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The Effect of Augmented Reality-Assisted Problem Based Learning on Mathematical Reasoning Ability

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Abstract: The Effect of Augmented Reality-Assisted Problem-Based Learning on Mathematical Reasoning Ability. Objectives: This study aimed to determine the effect of Problem-Based Learning (PBL) models-assisted Augmented Reality (AR) on mathematical reasoning abilities (MRA)**. Methods:** This study used a quasi-experimental post-test-only control group research design. The research sample consisted of 34 students in the experimental class and 36 students in the control class who were selected using a purposive sampling technique. The research instrument was a essay test analyzed using IBM SPSS 27 and Winstep. **Findings:** The findings indicate a significant difference between the experimental and control classes with the Mann-Whitney U-test Asymp. Sig. 0.00 while the results of Cohen's d effect size were obtained at d = 1.54. Furthermore, the Wright maps that the percentage of MRA is high (14%), medium (76%) and low (10%). **Conclusion:** Students who receive the application of the PBL models-assisted AR become more active, able to solve given contextual problems well and are more innovative in expanding their knowledge related to mathematical material.

Keywords: problem based learning, augmented reality, mathematical reasoning ability.

Abstrak: Pengaruh Model Problem-Based Learning Berbantu Augmented Reality Terhadap Kemampuan Penalaran Matematis. Tujuan: *Tujuan dari penelitian ini adalah untuk mengetahui pengaruh model Problem Based Learning (PBL) berbantu Augmented Reality (AR) terhadap kemampuan penalaran matematis (MRA).* ***Metode:*** *Desain penelitian ini adalah quasi-experimental post-test-only control group design. Sampel penelitian sebanyak 34 siswa di kelas eksperimen dan 36 siswa di kelas kontrol yang dipilih menggunakan teknik purposive sampling. Instrumen penelitian ini berupa tes uraian yang dianalisis menggunakan IBM SPSS 27 dan Winstep.* ***Temuan:*** *Temuan ini menunjukkan perbedaan yang signifikan antara kelas eksperimen dan kelas kontrol, dengan Mann-Whitney U-test menghasilkan Asymp. Sig. 0,00 sedangkan hasil Cohen's d effect size diperoleh d = 1,54. Selanjutnya, peta wright menunjukkan bahwa persentase MRA tinggi (14%), sedang (76%), dan rendah (10%).* ***Kesimpulan:*** *Siswa yang mendapat penerapan model PBL berbantuan AR menjadi lebih aktif, mampu memecahkan masalah kontekstual yang diberikan dengan baik, dan lebih inovatif dalam memperluas pengetahuannya terkait dengan materi matematika.*

Kata kunci: *pembelajaran berbasis masalah, augmented reality, kemampuan penalaran matematis.*

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INTRODUCTION

Mathematical reasoning is defined as the basic abilities possessed by students in designing, solving problems, and practicing thinking to make logical conclusions in proving the truth of factual mathematical statements (Juandi & Tamur, 2021; Kollosche, 2021; Negara et al., 2022). Furthermore, mathematics and reasoning abilities are linked because knowledge of understanding mathematics is obtained from reasoning and reasoning ability are obtained and guided by skills in understanding mathematical theory (Agustyaningrum et al., 2019; Faradillah et al., 2018; Kollosche, 2021; Siregar et al., 2020)

In solving problems, mathematics always requires logical and directed reasoning so that students can explore their ideas, determine appropriate mathematical expressions and principles andare accustomed to giving arguments by the facts presented in finding solutions (Putra & Ikhsan, 2019; Ramdhani et al., 2019; Sukendra, 2019). Therefore, the role of mathematical reasoning abilities (MRA) for students serves to assist teachers in providing a focus on learning topics in class, solving problems when arguing through open discussions by defending their ideas, then triggering assumptions about the issues given so that students can dig up additional information, then process drawing conclusions and assessing the truth so that students can find solutions and generate ideas through models, facts and systematically (Firdausy et al., 2021; Hanna, 2020; Jeannotte & Kieran, 2017; Mata-Pereira & da Ponte, 2017; Sari et al., 2020).

Under field circumstances, the total percentage of MRA is still low (48%); it can see indicators that make conjectures (20%), indicators that manipulate math (13%) and indicators that come to conclusions, gather evidence andprovide justifications or supporting evidence for the correctness of the answer (17%) (Aprilianti & Zanthy, 2019). Furthermore, other research resulted that students did not meet the indicators, drew conclusions from a statement andprovided credible arguments, each of which reached a proportion of 87.5% (Firdausy et al., 2021).

