

GEOGEBRA-ASSISTED PROBLEM-BASED LEARNING AND DIRECT INSTRUCTION MODELS ON MATHEMATICAL CRITICAL THINKING BASED ON ADVERSITY QUOTIENT

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ABSTRACT

GeoGebra-assisted PBL and DI models are expected to enhance students' mathematical critical thinking skills by providing interactive learning experiences, while AQ serves as a key factor influencing how students persist and perform in problem-solving situations. This study aims to analyze the effect of PBL and DI models, assisted by GeoGebra, on students' mathematical critical thinking based on AQ. The method employed is a quasi-experiment with a one-group pretest-posttest design and a 3×2 factorial design. Data collection was carried out through mathematical critical thinking tests, AQ questionnaires, observation sheets, and documentation. Data analysis used paired sample t-tests, and two-way ANOVA tests with the help of SPSS software. The results showed that PBL and DI assisted by GeoGebra had a significant effect on students' mathematical critical thinking, with a high influence category. PBL learning assisted by GeoGebra had a greater influence than DI assisted by GeoGebra, with an influence in the medium category. In addition, the AQ level in general did not show a significant difference in students' mathematical critical thinking, but the results of further tests showed that students with AQ Climber had higher mathematical critical thinking than AQ Camper and AQ Quitter, and AQ Camper was higher than AQ Quitter. There was no interaction effect between learning and AQ level on students' mathematical critical thinking. This finding indicates that GeoGebra-assisted PBL is more effective in students' mathematical critical thinking without being influenced by differences in AQ levels.

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INTRODUCTION

Mathematics education in the modern era requires students to master high-level thinking skills, especially critical thinking, as a basis for solving complex problems, making decisions, and analyzing information in depth (Facione, 2015; Trilling & Fadel, 2009). However, various studies show that students' critical mathematical thinking skills in Indonesia are still relatively low due to learning that tends to be teacher-centered and focuses on routine procedures (Mutiar

et al., 2024; Nurussalma et al., 2024). As a consequence, students exhibit decreased engagement in the process of investigating and exploring concepts that underpin the development of critical thinking. This situation necessitates educational innovations capable of enhancing student engagement, participation, and analytical skills within the mathematics learning process (Mutakinati et al., 2018).

One educational approach considered effective in fostering the development of critical thinking is Problem-Based Learning (PBL). PBL presents authentic, real-world problems as the initial foundation for learning, motivating students to investigate information, develop hypotheses, evaluate solutions, and engage in reflective practices (Arends, 2012; Engle, 1981). Through this process, students are faced with situations that require the application of concepts, logical reasoning, and the ability to make decisions independently, so that critical thinking can develop optimally (Bilgin et al., 2009).

Besides PBL, Direct Instruction (DI) is also a widely used learning model in mathematics. DI focuses on conveying concepts clearly, systematically, and step-by-step, helping students understand the procedures and steps for solving problems sequentially (Sekar, 2020). Although DI tends to be teacher-centered, this model is effective in improving procedural accuracy and basic mathematical understanding (Supartini, 2021), which is also an important element to support critical thinking processes at a higher level.

The use of learning technologies such as GeoGebra further strengthens the effectiveness of both models. GeoGebra allows for the visualization of concepts, the manipulation of mathematical objects, the exploration of graphs, and the dynamic observation of relationships between variables (Saha et al., 2010). With interactive displays, students can see parameter changes in real-time, test conjectures, conduct visual experiments, and understand abstract concepts more concretely (Bedada & Machaba, 2022). A recent meta-analysis shows that GeoGebra-assisted learning can significantly improve mathematical thinking skills, including critical thinking (Azis & Rohaeti, 2025).

However, learning success is influenced not only by models and media, but also by students' psychological characteristics, one of which is the Adversity Quotient (AQ). AQ pertains to a student's capacity to confront challenges, maintain perseverance under stress, and effectively address intricate learning obstacles (Astiantari et al., 2022; Putri & Mariyati, 2025). Students with high AQ tend to be persistent, optimistic, and better able to overcome learning obstacles, while students with low AQ tend to give up easily and avoid challenging math tasks. Because learning mathematics often demands mental stamina and the ability to cope with temporary setbacks, AQ is an important factor that can determine student achievement, especially in the context of critical thinking (Nurlaelah et al., 2021).

