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Does Brain-Based Learning Improve Mathematical Reflective Thinking Ability in Quadratic Functions?: A Quasi-Experimental Study

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Abstract: This research examined the impact of Brain-Based Learning model versus conventional model on mathematical reflective thinking abilities among State Senior High Schools students in Jakarta. Employing a quantitative quasi-experimental approach with nonequivalent control group design, the study involved 48 students selected from a population of 286 grade X students using purposive sampling. Data was collected through a three-essay assessment instrument based on mathematical reflective thinking indicators, previously validated for validity and reliability. Analysis included descriptive statistics, normality test, homogeneity test, and t-test. Results show that the experimental class achieved a higher average post-test score of 17.54 compared to the control class score of 9.37. The t-test revealed a significant difference with Sig (2-tailed) = 0.000 < 0.05, leading to the rejection of H0 and the acceptance of H1. Therefore, the Brain-Based Learning model significantly enhances students' mathematical reflective thinking skills compared to the conventional model. This finding confirms that brain-based learning is able to optimize students' cognitive processes in developing mathematical reflective thinking skills, which include aspects of reacting, comparing, and contemplating. The improvement of this ability is very important considering the low level of students' mathematical reflective thinking ability previously described in this research.

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Introduction

Mathematical reflective thinking is categorized as a high-order ability that is essential to be improved in students for solving mathematical problems (Hidayat et al., 2021). According to (Kholid et al., 2021), reflective thinking represents a mental procedure for problem identification and resolution that utilizes accumulated knowladge and experince, progressing from states of confusion toward improved comprehension and the generation of fresh strategies. In problem solving, reflective thinking focuses on the stages of the process and achieving goals before getting the final solution (Sari et al., 2020). The stages include evaluating what is already known, identifying information that is still needed, and designing steps to overcome these gaps based on experience (Funny et al., 2019). Reflective thinking can provide deeper learning through improving the quality of learning (Kurt, 2018). Reflective thinking serves the purpose of expanding individual knowledge with a view to paving the way for self-discovery and development (Pretorius & Ford, 2016).

According to (Muntazhimah et al., 2021), through reflective thinking, students can analyze and determine the right problem-solving approach more efficiently. Consistent with the research by (Kaplan et al., 2017) in the Gümüşhane city of Turkish found that reflective thinking skills can help students in understanding how they learn and solve problems.

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Meanwhile, according to (Permatasari et al., 2020) reflective thinking is a fundamental skill that students need to master because it can help in evaluating their learning experiences as well as formulating appropriate strategies to achieve learning goals.

In the context of mathematics learning, quadratic function is one of the materials that require high reflective thinking skills. This is because the quadratic function involves analyzing, interpreting and evaluating information to understand the concept and apply it in different contexts. Mastery of the quadratic function concept also has an essential role given the close relationship with various other disciplines (Kurniasari et al., 2021).

In fact, reflective thinking skills still receive less attention from teachers during learning (Akpur, 2020), this corresponds to research by (Nurrohmah & Pujiastuti, 2020) shows that students' mathematical reflective thinking skills are less than optimal, namely obtaining a percentage of 23.07% at a low level, 65.4% at a medium level and only 11.53% at a high level. In addition, research conducted by (Sari et al., 2020) through observations and interviews at SMA Negeri 15 Bandar Lampung showed that teachers rarely train and develop students' knowledge and rarely use special learning models, resulting in a lack of development of reflective thinking skills in students.

In addition, observations made (Azmi & Yunita, 2022) at MAN 6 North Aceh show that many students experience obstacles in solving math problems, especially in quadratic function material. These obstacles contribute to the weak mathematical abilities of students. Similar results were found in a study at SMA Negeri 7 Palu, which indicated that most students experienced problems in several areas of quadartic function material, including applying formulas, graph construction, understanding extreme values, and cusp analysis. These findings also reinforce the conclusion that students' ability to master the concepts and applications of quadratic functions is still at a low level (Jannah & Bakri, 2021).