The inadequate MRA was produced by various factors, including (1) pupils' continued passive participation in learning activities; (2) they often forget the math material that had been discussed; (3) they cannot explore their ideas and are less thorough in solving mathematical problems; (4) still using the rote method in solving math problems; and (5) lack of development through appropriate learning models (Aprilianti & Zanthy, 2019; Sugiarti et al., 2020). One of the learning models used in the independent curriculum is the Problem-Based Learning (PBL) models.

The PBL models is a learning paradigm that efforts maximizing and involving students in a structured group work process so that students can utilize concepts, understand and solve issues andexplore and collect information relevant to a materials concept (Astriani et al., 2017; Lelapary, 2022).. In addition, learning that uses the PBL model is designed to strengthen, facilitate and increase students' creativity in solving problems and social skills in study groups (Aslan, 2021; Lelapary, 2022; Siagian et al., 2019; Tanjung et al., 2022; Wijayanti et al., 2022).

In the learning process in class, teachers can use the PBL models, which leads to the use of technology, mindset andthe relationship between mathematical ideas, there by helping students improve problem-solving (Boonmoh et al., 2021; Juandi & Tamur, 2021; Tanjung et al., 2022). One technology that can use in the PBL models is Augmented Reality (AR). AR is a technology that can collaborate between reality and virtual by presenting 3D objects by representing illustrations of 3D objects that are difficult to make accurate and more interesting, as well as providing knowledge related to subjects that can be considered complex, it can use as a learning strategy (Garzón & Acevedo, 2019; Ibáñez & Delgado-Kloos, 2018; Salinas & Mendívil, 2017). Therefore, the application of AR has succeeded in facilitating learning and encouraging students to carry out and enrich meaningful experiences and be able to foster constructive learning realities and is considered suitable in the application of science and can stimulate positive thinking (Cerqueira et al., 2019; Chen et al., 2017; Fidan & Tuncel, 2019; Garzón et al., 2019).

Several relevant studies are related to PBL models with the help of technology on MRA. First, research using the PBL models of mathematical reasoning, video scribe andlearning motivation shows that using video scribe learning materials in the classroom has a significant effect on students value Sig. 0,05, which boosts their enthusiasm for learning, influences the emergence of learning motivation andfacilitates mathematical reasoning in students (Wijayanti et al., 2022). Second, research on MRA and PBL models shows that applying the PBL models in learning mathematics significantly affects the value of Sig. 0.000 ($\alpha \leq$ 0.005) on students MRA, to be able to stimulate and force students to think highly in improving their MRA (Sari et al., 2020).

Third, research on AR, mathematics during Covid-19 and PBL models shows that learning that combines PBL models with AR-based student worksheet achieves individual and classical mastery and can improve the mathematical literacy skills of students who are included in the medium category, this has an impact on the independence of students in discovering mathematical concepts, increasing the interest and learning outcomes of students at all ages and increasing the activity of students in learning mathematics (Sholikhah & Cahyono, 2021) Fourth, research on communication skills, PBL, culture and AR shows that using the PBL models assisted by AR-assisted culture has the effectiveness of students mathematical communication abilities with a value of Sig. 0.001 ($\alpha <$0.005), so that the combination of AR-assisted culture in PBL models can improve students mathematical communication skills (Batubara et al., 2022). As with the relevant research above, it can conclude that the PBL models that utilizes technology through learning media AR produce significant results and can enhance students MRA.

As a result, a study gap exists because no research involving PBL models-assisted AR on MRA has been conducted. As the result of the study's novelty, the researchers want to know how the effect PBL models-assisted AR on mathematical thinking ability (MRA).

■ METHODS

Participant

In this study, class X in senior high school Jakarta served as the population. Two classes were used as the research group: the experimental class (34 students) and the control class (36 students). The sampling technique for this study was purposive sampling based on recommendations from mathematics teachers due to time limitations and the secrecy of school documents. The choice of this technique was due to certain constraints and considerations (Sugiyono, 2022).

Research Design and Procedures

This study used a quasi-experimental method with a quantitative methodology. The research design used a post-test-only control design, with two groups selected as experimental and control classes. The learning treatment will only be given to the experimental class (X_1) according to the lesson schedule and without changing the student's learning situation (Lelapary, 2022; Sugiyono, 2022). Then, O_1 and O_2 represent the experimental and control classes.