The interaction between learning models, digital media, and AQ is a key issue in mathematics education research. GeoGebra-assisted PBL is thought to be more effective for students with high AQ because it demands independence, exploration, and resilience in problem-solving. Conversely, GeoGebra-assisted DI may be more appropriate for students with low AQ who require directed instruction before tackling more complex tasks. However, research analyzing the relationship between these three aspects is still limited, especially in quantitative contexts, comparing the acquisition and improvement of mathematical critical thinking skills (Nasution, 2024).

Therefore, it is essential to undertake research that investigates the impact of PBL and DI models supported by GeoGebra on students' mathematical critical thinking in relation to AQ. This research is anticipated to offer both theoretical and practical contributions to the development of mathematics learning strategies that are tailored to students' cognitive and psychological needs, while also advancing scientific investigations into the integration of

learning models, technology, and personality traits within the framework of 21st-century education.

METHOD

This study used a quasi-experimental methodology featuring two designs, specifically a one-group pretest–posttest and a 3×2 factorial as elucidated by Gall et al., (2010). The research subjects were 11th-grade students at MAN 1 Medan. The sample selection was conducted using a nonprobability purposive sampling technique, which randomly determines the sample based on certain criteria that meet the research needs. The instruments used included a mathematical critical thinking test, an AQ questionnaire, an observation sheet, and documentation. The critical thinking test instrument was compiled based on four indicators, according to Facione (2015), namely: (1) interpretation, (2) analysis, (3) evaluation, and (4) inference. The AQ questionnaire was compiled based on the operational definition of the AQ concept that has been used in previous research. The observation sheet was directed to record various teacher and student activities during the learning process with the application of the GeoGebra-assisted PBL model. Meanwhile, documentation was used as a supplement to obtain written data, photos, and other relevant information. Data analysis was carried out using parametric statistical techniques, namely the paired sample t-test, and the two-way ANOVA test, with the support of SPSS software.

RESULTS AND DISCUSSION

Results

The Effect of GeoGebra-Assisted PBL on Students' Mathematical Critical Thinking

The decision to accept or reject the hypothesis regarding the significant influence of GeoGebra-assisted PBL on students' mathematical critical thinking is made based on statistical hypothesis testing, which is formally formulated through statistical hypotheses (H_0) and research hypotheses (H_1) as follows.

$$H_0: \mu_1 = \mu_2$$

$$H_1: \mu_1 \neq \mu_2$$

Hypotheses testing uses the SPSS version 29 program with the paired sample t-test technique, and the results of the statistical analysis are presented as follows.

Table 1. Result for Paired Samples Statistic

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Posttest_PBL Geo-	74.66	29	12.951	2.405
	Pretest PBL Geo	27.07	29	13.985	2.597

Table 2. Output Samples Correlations

	N	Correlation	Significance	
			One-Sided p	Two-Sided p
Pair 1 Posttest PBL Geo- Pretest_PBL_Geo	29	.403	.015	.030

Table 3. Output Paired Differences

	Mean	Std. Deviation	T	df	Sig. (2-tailed)
Pair 1 Posttest PBL Geo- Pretest PBL Geo	47.586	14.737	17.389	28	<.001

Table 4. Effect Size for Paired Output Samples

N		Standardizer ^a	Point Estimate
Pair 1 Posttest PBL Geo - Pretest PBL Geo		Cohen's d	14.737
		Hedges' correction	15.147
			3.229
			3.142

Based on the output results presented previously, there are three main findings as follows.

1. Output paired samples correlation shows that the significance value is 0,030, which is below the significance limit $\alpha = 0,05$. This finding indicates a significant correlation between the pretest and posttest scores of mathematical critical thinking in students who received GeoGebra-assisted PBL learning. The correlation coefficient obtained $r = 0,403$ belongs to the medium category, so $r^2 = 0,403^2 = 16\%$ Variations in posttest scores can be explained by variations in pretest scores. This means that posttest scores have a positive effect on pretest scores.
2. Output paired samples test shows a significance value $< 0,001$ which is below the significance level of $\alpha = 0,05$. Thus, the research hypothesis (H_1) is accepted, and it can be stated that GeoGebra-assisted PBL has a significant influence on students' mathematical critical thinking.
3. Output paired samples effect sizes shows that Cohen's d value is 14,737 with a point estimate of 3,229, which is greater than 0,80. This indicates that the magnitude of the influence of GeoGebra-assisted PBL is in the high category on students' mathematical critical thinking.

