

Students' Visual Reasoning Ability in Solving Quadratic Function in Terms of Learning Style

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ABSTRACT

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Visual reasoning plays an important role in problem-solving and the success of the student's learning mathematics. This study aims to reveal the students' visual reasoning ability in solving quadratic function problems in terms of activist, reflector, and pragmatic learning styles. This research used a qualitative approach with a case study were 30 9th-Grade students at one of the public junior high schools in Karanganyar District, Central Java, Indonesia. The Learning Style Questionnaire (LSQ) from Honey and Mumford was used to categorize the students' learning style. In each category, the researcher selected two students purposively to be interviewed. The researchers used two quadratic equation problems to explore the students' visual reasoning profile. Before being used, the questions were validated by two experts in mathematics education. The result showed that students with activist learning styles unable to demonstrate all indicators of visual reasoning. The students with pragmatics learning style can exhibit only one indicators of reasoning, namely interpretation. Then, students with reflector and theoretical learning style able to perform all indicators of visual reasoning. Thus, it can be concluded that the student's learning style affect the visual reasoning ability in solving quadratic function.



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A. INTRODUCTION

Visual reasoning has an important contributes to the student success in solving problem and learning mathematic (Debrenti, 2015; Hamid, Idris, & Tapsir, 2019; Mudaly & Narriadoo, 2023; Sholihah & Maryono, 2020). Mathematics is not inseparable from the analysis of graphs or pictures as in the field of geometry, which provides methods of solving problems through graphs, diagrams, and coordinate systems. Students must use visual reasoning to be able to solve problems related to graph analysis (Hamid & Idris, 2014). Natsheh and Karsenty (2014) argues that visual reasoning is the ability to obtain implicit information from a given visual representation and generate precise conclusions according to the understanding of the concept. Graphical representations that represent relationships between mathematical formulas, establish relationships between visual information, and represent visual information as mathematical relationships. Then visual reasoning is the ability to understand problems, concepts, objects, or processes in visual form (Hamid, 2017).

Hamid and Idris (2014) using three visual reasoning indicators: investigation, interpretation, and application. In the investigation indicators, students have visual reasoning skills if they are able to describe visual pictures using their own language. In interpretation

indicators, students have visual reasoning skills if they are able to determine the relationship between the information in the picture before solving the problem. Furthermore, in the application indicators, students have visual reasoning skills if they are able to estimate the value of a variable and draw conclusions from visual picture data. Geçici and Türnüklü (2021) shows that visual reasoning can be used in all areas of mathematics from primary to higher education. Regardless of the field of geometry, in which visual representations are widely used, visual reasoning can be used in areas such as numbers, algebra, and statistics. Visual reasoning will contribute to students' reasoning skills in routine and non-routine problem-solving processes. In addition, mathematics learning designed based on the visual reasoning component will improve the quality of teaching.

Besides the reasoning, individual differences such as learning styles also affect student's learning success (Haryono & Tanujaya, 2018). Learning styles are behaviors or learning methods that students carry out in order to receive and fully understand information or knowledge, and process it to provide information or knowledge to others so that the knowledge can be useful (Fatkhriyah et al., 2019). Sundayana (2016) states that learning styles are students' habits in interpreting information, dealing with new situations, and processing information. Learning style is one of the important factors that can affect student learning achievement. However, the use of student-appropriate learning styles is often overlooked (Keliat, 2016).

There are various learning styles that have been studied by experts, one of which is the Honey and Mumford learning styles. Honey and Mumford classify learning styles into four groups of activists, reflectors, theorists, and pragmatists (Mumford, 2006). Activist learning styles tend to learn as they do. The theoretical learning style prefers to understand, analyze and integrate theories and describe new information about theories through logical and systematic thinking. Then, the reflector learning style tends to observe, think about, and learn what happened. Furthermore, pragmatic learning styles are more likely to understand the benefits of the information learned in everyday life (Darmanta & Wrastari, 2014).

Research related to student learning styles associated with reasoning ability is more dominated by VAK (Visual, Auditory, Kinesthetic) learning styles. For instance, Wahyudi and Walid (2020) examines students' mathematical reasoning abilities based on VAK learning styles in learning with the Missouri model. Furthermore, the study of students' mathematical reasoning profiles is also dominated by reviews based on VAK learning styles (Nurhayati & Subekti, 2017; Putri et al., 2022; Ridwan, 2017; Zulfah et al., 2021). Related visual studies, Utami and Masduki (2023) has studied the visual reasoning in terms of VAK learning style. Darmadi and Sanusi (2020) and Darmadi et al. (2020) have also examines visual reasoning in terms of gender differences. The previous studies showed that there are still limited studies that explore the differences in learning styles with students' visual reasoning abilities. In this study, researchers focused on Honey and Mumford's learning styles which include activist, reflector, theoretical, and pragmatic learning styles.