The process of implementing the treatment in this study used the application of the PBL models-assisted AR. The application of learning will use used PBL model with syntax namely, (1) Orienting students to problems, (2) Organizing students to learn, (3) Guiding individual and group investigations, (4) Developing and presenting works and(5) Analyze and evaluate the problem-solving process (Mustafa et al., 2019). This research was conducted from October 2022-March 2023.

Instrument

The research test instrument consisted of 6 test items describing MRA which had previously been tested for validity and reliability. The MRA indicator, which is the reference for this study, was adapted from relevant studies with the same meaning and purpose, namely, (1) performing calculations; (2) making predictions; and (3) drawing conclusions (Firdausy et al., 2021). Validity and reliability test of this instrument uses expert validation, has proven its validity and uses the Rasch model through Winstep software. Researchers use the Rasch models because it is considered appropriate to see the interaction of persons and items together so that the value indicates the suitability of the selected sample (Ölmez & Ölmez, 2019).

The data in this study was analyzed using Cohen's d Effect Size Test on IBM SPSS 27 software to compare the effect of the PBL models-assisted AR on MRA in the experimental and control classes. Before measuring the Cohen's d Effect Size Test, the researcher conducted the Mann-Whitney U-test because the resulting data was not normally distributed, namely the Sig. $<$0.05 (Bektiarso et al., 2021), this is done to determine whether there is a significant difference between the experimental and control classes.

Expert validity was conducted on two expert validators, mathematics education lecturers and mathematics teachers. Then it was tested on 108 students from class X at a senior high school Jakarta to measure the test instruments' validity and reliability. The validity test looks at the misfit item and person fit item, where the item and person are said to be valid if they meet at least two criteria (Puspitaningrum et al., 2021). Furthermore, Cronbach's Alpha (KR-20), Item and Person Reliability andItem and Person Separation are used to assessing the reliability test, where the test instrument can be said reliable if the KR-20 value is $>$ 0.70 (Barbera et al., 2021; Faradillah & Febriani, 2021).

Table 1. The result of validity and reliability test

	Validity		Reliability		
	Fit	Misfit	Reliability	Separation	KR-20
Item	6	-	0.69	1.48	0.71
Person	70	38	0.62	1.29	

Table 1 shows that all items are valid and suitable for use as instruments for testing MRA. The person fit that is accurate and timely for use as a sample is 70 out of 108 class X at senior high school Jakarta. This means the research test instrument data is said to be valid (Faradillah & Febriani, 2021; Puspitaningrum et al., 2021). In addition, the reliability test results also show that the value of the item reliability is higher than the person reliability, so it is considered sufficient. The item separation of 1.48 is higher than the person separation value of 1.29, so the description of this test instrument is of better quality. In the results of Cronbach's Alpha (KR-20), this data is included in the high criteria because the KR-20 $>$ 0.70 is 0.71. It demonstrates that the test instrument is reliable and suitable for a test of MRA (Faradillah & Febriani, 2021; Puspitaningrum et al., 2021).

Data analysis

The data in this study was analyzed using Cohen's d Effect Size Test on IBM SPSS 27 software to compare the effect of the PBL models-assisted AR on MRA in the experimental and control classes. Before measuring the Cohen's d Effect Size Test, the researcher conducted the Mann-Whitney U-test because the resulting data was not normally distributed, namely the Sig. $<$0.05 (Bektiarso et al., 2021), this is done to determine whether there is a significant difference between the experimental and control classes.

RESULTS AND DISCUSSION

Statistical descriptions seen using IBM SPSS 27 software according to the data on the results of the post-test scores of students in the experimental and control classes.