Therefore, special learning approaches must be designed to be more interesting and facilitate student understanding. The coice of an effective pedagogical approach can boost efficiency and simplify the execution of instructional processes for both teachers and students (Sari et al., 2020). One possible solution is to utilize the Brain Based Learning strategy. The concept of this approach is based on Neuroscience which requires active involvement and full awareness of students (Amjad & Tabbasam, 2024).

The Brain Based Learning method seeks to establish an enjoyable educational environment and foster positive student attitudes. This strategy supports improved academic outcomes by emphasizing the importance of student cooperation, collaboration and motivation. Through the implementation of real experiences, Brain Based Learning helps students and teachers optimize the learning process more efficiently and meaningfully (Harden & Jones, 2022; Oghyanous, 2017).

The research that has been conducted by (Ni'amah, 2018) and (Susanti et al., 2023) shows that Brain Based Learning has proven to be more successful in enhancing students' mathematical reflective thinking ability compared to conventional methods. In research (Syarifuddin et al., 2025), Brain Based Learning can also improve other mathematical abilities such as the ability to think systematically.

In addition, Brain Based Learning has been widely applied to other abilities that produce positive effects, especially critical thinking skills (Amelia & Afri, 2023; Solihah, 2019; Utami et al., 2020), but there are still few who discuss the relationship between Brain Based Learning and mathematical reflective thinking skills. The novelty of this research lies in the Brain Based Learning stages that integrate brain gym movements and the development of reflective thinking ability instruments that measure three specific dimensions (reacting,

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comparing, and contemplanting) within the context of high-level mathematical material, namely quadratic functions, while providing new perspectives on the implementation of neuroscience based approaches in the Madrasah environment. Therefore, this study aims to examine the impact of the Brain Based Learning model on mathematical reflective thinking ability on quadratic function material.

This study is expected to provide valuable insights for mathematics educators in implementing neuroscience based teaching approaches, while contributing to the limited literature on the application of Brain Based Learning in students' mathematical reflective thinking abilities in mathematics education, particularly in the Madrasah education environment.

Research Method

A quantitative approach is utilized in this research, which is a research approach that applies numerical information and statistical procedures to verify theories, find answers, and study the relationship between the factors studied (Susanto et al., 2024). Using a *quasi-experimental* method with a *nonequivalent control group design*, this research was conducted at one of the East Jakarta State Aliyah Madrasah in the 2024/2025 academic year. In the *nonequivalent control group* design, the selection of research subjects for experimental and control groups is not done randomly and the process is similar to the *pretest-posttest experimental control group design* shown in Table 1 (Abraham & Supriyati, 2022).

Table 1. Non-equivalent Control Group Design

Group	Pretest	Treatment	Posttest
A	O_1	X	O_2
B	O_3	-	O_4

Description:
A : Experimental group
B : Control group
O_1 : Pretest of experimental group
O_2 : Posttest of experimental group
X : Experimental group treatment (Brain Based Learning)
\- : Control group treatment (Conventional)
O_3 : Pretest of control group
O_4 : Posttest of control group

This research involved a sample of two classes with 24 participants each, drawn from the total grade X population of 286 students from 8 classes. Purposive sampling was the technique adopted for this investigation, based on certain considerations (Sugiyono, 2013). In this case, the selection of the experimental and control class was based on considerations provides by mathematics teacher at the school to represent the entire population. Initially, 69 students were recruited (34 students in class X-A dan 35 students in class X-B), with class X-A designated as the experimental class receiving Brain Based Learning model and class X-B serving as the control class experiencing conventional learning model.

Following data collection procedures, only 48 students who completed both pretest and posttest assessments were included in the final analysis, with 24 participants from each class. Data exclusion was necessary due to absenteeism and incomplete responses to maintain the validity of the pretest-posttest comparison design. Subsequenlty, outliers detection was

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conducted on the complete dataset of 48 participants using SPSS version 26.0 for Windows. No extreme values requiring removal were identified, therefore all data from the 48 students were retained for the final statistical analysis.