The Effect of GeoGebra-Assisted DI on Students' Mathematical Critical Thinking

The decision to accept or reject the hypothesis regarding the significant influence of GeoGebra-assisted DI on students' mathematical critical thinking is made based on statistical hypothesis testing, which is formally formulated through statistical hypotheses (H_0) and research hypotheses (H_1) as follows.

$$H_0: \mu_1 = \mu_2$$

$$H_1: \mu_1 \neq \mu_2$$

Table 5. Result for Paired Samples Statistic

		Mean	N	Std. Deviation	Std. Error Mean
Pair 2 Posttest DI Geo- Pretest DI Geo		66.38	29	10.428	1.936
		29.14	29	11.957	2.220

Table 6. Output Samples Correlations

	N	Correlation	Significance	
			One-Sided p	Two-Sided p
Pair 2 Posttest DI Geo- Pretest DI Geo	29	.726	<.001	<.001

Table 7. Paired Sample t-Test Mathematical Critical Thinking

	Mean	Std. Deviation	T	Df	Sig. (2-tailed)
Pair 2 Posttest DI Geo- Pretest DI_Geo	37.241	8.408	23.853	28	<.001

Table 8. Effect Size for Paired Output Samples

N		Standardizer ^a	Point Estimate
Pair 2 Posttest DI Geo - Pretest DI Geo	Cohen's d	8.408	4.429
	Hedges' correction	8.642	4.310

Based on the output results presented previously, there are three main findings as follows.

1. Output paired samples correlations shows that the significance value is 0,030 which is below the significance limit $\alpha = 0,05$. This finding indicates a significant correlation between the pretest and posttest scores of mathematical critical thinking in students who received GeoGebra-assisted DI learning. The correlation coefficient obtained $r = 0,726$ included in the high category, so $r^2 = 0,726^2 = 53\%$ Variations in posttest scores can be explained by variations in pretest scores. This means that posttest scores have a positive effect on pretest scores.
2. Output paired samples test shows a significance value $< 0,001$ which is below the significance level of $\alpha = 0,05$. Thus, the research hypotheses (H_1) is accepted, and it can be stated that GeoGebra-assisted DI has a significant influence on students' mathematical critical thinking.
3. The paired samples effect sizes output showed a Cohen's α value of 8,408 with a point estimate greater than 0,80. This indicates that the magnitude of the influence of GeoGebra-assisted DI on students' mathematical critical thinking is in the high category.

The Effect of GeoGebra-Assisted PBL with GeoGebra-Assisted DI, Differences in the Influence of AQ Levels, and the Interaction Effect between Learning and AQ Levels on Students' Mathematical Critical Thinking

The decision to accept or reject the three hypotheses in this study was made based on the results of the data analysis. The three hypotheses are described as follows.

1. There is a difference in the influence of GeoGebra-assisted PBL and GeoGebra-assisted DI on students' mathematical critical thinking.

2. There are differences in the influence of AQ levels on students' mathematical critical thinking.
3. There is an interaction effect between learning and AQ level on students' mathematical critical thinking.

Statistical hypotheses (H_0) and research hypotheses (H_1) formally as follows.

- 1) $H_0: \alpha_1 = \alpha_2$
 $H_1: \alpha_1 \neq \alpha_2$
- 2) $H_0: \beta_1 = \beta_2 = \beta_3$
 $H_1: \text{bukan } H_0$
- 3) $H_0: \alpha_1\beta_1 = \alpha_1\beta_2 = \alpha_1\beta_3 = \alpha_2\beta_1 = \alpha_2\beta_2 = \alpha_2\beta_3$
 $H_1: \alpha_i\beta_j \neq 0$

In testing the three hypotheses, data were used regarding the improvement of students' mathematical critical thinking in GeoGebra-assisted PBL learning and GeoGebra-assisted DI based on the AQ category. Data analysis was carried out using the General Linear Model (Two-Way ANOVA). The analysis process was assisted by SPSS software and produced the following output.