Table 2. Descriptive statistics data post-test score results

Indicators	Class	N	Min	Max	Mean	Std. Deviation	Percent
Performing Calculations	Experiment	34	40	100	77.06	14.466	71.4%
	Control	36	20	100	75.00	21.044	68.8%
Making Predictions	Experiment	34	20	100	70.88	17.815	63.6%
	Control	36	20	80	54.17	17.300	42.8%
Drawing Conclusions	Experiment	34	30	100	79.71	17.835	74.6%
	Control	36	20	90	32.78	19.944	16.0%
Valid N (listwise)		70					

Table 2 shows that each MRA indicator in the experimental class has better results than the control class. The overall average value of the experimental class > control class evidences this. Each indicator obtained an average value of >70 in the experimental class, indicating a high category (Ramdan & Roesdiana, 2022). In the control class, only indicators performing calculations are included in the high category, while indicators making predictions and drawing conclusions are included in the medium and deficient categories, respectively. Based on the findings showing that the MRA of students in the experimental class is superior to the control class, where the PBL models-assisted AR as a learning support medium can positively and effectively influence students according to their characteristics and interventions (Fidan & Tuncel, 2019; Garzón et al., 2020; Lelapary, 2022).

A prerequisite analysis test was carried out to determine the effect of the experimental class's MRA after applying the PBL models-assisted AR, with the control class which didn't give treatment (normality and homogeneity test) with a significant value $\alpha > 0.05$ (Bektiarso et al., 2021). The findings of the precondition analysis of the research data below.

Normality Test

By using the Kolmogorov-Smirnov method, the following table presents the results of the data normality test.

Table 3. Tests of normality using kolmogorov-smirnov

Class	Statistic	df	Sig.
Experiment	0.14	34	0.06
Control	0.24	36	0.00

a. Lilliefors Significance Correction

Table 3 shows the value of Sig. on Kolmogorov Smirnov in different experimental and control classes. In the experiment class the value of Sig. 0.06 ($\alpha > 0.05$), then the data is normally distributed. In the control class, it is 0.00 (0.05), indicating that the data is not normally distributed. It is by the normality test requirements of data normally distributed if 0.05 (Lelapary, 2022; Sugiarti et al., 2020). Because the data obtained were not normally distributed, the next step was to carry out the Mann-Whitney U-test. That is in line with research which shows that to the Mann-Whitney U-test was used to identify differences between experimental and control groups in data that were not normally distributed (Darhim et al., 2020).

Mann-Whitney U-Test

The Mann-Whitney U-test was used because the normality test results were not fulfilled as a parametric prerequisite test, necessitating a non-parametric test.

Table 4. Mann-whitney u-test results

	Post-test Score
Mann-Whitney U	157.00
Wilcoxon W	823.00
Z	-5.36
Asymp. Sig. (2-tailed)	0.00

Table 4 shows the value is obtained from Asymp. Sig. (2-failed) is 0.00 ($\alpha > 0.05$), then H_0 is denied and H_1 is accepted, meaning that there is a significant difference in the PBL models-assisted AR on students MRA in the experimental and control classes. It is in line with research which shows significant differences in the MRA of students who are given the application of the PBL models (Lelapary, 2022). Therefore, there is a significant difference; the research data indicates that the "PBL models-assisted AR affects MRA."

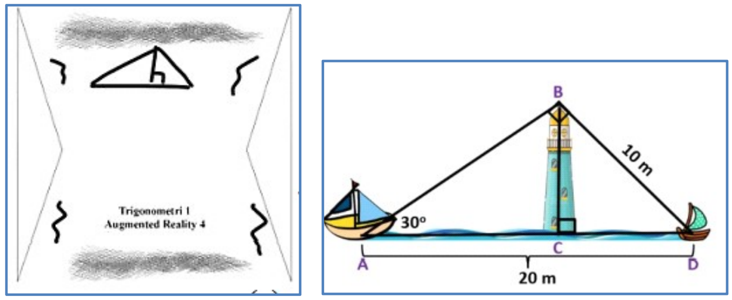
Hypothesis Test

In complementing the Mann-Whitney U-test data, a Cohen's d effect size calculation is carried out. The results of Cohen's d calculations on test instrument for MRA in two classes. The mean in the experimental class $= 71.06 > 44.78$ = mean control class. his means that the research hypothesis H_1 is accepted and H_0 is denied, implying that the PBL models-assisted AR significantly affects MRA with a difference in the average value of 26.28.

Then using Cohen's d an effect size test was performed andCohen's d value was obtained at $d = 1.54$ indicating that the effect of the PBL models-assisted AR on MRA is classified as very large ($ES > 1.2$) (Cohen, 1988; Sawilowsky, 2009). Research has shown that students MRA using the PBL models are more effective than conventional models (Sari et al., 2020).

Figure 1 shows the AR visualization used by researchers during learning activities. The existence of PBL models-assisted AR positively influences learning activities. It can be from a series of learning activities under the PBL models syntax carried out for five meetings.