The measurement of mathematical reflective thinking ability occurated through a three item essay examination on quadratic function topics, designed according to mathematical reflective thinking ability indicators that formed the research's instrument presented in Table 2. The indicator consists of *reacting*, *comparing* and *contemplanting* (Muntazhimah, 2019).

Table 2. Indicators of Mathematical Reflective Thinking Ability on Quadratic Function Material

No	Indicator	Indicator Definition
1	*Reacting* (thinking for action)	Students can determine the equation of a quadratic function based on certain point information in a real context.
2	*Comparing* (reflective thinking for evaluation)	Students can determine the vertex point and draw a graph based on the characteristics of a quadratic function.
3	*Contemplanting* (reflective thinking for critical inquiry)	Students can interpret the maximum height and time to reach the maximum height, and analyze contextual problems in quadratic functions.

The test instrument was previously validated by three specialist, two expert lecturers and one mathematics teacher. Following the instrument's approval for use, it was administered to 91 participants who had previously learned quadratic function material at different schools, and validity and reliability outcomes were calculated using Microsoft Excel 2019. Validity represents the degree of precision and correctness of an instrument in performing its measurement function to accurately reflect the actual state of the measured object, while reliability is the level of trust in a measurement result which is indicated through the consistency of relatively similar results when measurements are repeatedly taken on the same group of subjects (Farida & Musyarofah, 2021; Ramadhan et al., 2024; Saputri et al., 2023; Subhaktiyasa, 2024).

After the instrument has obtained validity and reliability results, students in both control and experimental groups will receive a pre-test to assess their intial capabilities. The treatment is then implemented, ending with a post-test to evaluate students's reflective thinking capabilities after treatment completion. The reliability test interpretation is specific in Table 3.

Table 3. Interpretation of Reliability Test

Value	Interpretation
$a > 0.8$	Very high
$0.7 < a \leq 0.8$	High
$0.6 < a \leq 0.7$	Fair
$0.5 < a \leq 0.6$	Low
$a < 0.5$	Very low

Source: (Anjani & Alyani, 2025)

Following the collection of pre-test and post-test score data, normality test, homogenity test, and hypothesis test were executed with either parametric Independent sample t-test or non-parametric Mann Whitney test when data distribution was not normal, utilizing SPSS Version 26.0 for Windows software.

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Results and Discussion

Results of Data Analysis

The validation test outcomes for the research instrument were determined using the product moment correlation formula, which indicated that calculated r-count higher that the r-table (0.2061) for 91 students at one of the Tangerang State Aliyah Madrasah. Furthermore, the reliability test employoed Cronbach's Alpha, which indicates reliability levels within a 0 to 1 range, where elevated values signify more dependable measurement (Farida & Musyarofah, 2021).

Table 4. Validity and Reliability Test

Number	*r-count*	*r-table*	Description
1	0,639312	0,2061	Valid
2	0,891175	0,2061	Valid
3	0,903328	0,2061	Valid
	r_{11}	0,7105	Reliable

From the analytical data presented in Table 4, all items in the reflective thinking ability instrument shows r-count > r-table, therefore it can be inferred that the three questions achieve the validity criteria. Furthermore, the reliability test outcomes reveal an r_{11} value of 0.7105, which according to the interpretation in Table 3 demonstrates that the instrument possesses high reliability levels.

After conducting validation and reliability tests with results that show the instrument is valid and reliable, the instrument is used as a research instrument in different schools. This research was executed at one of the East Jakarta State Aliyah Madrasah, in an experimental group with data on reflective thinking ability using the Brain Based Learning model and a control group with data on mathematical reflective thinking ability applying a conventional model. The following are the results of calculations assisted by the SPSS version 26.0 for windows application on data analysis.

