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Analysis of Students' Mathematical Reasoning Ability in Quadratic Functions through the Use of Desmos

Adinda Muhfyana[1*], Chelsea Rivera Pasaribu[2], Dave Marcellino Sancia[3], Dwi Octa Marcellita Girsang[4], Mariatul Kiftia Shakila[5], Tiara Sondang Sianipar[6], Rani Nuldiva Situmorang[7]
[1-7] Mathematics Education Study Program, FMIPA, Medan State University, Indonesia
Corresponding Author: adindamhsb0211@gmail.com

Abstract. This study aims to analyze students' mathematical reasoning abilities in quadratic function material through the use of Desmos. The research employed a qualitative descriptive approach using a case study and usability testing method. Data were collected through post-tests and interviews involving students' responses in solving quadratic function problems. The analysis focused on several indicators of mathematical reasoning, including procedural skills, conceptual understanding, and analytical ability. The results show that students generally demonstrate adequate procedural reasoning, particularly in substitution and computation tasks. They are also able to relate algebraic representations to geometric interpretations, such as determining intercept points and analyzing the direction of parabolas. However, limitations were found in conceptual understanding, especially in identifying graph characteristics without relying on procedural steps. The use of Desmos significantly supports the development of students' mathematical reasoning by providing real-time visualization, facilitating exploration of function parameters, and enabling verification of results. Overall, Desmos contributes to enhancing procedural, conceptual, and analytical dimensions of mathematical reasoning, although its effectiveness depends on proper instructional design.

Keywords: Desmos, Educational Technology, Mathematical Reasoning, Mathematics Learning, Quadratic Functions.

1. INTRODUCTION

Mathematics education plays a crucial role in developing the quality of human resources, particularly in fostering logical, analytical, systematic, and critical thinking skills. Mathematics is not merely viewed as a collection of concepts and computational procedures, but also as a means of training structured thinking in addressing various problems. In the context of 21st-century education, mathematical reasoning ability is one of the key competencies that students must possess. This ability enables students to understand relationships between concepts, draw logical conclusions, and provide valid justifications for each step in problem solving. Mathematical reasoning is also considered part of higher-order thinking skills that involve making generalizations, constructing arguments, and solving problems logically (Siregar et al., 2022). Therefore, mathematics learning should not only focus on procedural mastery but also on the development of deep reasoning skills.

2. LITERATURE REVIEW

Mathematical reasoning in learning encompasses various aspects, including the ability to make conjectures, perform mathematical manipulations, construct logical arguments, and draw conclusions based on patterns or relationships. However, in practice, mathematics learning at the school level still faces several challenges, particularly the low level of students'

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mathematical reasoning ability. Previous studies indicate that students' reasoning abilities are not yet optimal and are often influenced by instructional approaches that do not sufficiently engage students in meaningful learning processes (Siregar et al., 2022; Martin & Melle, 2020). This is reflected in students' tendency to memorize formulas and follow solution steps without understanding the underlying rationale. As a result, students often struggle when faced with problems that require reasoning or non-routine solutions (Seah & Cai, 2021).

These issues are also evident in learning quadratic functions, which is an essential topic in the mathematics curriculum. Many students experience difficulties in understanding fundamental concepts of quadratic functions, such as factorization, the meaning of solutions, and the relationship between algebraic expressions and their graphical representations. Research shows that students often rely on procedural approaches without fully understanding the underlying concepts, leading to misconceptions and errors in solving quadratic equations (Hu et al., 2021; Wong & Ho, 2020). These difficulties indicate that students' mathematical reasoning has not yet developed optimally, particularly in connecting multiple representations of mathematical ideas (Jones et al., 2023).

In fact, quadratic functions offer significant potential for developing students' mathematical reasoning ability. Through the learning process, students can be trained to observe patterns in graph transformations, analyze relationships between variables, and draw conclusions based on exploration. The use of technology, such as Desmos, can serve as an effective tool to support this process. Studies indicate that the integration of Desmos in mathematics learning can enhance conceptual understanding, student engagement, and overall learning outcomes by enabling interactive visualization and exploration (Mediana & Dio, 2025; Riley & Kotsopoulos, 2021). Therefore, integrating technology into the teaching of quadratic functions is expected to be an effective approach to enhance students' mathematical reasoning ability.

The rapid development of information and communication technology in the digital era has significantly influenced various aspects of life, including education. In mathematics learning, technology plays a crucial role in helping students understand abstract concepts. Mathematics is often perceived as a difficult subject because it requires logical and analytical thinking, as well as the ability to interpret symbolic representations that are not always easily understood by students. Therefore, the integration of technology into mathematics learning has become an effective solution to improve the quality of instruction, particularly in facilitating the visualization of complex concepts (Heryanti et al., 2024).