Syntax activities orient students to ongoing problems, with the teacher explaining learning topics and directing and inviting students to identify



(a) (b)

Figure 1. (a) barcode AR (b) AR visualization

and formulate problems. The movement of organizing students for learning takes place with the teacher forming small groups to discuss a situation given through worksheets. The activity of guiding individual and group investigations took place with students actively asking the teacher about the worksheets provided and also being active in exchanging ideas with their group mates. Furthermore, developing and presenting the work results takes place by continuing discussion activities until a solution is obtained regarding the worksheets provided through the AR-assisted mathematics module or other relevant sources. In this activity, all students are encouraged to be able to plan appropriate solutions, present the results of their group discussions andrespond to and evaluate the presentation of the results of their conversations (Mustafa et al., 2019).

The last activity in the PBL models syntax is to analyze and evaluate the problem-solving process. In this activity, students are encouraged to actively examine and assess the results of other group discussions, where the teacher only guides and completes the information conveyed by the discussion group. The overall activity in the PBL model syntax encourages students to actively analyze, argue, formulate hypotheses, solve, discover, solve problems from the surrounding environment anddevelop their thinking by building work groups to achieve the goals of the learning process (Siagian et al., 2019; Suhirman et al., 2021).

The findings show that the presence of PBL models-assisted AR in learning has a positive and exciting impact on students in understanding and solving contextual problems (Fidan & Tuncel, 2019). Other findings are more specific, showing the effect of PBL models-assisted AR on a positive and significant increase in mathematical ability (Batubara et al., 2022).

Furthermore, the results of students answer in the experimental and control classes will be obtained by students with the highest and lowest post-test scores. The figure below depicts the results of student responses to the MRA test instrument.

Figure 2 shows the level of MRA of 70 respondents who gave answers from the given test instruments and then analyzed using the wright maps table in the Winstep software. In left column represents the categories of high (14%), medium (76%) and low (10%) levels of MRA, the number code represents the student coding, a letter code represents the gender code and code class, with P is female, L is male, E is the experimental class and C is the control class. Meanwhile, in right column shows item items with difficulty levels. Description of students' answers with high categories represented by S11PE, medium by S33LE and low by S48LC.

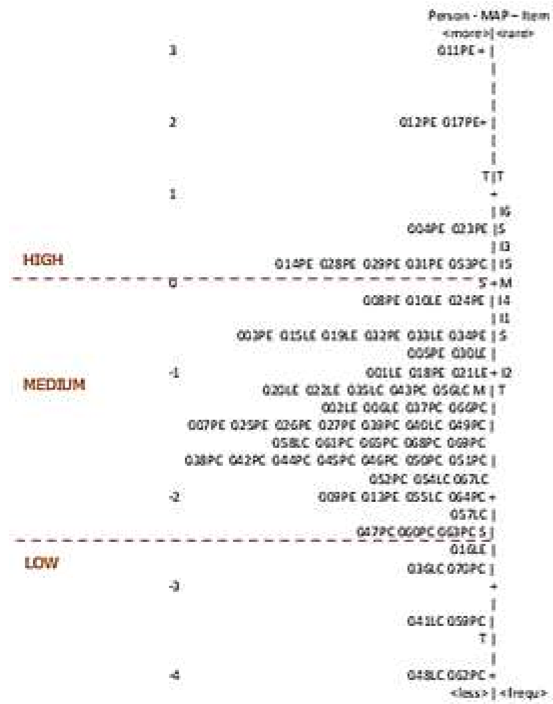
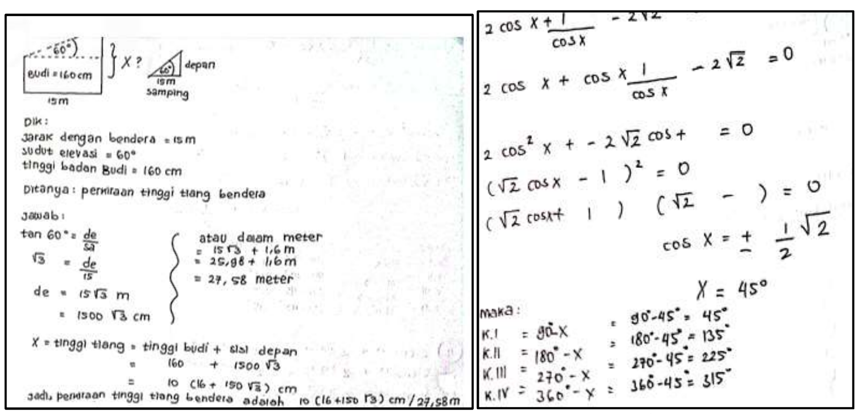
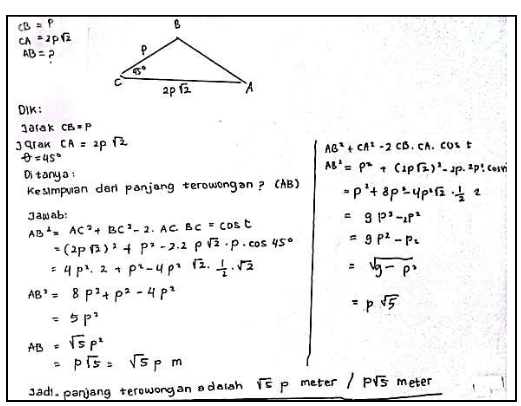