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Pretest Kelas Eksperimen	24	12	3	15	7,25	3,166
Posttest Kelas Eksperimen	24	18	8	26	17,54	4,597
Pretest Kelas Kontrol	24	7	1	8	3,37	1,715
Posttest Kelas Kontrol	24	11	5	16	9,37	3,104
Valid N (listwise)	24					

Figure 1. Descriptive Statistics

The figure 1 shows that the experimental class pretest scores ranged from 3 to 15, with an average of 7.25 and a standard deviation of 3.166. Then the experimental class posttest scores ranged from 8 to 26, with an average of 17.54 and a standard deviation of 4.597. Control class pretest scores ranged from 1 to 8, with an average of 3.37 and a standard deviation of 1.715. Then the control class posttest scores ranged from 5 to 16, with a mean of 9.37 and a standard deviation of 3.104. These results show that the experimental class experienced a much higher increase than the control class, with an average increase in the experimental class score of 10.29, while the control class score was only 6. Next, the normality test was conducted. The results of this test are presented in Figure 2.

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Tests of Normality

	Kelas	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Kemampuan Berpikir Reflektif Matematis	Pretest Kelas Eksperimen	,178	24	,048	,929	24	,095
	Posttest Kelas Eksperimen	,120	24	,200*	,962	24	,489
	Pretest Kelas Kontrol	,149	24	,177	,930	24	,097
	Posttest Kelas Kontrol	,171	24	,067	,923	24	,067

Figure 2. Test of Normality

This study uses the Shapiro-Wilk test. The test was used because the number of samples in this research amounted to 48 people or less than 50 people (Haryono, 2023). In the Figure 2, the normality test findings of the experimental class pre-test reflective thinking ability data obtained a Sig. value of 0.095. Furthermore, the experimental class post-test obtained a Sig. value of 0.489. Then the control class pre-test obtained a Sig value. 0.097. The control class post-test acquired a Sig value. 0.067. Because the Sig values of all classes show results > 0.05, these samples come from a normally distributed population and are valid for using parametric procedures such as independent sample t-test. This also gives the decision H_0 is accepted.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Kemampuan Berpikir Reflektif Matematis	Equal variances assumed	1,596	,213	7,213	46	,000	8,167	1,132	5,888	10,446
	Equal variances not assumed			7,213	40,37	,000	8,167	1,132	5,879	10,454

Figure 3. Independent Sample T-Test

Based on Figure 3, Sig value. 0.213 > 0.05 on Lavene's test for equality of variance indicates that there is an equal variance of data between the experimental and the control class or it can be said the data is homogeneous. This also gives the decision H_0 is accepted. After verifying the normality and homogeneity tests are met, proceed with independent sample t-test.

From Figure 3. value of Sig (2-tailed) shows the result of 0.000 < 0.05 with the assumption of equal variances assumed, thus giving the conclusion H_0 is rejected. Thus, it could be determined that a significant difference exists in reflective thinking ability between the experimental and control class, specifically contrasting the Brain Based Learning model implemented in the experimental class against the conventional model applying in the control class.

Discussion

The Brain Based Learning model was utilized in experimental class, while conventional model approaches were used in the control class. The teaching approach applied in the experimental class resulted in progress as illustrated descriptively in Figure 1, where the post-test mean value of 17.54 was greater than the pre-test mean value of 7.25. Likewise, the control class experienced an increase in the post-test mean value of 9.37 was higher than the pre-test mean value of 3.37. In addition, when comparing the post-test scores between

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both class, a clearly significant difference, namely the experimental class which obtained 17.54 greater than the control class by 9.37.

The findings of this study reinforce the understanding that Brain Based Learning is not just an alternative method, but an approach that fundamentally changes the way students process mathematical information. The significant improvement in reflective thinking skills (from an average of 7.25 to 17.54) shows that when learning is aligned with the natural workings of the brain, students can develop higher-level cognitive skills more optimally. Mthematicak reflective thinking skills, which encompass the aspects of reacting, comparing and contemplanting, can be developed through appropriate pedagogical interventions.

According to the data analysis results using the t-test shown in Figure 3, the sig value (2-tailed) of 0.000 less than the 0.05 significant value. Therefore, it was established that a distinction exists between the experimental class employing the Brain Based Learning and the control class employing conventional model. The application of the Brain Based Learning model in this study shows that it greatly supports the improvement of students’ mathematical reflective thinking skills in complex material, such as quadratic functions. The components of Brain Based Learning, which include pre-preparation, preparation, initiation and acquisition, elaboration, incubation and memory formation, verification and belief checking, as well as celebration and functional integration, have been proven to support mathematical reflective thinking skills. Especially in the initiation and acquisition, elaboration, and incubation and memory formation stages, as these stages train students to identify problems, evaluate problems, and integrate information deeply.