The use of technology in learning does not merely function as a supporting tool but also as a medium to create more interactive and meaningful learning experiences. Technology enables students to explore, simulate, and experiment with mathematical concepts directly, transforming the learning process from passive to active and constructive. Furthermore, technology can enhance students' motivation and interest in learning by providing more engaging and varied learning experiences (Suhendra et al., 2025). Thus, the integration of technology in mathematics education has become an essential component in improving students' conceptual understanding and thinking abilities.

One example of technology utilization in mathematics learning is the use of the Desmos application. Desmos is a web-based application that provides dynamic graphing features, allowing students to visualize mathematical concepts interactively, especially in quadratic function topics. Through Desmos, students can observe how graphs change in response to variations in equation parameters, helping them understand the relationship between algebraic expressions and their graphical representations more deeply. This is particularly important because one of the main difficulties students face in learning quadratic functions is understanding the relationship between equations and their corresponding graphs (Lubis et al., 2024).

The use of Desmos in learning also offers several advantages, such as increasing student engagement, facilitating exploratory learning, and providing immediate feedback. Students are not only recipients of information from teachers but are also actively involved in discovering concepts through experimentation and observation. In addition, Desmos supports both independent and collaborative learning, which can enhance students' critical and creative thinking skills (Suhendra et al., 2025). Therefore, Desmos can serve as an effective alternative learning medium in supporting technology-based mathematics instruction.

Although various studies have shown that the use of Desmos can improve students' interest and learning outcomes, most of these studies focus on media development, learning interest, and academic achievement. For instance, Heryanti et al. (2024) emphasized the development of Desmos-based learning media and examined its effectiveness in teaching quadratic equations. Meanwhile, Suhendra et al. (2025) focused on analyzing students' learning interest using Desmos, and Lubis et al. (2024) investigated its impact on students' learning outcomes in quadratic function material. These findings indicate that Desmos has significant potential in enhancing the quality of mathematics learning.

However, studies that specifically examine students’ mathematical reasoning abilities through the use of Desmos are still limited. In fact, mathematical reasoning is a fundamental competency in mathematics learning, as it involves the ability to analyze, draw conclusions, connect various concepts, and solve problems logically and systematically. Low levels of mathematical reasoning can hinder students’ overall understanding of mathematical concepts, especially in abstract topics such as quadratic functions.

Moreover, previous studies have not thoroughly explored the relationship between the use of technology and higher-order thinking skills, particularly mathematical reasoning. Most research has focused on basic cognitive aspects, such as conceptual understanding and learning outcomes, without further investigating how technology can support the development of higher-level thinking skills. Therefore, more comprehensive research is needed to examine students’ mathematical reasoning abilities within technology-based mathematics learning.

Based on the above considerations, this study aims to analyze students’ mathematical reasoning abilities in quadratic function material through the use of Desmos. This research is expected to provide a deeper understanding of how Desmos can support the development of students’ mathematical reasoning skills. In addition, the findings of this study are expected to serve as a reference for educators in designing more innovative and effective learning strategies, as well as contributing to the improvement of mathematics education quality in the digital era.

3. RESEARCH METHOD

This study employed a case study and usability testing method with an evaluation survey approach conducted through interviews and direct observation of Desmos' use to find the solution area by the research subjects. The study focused on students' mathematical reasoning skills in quadratic functions through the use of Desmos, as well as observing and analyzing the difficulties students experienced when using the application to find the solution area of a quadratic function.

This study uses a qualitative descriptive approach to understand phenomena in natural settings. According to Sugiyono (2018), this approach is used to gain a deep understanding of a phenomenon in its real condition. The data were obtained from post-tests and interviews on students’ reasoning skills in quadratic function material. According to Lestari et al. (2026), the data source comes from students’ written answers that show their thinking process in solving problems.

Data were collected through post-tests and interviews. According to Lestari et al. (2026), tests are used to measure students' abilities, while interviews are used to explore students' thinking processes in more depth. The data were analyzed using a qualitative descriptive method through three steps: data reduction, data display, and conclusion drawing. According to Sugiyono (2018), these steps are used to organize and interpret data so that the research results can be clearly understood.

4. RESULT AND DISCUSSION

Result

The following is a summary of the five question items given to students along with the answer key and mathematical reasoning indicators measured:

Table 1. Analysis of Reasoning Indicators on Each Question Item.