Figure 2. The level of mra with wright maps



(a) (b)



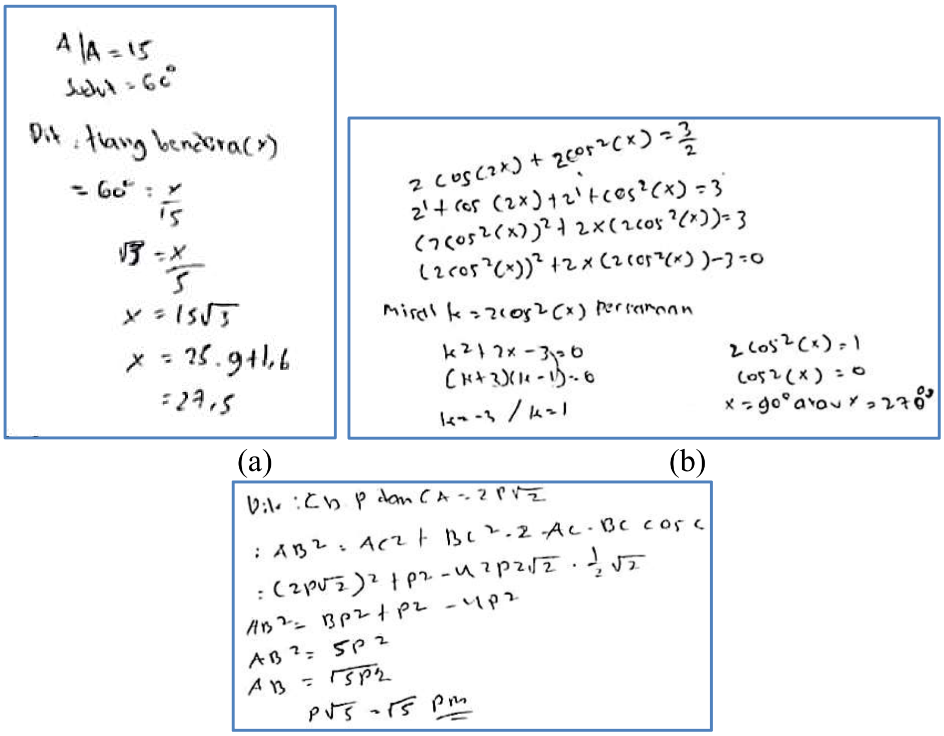
(c)

Figure 3. (a) Performing calculations (b) Making predictions (c) Drawing conclusions

The Result of S11PE

Figure 3 shows the results of students with code S11PE in the high category of MRA and are students who get the application of the PBL models-assisted AR. The results of the S11PE answers show complete and correct answers on the given posttest and meet all indicators of MRA. According to studies, students who fulfill each indicator and give accuratelete answers (Agustyaningrum et al., 2019). In addition, this also indicates that students can be faced with complex problems to make students more proficient in considering the right solution to the problem given (Aprilianti & Zanthy, 2019)

Result of S33LE



(a) (b)

