based Learning to improve Critical Thinking Skills

Improving Critical Thinking Skills Through a Problem Based Learning Approach Based on Augmented Reality (AR) at SMA 1 Seunuddon in Mathematics Subjects in Geometry Material aims to explore how innovative learning methods can help students develop critical thinking skills, especially in understanding geometric concepts. often considered abstract and difficult to understand. This research was carried out at SMA 1 Seunuddon, with a focus on the application of Problem Based Learning (PBL) combined with Augmented Reality (AR) technology to make geometry learning more interactive and interesting. In this research, the first step was to develop a test instrument to measure students' critical thinking skills. The instrument is tested to ensure its quality, including validity, reliability, discriminating power, and the level of difficulty of the test questions. The validity of the instrument shows that the questions are relevant to the research objectives, namely to measure critical thinking skills in geometry material. In addition, test reliability shows that the test questions provide consistent results, whether used in retesting or in other classes. The differentiating power of the questions is also quite good because it is able to differentiate between students who have high and low critical thinking skills. The difficulty level of the questions is adjusted to suit the student's ability level, not too easy or too difficult.

After the instrument is tested and declared feasible, the test questions are used to measure students' critical thinking skills through pretest and posttest. This research involved two class groups. One group was taught using an AR-assisted PBL approach, while the other group used conventional learning methods. Before treatment, both groups were given a pretest to measure students' critical thinking skills, and after the learning process was completed, they were given a posttest to measure the extent to which students' critical thinking skills had improved. The results of the pretest and posttest were then analyzed using the N-Gain method to measure changes in critical thinking skills. N-Gain provides information about how much critical thinking skills have increased between pretest and posttest, with high, medium and low categories based on the N-Gain value obtained. The N-Gain calculation provides a clear picture of whether the application of AR-assisted PBL is effective in improving students' critical thinking skills.

Next, to verify whether the data from the pretest and posttest are normally distributed or not, a normality test is carried out. The results of the normality test show that the data from both classes, both those using AR-assisted PBL and those using conventional learning, are not normally distributed. Because the data was not normally distributed, a non-parametric statistical test was used to compare the two groups, namely the Mann-Whitney U Test. The results of the Mann-Whitney U Test show a p value = 0.00, which is smaller than 0.05, which means there is a significant difference between the group that uses AR-assisted PBL and the group that uses conventional learning. In other words, the application of the AR-assisted PBL approach has a significant positive influence on improving students' critical thinking skills, especially in learning geometry.

Many students find it difficult with these concepts because of their abstract nature, especially when they have to describe or visualize geometric shapes in three-dimensional space using only pictures on the blackboard or textbook (Farisi et al., 2017). AR, which allows students to see geometric objects directly in three dimensions in the real world, can be an effective solution to overcome this problem. Basically, PBL is a learning method that focuses on solving real world problems (Kusumawati et al., 2022). Students are not only given theories or mathematical formulas, but are faced with a problem that students must solve by applying the knowledge that students have learned. In the context of geometry material, the problems given can be practical challenges involving geometric concepts that are difficult to understand, such as calculating the volume of a spatial figure or determining the surface area of an object.

To improve the learning experience, AR-assisted PBL is used to visualize geometric concepts in the form of three-dimensional objects that can be viewed and studied directly via devices such as smartphones or tablets (Rahmatia, 2020). By using AR-assisted PBL, students can see and interact with 3D models of geometric shapes, such as cubes, spheres, prisms, or pyramids, that appear in the real world on the student's device screen. Students are learning how to calculate the volume of a block, students can use the AR application to see the block model in the student's classroom.

Students can manipulate the blocks to rotate, enlarge, or reduce to better understand the relationship between length, width, and height. With visualizations like this, students can immediately see how changes in size on one side affect the overall volume, which helps students understand this concept more easily.

The application of AR-based PBL in geometry classes is when students are given the task of designing a garden with various geometric shapes, such as cubes, blocks and tubes. Students must calculate the volume and surface area of each spatial figure that students choose to include in the garden design. In the process, students use the AR application to view 3D models of the objects that students choose. Determining the volume of a tube, students can see and rotate the tube in the classroom using AR devices. Students can measure the radius and height of the tube on the student's device screen, then calculate the volume using the formula they have learned. After that, students work in groups to discuss solutions and share student findings. Students not only calculate numbers, but also explain the student's thought process, why students choose certain formulas, how the relationship between geometric dimensions works, and how the AR application helps students understand the material. By using PBL and AR, this research can improve students' critical thinking skills. In this learning process, students are invited not only to look for the correct answer, but also to analyze, evaluate, and question every step that students take in solving problems. Through interaction with geometric objects in 3D form, students are expected to gain a deeper and more concrete understanding of the concepts they are learning.

3 CONCLUSION

This research shows that the application of the Problem Based Learning (PBL) learning model combined with Augmented Reality (AR) technology can significantly improve students' critical thinking skills.

RECOMMENDATIONS

There are several suggestions that can be given to related agencies and future researchers to develop or expand the application of this method:

1. Schools and educational institutions can consider integrating Augmented Reality (AR) in the curriculum.
2. Teachers need to be given special training regarding the use of AR technology in learning.
3. Educational institutions or educational material developers can work together to design and develop AR-assisted learning modules that suit various topics in mathematics and other subjects.
4. Future researchers can also conduct research by exploring various applications and different types of AR technology.
5. Future research could also test the application of AR-assisted PBL in other subjects, besides mathematics, such as science, history, or even languages.
6. Future researchers can expand the scope of this research by involving more schools or educational institutions from various regions and backgrounds.

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AUTHOR'S CONTRIBUTIONS

The authors of this article contributed to several important aspects of this research. First, the author is responsible for designing and developing the research design, starting from selecting the Problem Based Learning (PBL) approach assisted by Augmented Reality (AR) to preparing test instruments to measure students' critical thinking skills in geometry material. The author also carried out data analysis, including N-Gain calculations, normality tests, and the Mann-Whitney U test to analyze the research results statistically. Apart from that, the author also played a role in compiling and writing this article, organizing research findings, and connecting them with relevant literature to provide a comprehensive picture of the effectiveness of using AR-assisted PBL in improving critical thinking skills. It is hoped that the author's contribution can provide new insights for the development of innovative learning methods and their application in mathematics education.

CONFLICT OF INTEREST

The author states that in this research there are no conflicts of interest that influence the results or research process. All research steps were carried out objectively and independently, without any influence from any party that could affect the integrity and reliability of the results of this research. This research is completely based on valid data and transparent analysis for the sake of academic interests and scientific development.

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