Brain Based Learning provides opportunities for students to think freely without pressure, with a conducive learning atmosphere and rich stimuli to increase thinking creativity (Farida, 2021). The execution of the Brain Based Learning model provides considerable advantages for enhancing student participation, creating an emotionally supportive environment utilizing multisensory experiences and fostering abilities in students (Jumaah, 2024; Trníková, 2024).

In this study, researchers used brain gym movements such as cross movement and hook ups and played relaxing music during the incubation and memory formation stages. This was useful for restoring students’ attention to the learning process without pressure and optimizing connections between neurons in brain.

In utilizing multisensory experience in learning using Brain Based Learning model can include visual and acoustic media (music). In addition, in Brain Based Learning physiological effects can also help optimize the learning process, such as relaxation and physical exercise (Novalianti et al., 2021). In this study, researchers used acoustics (music) during students' discussions with their groups. Furthermore, in the incubation and memory setting stages of Brain Based Learning, the researcher asked students to stretch in the form of *brain gym*, namely doing cross movements, brain buttons and hook ups.

The *brain gym* movement itself has the benefit of making better connections between the right and left parts of the brain, thus activating neurons that support during the learning process (Jalilinasab et al., 2021). In line with research conducted (Ramos-galarza et al., 2023) in Latin America with 67 students aged 12-14 years, showing that *brain gym* can improve the math skills of students in high school both control and experimental groups. The research conducted by (Novalianti et al., 2021) at SMAN 4 Mataram with 50 students proved that the Brain Based Learning model assisted by brain gym can affect students' critical thinking ability.

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In addition, research conducted by (Susanti et al., 2023) at an Islamic Junior High Schools in Sumedang City which proves that the Brain Based Learning yields better results than the Discovery Learning in improving mathematical reflective thinking ability. It also shows that students' response to Brain Based Learning learning is higher in the aspect of interest in learning mathematics.

Furthermore, in a study conducted by (Yuda et al., 2018) at State Elementary School in Sinabun Village which showed the difference between the group given the Brain Based Learning model and conventional model. This demonstrates that the group given the Brain Based Learning model gets an average learning outcome of 31.9 higher than the group given the conventional model of 26.5.

This study offers concrete solutions to overcome the low level of mathematical reflective thinking skills among students, which has long been a challenge in mathematics education in Indonesia. With a significant improvement from the initial low level to a much better level of ability, this method offers real hope for efforts to improve the quality of mathematics education nationwide.

Conclusion

According to the data analysis findings and discussion outcomes, it could be determined the Brain Based Learning model significantly impacts students' mathematical reflective thinking capabilities when contrasted to conventional teaching model. This is evidenced by the independent sample t-test which shows a Sig (2-tailed) value of $0.000 < 0.05$ significant value, so H_0 is rejected and H_1 is accepted. Descriptively, the experimental class using the Brain Based Learning model acquired an average post-test score of 17.54 which was substantially higher than the control class with an average of 9.37.

This finding confirms that brain-based learning is able to optimize students' cognitive processes in developing mathematical reflective thinking skills, which include aspects of *reacting*, *comparing*, and *contemplanting*. The improvement of this ability is very important considering the low level of students' mathematical reflective thinking ability previously described in this research.

Recommendation

From the results and discussion that have been described, researchers recommend that teachers remain open to other learning models in order to provide students with diverse learning experiences, one of which is the Brain Based Learning model. This teaching model has the potential to improve students' mathematical reflective thinking skills.

Futhermore, this model can also be integrated with learning media, such as flash cards, Cabri 3D soft ware, or other learning media. Further studies are suggested to investigate how the Brain Based Learning approach compares with other mathematical competencies or alternative instructional methods.

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