Table 9. Statistical Output of Mathematical Critical Thinking Based on Learning and AQ

AQ	Model	Mean	Std. Deviation	N
Climber	PBL-Geo	.7386	.11127	7
	DI-Geo	.5443	.10690	7
	Total	.6414	.14544	14
Camper	PBL-Geo	.6633	.16999	12
	DI-Geo	.5458	.10875	12
	Total	.6046	.15191	24
Quitter	PBL-Geo	.5940	.18374	10
	DI-Geo	.5000	.09165	10
	Total	.5470	.14932	20
Total	PBL-Geo	.6576	.16720	29
	DI-Geo	.5297	.10137	29
	Total	.5936	.15147	58

Table 10. Two-Way ANOVA Output on Mathematical Critical Thinking

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.337 ^a	5	.067	3.617	.007	.258

Intercept	19.712	1	19.712	1056.434	<.001	.953
AQ	.078	2	.039	2.100	.133	.075
Model	.252	1	.252	13.527	<.001	.206
AQ * Model	.022	2	.011	.585	.561	.022
Error	.970	52	.019			
Total	21.746	58				
Corrected Total	1.308	57				

a. R Squared = .258 (Adjusted R Squared = .187)

Based on the SPSS output above, namely the test of the between-subject effect, the significance value is used for:

1. Corrected Model. In the line corrected model, it can be seen how much influence the independent variable has on the dependent variable. The significance value of the corrected model is 0,007. This means that the significance value is smaller than the value $\alpha = 0,05$. Therefore, the analysis model used in the Two-Way ANOVA is valid. This means that observations of learning and AQ levels jointly influence students' critical mathematical thinking.
2. Intercept. The significance value of the intercept is $< 0,001$. This means that the significance value is smaller than the value $\alpha = 0,05$. This explains that the constant value in this model is significant and is not influenced by the independent variable, so that the dependent variable in this research analysis changes without being influenced by the independent variable.
3. The interaction effect between learning and AQ level on mathematical critical thinking is shown in the AQ*model. The results show that the significance value obtained is 0,561, where the significance value is greater than the value $\alpha = 0,05$. This means that there is no interaction effect between learning and AQ level on students' mathematical critical thinking. This is reinforced by R Squared value, which is close to 0, so that it can be stated that together learning and AQ level do not affect mathematical critical thinking. To see the absence of an interaction effect is shown in the estimated marginal means, where the average achievement of students for each AQ level of Climber, Camper, and Quitter who learn with GeoGebra-assisted PBL is successively higher than students who learn with GeoGebra-assisted DI.

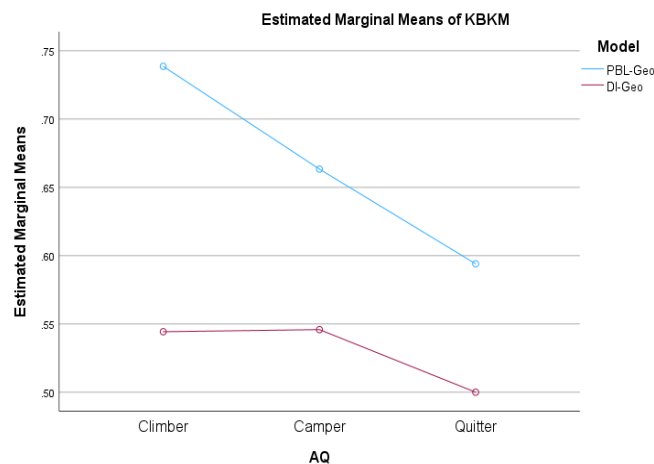


Figure 1. Students' Mathematical Critical Thinking Based on Learning and AQ Level

Discussions

Based on the analysis results, GeoGebra-assisted PBL was proven to have a high influence on students' mathematical critical thinking skills, as reflected in the effect size value. This finding is in line with the opinion of Ramadhanti et al., (2022), PBL helps students get used to thinking and solving problems and increases self-confidence and interest in learning. Previous research also supports this, such as research by Widyatiningtyas et al., (2015) and Soraya et al., (2019), which states that PBL is significant in improving students' mathematical critical thinking and social aspects.