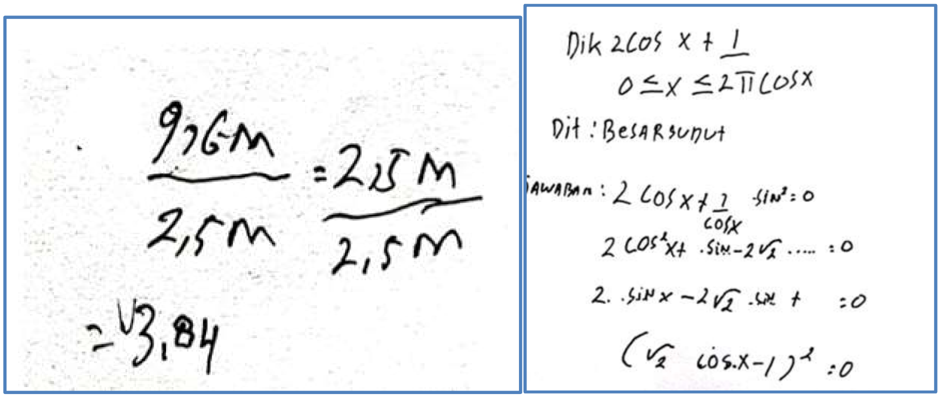
(c)

Figure 4. (a) Performing calculations (b) Making predictions (c) Drawing conclusions

Figure 4 shows the results of students with code S33LE in the moderate category of MRA and are students who get the application of the PBL models-assisted AR. The answers' results show correct replies but need complete all indicators on the post-test questions given. That is by research shows that students give valid arguments even though there are deficiencies (Agustyaningrum et al., 2019; Rizqi & Surya, 2017).

The Result of S48LC

Figure 5 shows the results of students with code S48LC in the low category of MRA and students who didn't get the the application of PBL models-assisted AR. S48LC can only solve two questions, but the arguments are not correct. These questions represent indicators of performing calculations and making predictions, while questions of indicators of drawing conclusions are unanswered. In the performing



(a) (b)

Figure 5. (a) Performing calculations (b) making predictions

calculations indicator, students misinterpret the answers to the questions presented, so the answers are wrong and need to provide better mathematical systematics. Furthermore, students could only offer one correct argument on the making predictions indicator, namely writing answers using mathematical systematics. Still, the answers given needed to be completed, so the calculation of the solution to the problem needed to be revised. That is in line with findings that show that students with low category reasoning ability provide incomplete arguments, no answers, or even only provide ideas/responses from completed solutions due to students ability to solve problems (Agustyaningrum et al., 2019). In addition, research has shown that MRA is low because students are still confused and do not provide clear answers (Sari et al., 2020).

Based on the analysis above, students who get the application of the PBL models-assisted AR dominate the medium and high categories. In comparison, the medium and low categories dominate by students who don't give treatment. In the low category, students still have difficulty solving questions and compiling answers ultimately. Efforts to overcome these difficulties are to use a learning model that can encourage students to obtain, select, store andsolve the problems they face and end with appropriate, exciting conclusions (Lelapary, 2022). That supports the findings, which show that learning using the PBL models can help students in all the solutions above so that students begin to be enthusiastic about achieving learning goals (Juandi & Tamur, 2021; Malmia et al., 2019). In addition, the PBL models-assisted AR significantly enhances and facilitates learning activities to solve problems and logical reasoning abilities (Batubara et al., 2022; Cerqueira et al., 2019; Fidan & Tuncel, 2019).

CONCLUSIONS

Based on the results and discussion above, the Problem-Based Learning (PBL) models-assisted Augmented Reality (AR) has a significant influence on students mathematical reasoning ability (MRA) with a Mann-Whitney U-test result value of 0.00 ($\alpha < 0.05$). Then, based on Cohen's d effect size students are included in the very large classification. It means that students in the experimental class have better MRA than the control class, where students in the experimental class dominate students with high-category MRA. Based on Wright Maps, it was found that students in the high, medium and low categories were students in the high and medium categories dominated by students in the experimental class who received mathematics learning by applying the PBL models-assisted AR. In contrast, the low category was dominated by students in the control class who did not received treatment. Therefore, students who received the application of the PBL models-assisted AR became more active, able to solve given contextual problems well were more innovative in expanding their knowledge related to mathematical material. Based on the results, the PBL models-assisted AR can be used as an innovation, strategy, and learning model for mathematics teachers and supported by appropriate learning media. Researchers suggest that we as teachers can continue to explore and integrate learning models with media that are more appropriate and creative in learning activities, especially learning mathematics.

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