No.	Questions	Correct Answer	Reasoning Indicators
1	$f(x) = x^2 + 2x + 1$, value $f(-1) = ?$	b. 0	Function value substitution and computation ability
2	Graph $y = x^2 + 2x + 1$ shaped?	b. Parabola	Introduction of quadratic function graph representation
3	$f(x) = 2x^2 – 4x + 1$, value $f(3) = ?$	a. 7	Multi-step substitution and computing capabilities
4	$y = x^2 + 3x + 2$ intersect the y-axis at the point?	b. (0.2)	Understanding the cut-off point of the coordinate axis
5	Comparison of parabolic directions $y = 2x^2+3x+1$ and $y = -2x^2+3x+1$	c. (1) and above, (2) Down	Analysis of coefficients and properties of quadratic functions

Question 1: Evaluation of Function Values

Substitution into functions produces: $x = -1$

$f(-1) = (-1)^2 + 2(-1) + 1 = 1 - 2 + 1 = 0$

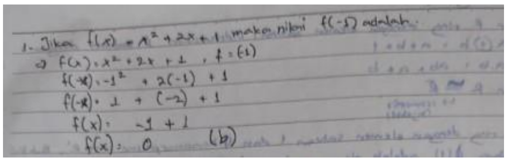

Figure 1. Student's Answer Sheet 1.

Based on the answer sheet, students perform substitution steps systematically and obtain correct results. This shows that students have met the indicators of procedural reasoning ability. This ability is in line with the characteristics of mathematical reasoning that involve symbolic manipulation and logical application of rules (Siregar et al., 2022).

Question 2: Identify the Shape of the Graph

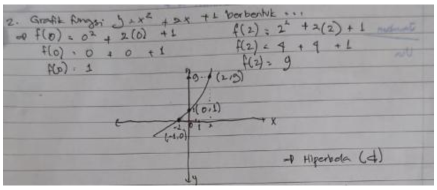

Figure 2. Student's Answer Sheet 2.

Conceptually, the quadratic function is always parabolic. However, on the answer sheet it is seen that the student specifies some points such as and, then tries to draw a graph.

$f(0) = 1f(2) = 9$

This step shows that students have tried to connect algebraic representations to the form of graphs. However, the final conclusion written is not correct. This indicates that students' understanding is still at the procedural stage, not yet reaching conceptual understanding. These findings are in line with research that states that students often have difficulty in relating algebraic forms to graphical representations on quadratic functions (Hu et al., 2021).

Question 3: Evaluate the Value of Multi-step Functions

Substitution yields:$x = 3$

$f(3) = 2(3)^2 - 4(3) + 1 = 18 - 12 + 1 = 7$

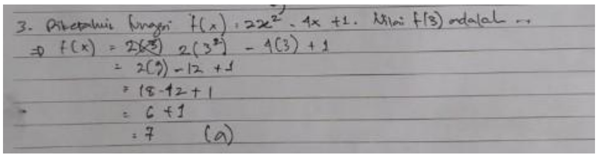

Figure 3. Student's Answer Sheet 2.

Students solve these problems with the right steps and correct results. This shows the ability to perform gradual computation as well as the precision in following the sequence of operations. Thus, the indicators of advanced procedural reasoning have been achieved, which are part of the ability to think systematically in mathematics (Siregar et al., 2022).

Question 4: Y-axis cut-off point

The y-axis cut-off point is obtained by:$x = 0$

$y = 0^2 + 3(0) + 2 = 2$

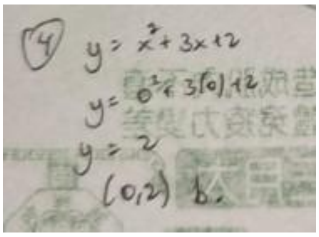

Figure 4. Student's Answer Sheet 4.

So the cut-off point is $(0, 2)$. On the answer sheet, students use the appropriate steps and obtain the correct result. This shows that students understand the relationship between constants in quadratic functions and cutpoints against y-axis. This understanding is important because it reflects the ability to relate algebraic representations to geometric representations (Lubis et al., 2024).

Question 5: Coefficient Analysis

For functions:

a. $y = 2x^2 + 3x + 1 \rightarrow$ open to the top
b. $y = -2x^2 + 3x + 1 \rightarrow$ open down

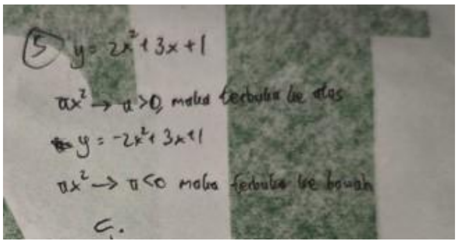

Figure 5. Student's Answer Sheet 3.