The analysis results show that the implementation of GeoGebra-assisted DI has a significant and high impact on students' critical mathematical thinking. This is in line with the advantages of Direct Instruction as stated de Jong et al., (2023), namely (1) based on the principle of behavior, where an action can produce different consequences, and (2) able to reduce cognitive load through the presentation of explicit and structured instructions so that students can focus more on the process of understanding new information, not on discovery activities. In addition, the findings Salam et al., (2019) shows that DI contributes positively to students' mathematics learning outcomes and spatial intelligence Royani et al., (2018) also strengthened these results by stating that direct, practical-based learning had an impact on improving students' science process skills and critical mathematical thinking abilities.

Based on the analysis above, it shows that GeoGebra-assisted PBL has a greater influence on mathematical critical thinking than GeoGebra-assisted DI. This is indicated by the average mathematical critical thinking score of students who learned with GeoGebra-assisted PBL, which was higher than students who learned with GeoGebra-assisted DI. This finding is in line with research Irawati et al., (2025) which states that the learning outcomes of high school students who implement PBL are superior. In addition, the study Rohmatulloh et al., (2022) also emphasized that the use of learning media integrated with PBL in mathematics learning has a positive impact on improving students' mathematical abilities.

Based on the analysis, it was found that AQ levels did not significantly influence mathematical critical thinking. This condition may occur because students' persistence without strong motivation and interest in learning tends not to produce optimal problem-solving processes (Nurfitriyanti et al., 2020). This finding is in line with research Nurfitriyanti et al., (2020) that AQ does not have a significant effect on mathematics learning achievement in general. The research Leonard & Amanah (2014) also strengthens these results by stating that there is no positive influence of AQ on mathematics learning achievement.

The analysis results show that there is no interaction between the learning model and AQ levels on students' mathematical critical thinking, so neither has a simultaneous effect. This result aligns with the findings Jumaisyaroh et al., (2016) & Syahbana (2012) which states that the interaction of learning models with initial abilities does not have a significant influence on students' mathematical critical thinking or aspects of students' learning independence.

CONCLUSION

1. GeoGebra-assisted PBL learning significantly influenced students' mathematical critical thinking, with a high influence category. Furthermore, there was a significant positive correlation between the pretest and posttest scores of mathematical critical thinking, with a correlation coefficient of 0,403, indicating that 16% of the variation in posttest scores was influenced by the pretest score.
2. GeoGebra-assisted DI learning showed a significant influence on students' mathematical critical thinking, with a relatively high level of influence. Furthermore, the correlation analysis revealed a significant positive correlation between the pretest

and posttest scores of mathematical critical thinking, indicated by a correlation coefficient of 0,726. This finding indicates that 53% of the variation in the posttest scores of mathematical critical thinking was influenced by the pretest scores.

3. GeoGebra-assisted PBL learning showed a greater influence than GeoGebra-assisted DI on mathematical critical thinking, with the difference in influence falling into the moderate category.
4. The analytical results indicate that AQ levels generally do not exert a substantial influence. Analytical reasoning in mathematics. Nevertheless, according to post hoc analysis, students with the AQ Climber category exhibit superior mathematical critical thinking compared to other students. The AQ Camper and AQ Quitter categories, along with pupils classified as AQ Campers. Students in the category exhibit superior improvement compared to those in the AQ Quitter category.
5. No interaction effect was found between the learning model and AQ level on mathematical critical thinking. This absence of an interaction effect is reinforced by the R-squared value approaching zero, thus concluding that the combination of learning and AQ level simultaneously does not have a significant effect on mathematical critical thinking.

Based on the above conclusion, several recommendations can be proposed for future research, namely considering the effectiveness of GeoGebra-assisted PBL and DI models by expanding the research subjects to different classes or educational levels, such as secondary school or higher education students, as well as applying these models to different learning materials beyond those used in this study. In addition, further research is also recommended to examine the effects of both models on other mathematical competencies, such as conceptual understanding, mathematical reasoning ability, and mathematical creative thinking skills.

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