The student correctly concluded that the coefficient sign determines the direction of the parabolic opening. This shows that the student has achieved analytical skills, which is to understand the relationship between the parameters of the function and its graph characteristics. This ability is part of higher-order thinking skills in mathematical reasoning (Siregar et al., 2022).

Discussion

Based on the analysis of the entire answer sheet, it can be seen that the students' thinking process is generally in line with the measured mathematical reasoning indicators. In questions 1 and 3, students showed accurate computing skills. In question 4, students were able to relate algebraic concepts to geometric representations. In question 5, students were able to analyze the properties of functions based on their coefficients.

However, in question 2, limitations were still found in conceptual understanding, especially in identifying the form of quadratic function graphs directly. This corroborates the finding that mathematics learning in schools still tends to focus on procedures rather than understanding concepts (Siregar et al., 2022). Thus, the results of the students' work show that mathematical reasoning skills develop gradually, ranging from procedural to analytical, although they are not evenly distributed across all indicators.

Analysis of the five questions shows that Desmos has a significant role in supporting the development of students' mathematical reasoning skills. This is in line with research that states that technology can help students understand abstract concepts through visualization (Heryanti et al., 2024).

Table 2. Desmos' Contribution to Students' Mathematical Reasoning Abilities.

Desmos Aspect	Benefits to Mathematical Reasoning	Relevance to Questions
Real-time Graph Visualization	Students can see the shape of the parabola firsthand, reinforcing conceptual understanding	Question 2: Identify the form of a quadratic function graph as a parabola
Exploring Coefficients with Sliders	Students observe the effect of a value on the direction of the parabolic interactively	Question 5: Comparison of parabolic directions based on a coefficient sign
Automated Point Plots	Makes it easier to identify cutoff points on the coordinate axis	Question 4: Function cut-off point with y-axis
Function Evaluation	Confirm the result of manual substitution with a graph value at a specific point	Questions 1 & 3: Verify the values of f(-1) and f(3)

Holistically, Desmos contributes to three dimensions of mathematical reasoning. First, the procedural dimension, where Desmos helps verify computational results. Second, the conceptual dimension, through the visualization of the relationship between algebra and graphs. Third, the analytical dimension, through the exploration of function parameters. This is supported by research that shows that the use of Desmos can improve students' understanding of concepts and engagement in mathematics learning (Mediana & Dio, 2025; Suhendra et al., 2025).

The results of this analysis provide several pedagogical implications that are relevant for mathematics education practitioners. First, the integration of Desmos in the learning of quadratic functions should be carried out in a structured and gradual manner, starting from the exploration of basic visualization in question 2, continued to verify the value of functions in questions 1 and 3, then identification of critical points in question 4, and ending with a comparative analysis of coefficients in question 5.

Second, teachers need to design scaffolding activities that help students transition from dependency on Desmos visualization to independent analytical reasoning skills. The ultimate goal of using technology in mathematics learning is not to replace mathematical thinking skills, but rather to reinforce them through meaningful visual and exploratory experiences.

Third, the test instruments used in this study can be used as a model for the development of similar instruments that integrate procedural and conceptual abilities in measuring mathematical reasoning, by utilizing the advantages of graphic technology as a supporting exploration medium. This is in line with the view that technology can create more interactive and meaningful learning and increase students' learning motivation (Suhendra et al., 2025).

5. CONCLUSION AND SUGGESTIONS

Based on the analysis that has been carried out on the question instrument and the use of Desmos, it can be concluded that several things can be concluded as follows. First, the five question items used comprehensively measure various dimensions of students' mathematical reasoning skills in quadratic function material, including computational skills (questions 1 and 3), representation identification (question 2), determination of critical points (question 4), and analysis of function properties (question 5).

Second, Desmos has proven to have significant potential as an interactive learning medium that supports the development of mathematical reasoning skills through dynamic visualization, parameter exploration, and visual verification of computational results. Third, the integration of Desmos in quadratic function learning can facilitate students' transition from procedural understanding to more in-depth and meaningful conceptual understanding.

Based on these conclusions, several suggestions can be made for the development of mathematics learning in the future. First, mathematics teachers are advised to systematically integrate Desmos in the learning of quadratic functions, especially to visualize the influence of a, b, and c coefficients on graph characteristics. Second, follow-up research needs to be conducted to empirically measure the level of students' mathematical reasoning ability before and after the use of Desmos, using experimental or quasi-experimental research designs. Third, the development of more comprehensive question instruments needs to be carried out by involving more mathematical reasoning indicators at a more diverse cognitive level.

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