Based on the aforementioned studies, the formulation of this study is how the characteristics of students' visual reasoning ability in solving quadratic function problems in terms of activist, reflector, theoretical, and pragmatic learning styles. Thus, the purpose of this study is to describe the characteristics of students' visual reasoning abilities in solving

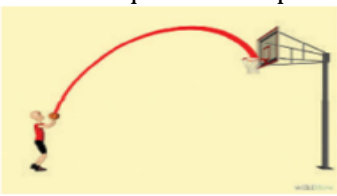
quadratic functions problems based on activist, reflector, theoretical, and pragmatic learning styles. This research is important to determine the relationship between visual reasoning ability and student learning styles, especially the Honey and Mumford models. Knowledge of student learning characteristics is useful for teachers to design appropriate mathematics learning strategies according to individual student differences, one of which is learning styles.

B. METHODS

This research uses a qualitative approach with a case study design. This research was carried out at one of the State Junior High Schools in Karanganyar Regency with the subject of 30 9th-Grade students. The learning style questionnaires, visual reasoning ability tests, and interview guideline are the instruments to collect the data. Researchers adopt the Learning Style Questionnaire (LSQ) developed by Honey and Mumford (2006) to classify students' learning styles. Furthermore, the test instrument consists of two quadratic function problems adopted from the 2018 edition Grade IX Junior High School/MTs Student Book of the Ministry of Education and Culture as presented in Table 1.

Table 1. Visual Reasoning Ability Test Questions

No	Questions
1	From the quadratic function $y = 2x^2 - 12x + 16$ a triangle will be created. The angular points of the triangle are the cut-off points of the x-axis and the breaking point. Determine the area of the triangle?
2	A basketball player is 170 cm tall. While the height of the basket is 3 meters. The basketball player throws the basketball 4 meters away from the position of the basket pole and the starting position of the ball is directly above the player's head. It turns out that the throw has a maximum height of 4.5 meters and is horizontally 2.5 meters away from the player. If the throw forms a parabola, determine whether the ball goes into the basket? Hint: Determine in advance the quadratic equation of a parabola.



Sumber: <http://www.wikihow.com>

Semi-structure interview guideline was compiled by researchers to deeper understanding the process of students solving visual reasoning problems. The test instruments and interview guidelines are validated first by two experts in mathematics education before used. A total of 30 students were given an LSQ questionnaire to identify students' learning styles. Based on the results of the questionnaire, the category of student learning styles was obtained as presented in Table 2.

Table 2. Student Learning Style Categories

Learning Style	Number of Students
Activist	5
Reflector	5
Theories	3
Pragmatic	3
Combination	14

Furthermore, the researcher selected 2 students in each four category of learning style (activist, reflector, theories, pragmatic) as subjects to be interviewed regarding students' visual reasoning abilities. Researchers choose the subjects with the same criteria of having the same learning style questionnaire score. To facilitate the data analysis, the researcher provides the code of each subject as presented in Table 3.

Table 3. Subject's Code

Subject Code	Learning Style
S1	Activist
S2	Activist
S3	Reflector
S4	Reflector
S5	Theories
S6	Theories
S7	Pragmatic
S8	Pragmatic

The selected subjects are then given a visual reasoning ability test that is worked on within 30 minutes. Table 4 is an assessment rubric to provide student answer scores that refer to visual reasoning indicators. Based on the student's answers, the student's visual reasoning test score is obtained as presented in Table 5.

Table 4. Visual Reasoning Ability Assessment Rubric

Indicator	Description	Score
Investigation	Students are unable to identify graphic	0
	Students are able to identify graphic but incorrect	1
	Students are able to correctly identify graphic	2
Interpretation	Students are unable to determine a point if the equation is known and the equation of a point	0
	Students are able to determine a point if the equation is known and the equation of a point but incorrect	1
	Students are able to determine a point if the equation is known and the equation of a point correctly	2
Application	Students are unable to calculate the area of a building, determine equations and provide conclusions	0
	Students are able to calculate the area of a building, determine equations and give conclusions but incorrect	1
	Students are able to calculate the area of a building, determine equations and give conclusions correctly	2

Table 5. Visual Reasoning Test Results Score

Subject	Score
S1	7
S2	6
S3	12
S4	12
S5	12
S6	12
S7	9
S8	8

Furthermore, researchers conducted interviews using interview guidelines that have been compiled to reveal deeper related to the students cognitive process in solving quadratic function problems based on visual reasoning indicators. Researchers triangulated students' answers with in-depth interviews. This is to ensure the validity of the data obtained related to the student's visual reasoning process in solving quadratic function problems. The data obtained are analyzed interactively since data collection based on Miles and Huberman's model, namely data reduction, data presentation, and conclusion drawing.

C. RESULT AND DISCUSSION

In this section, an analysis of students' visual reasoning based on learning styles is presented, which refers to the results of the analysis of students' answers in test questions and semi-structured interview results.

1. Activist Students

There were two subjects analyzed on activist learning styles, namely S1 and S2. Both subjects were able to determine the cut-off point and coordinate point of the curve but incorrect. Both subjects appear to be less meticulous in performing calculations. This is shown in the example of S1's answer related to question number 1 presented in Figure 1.

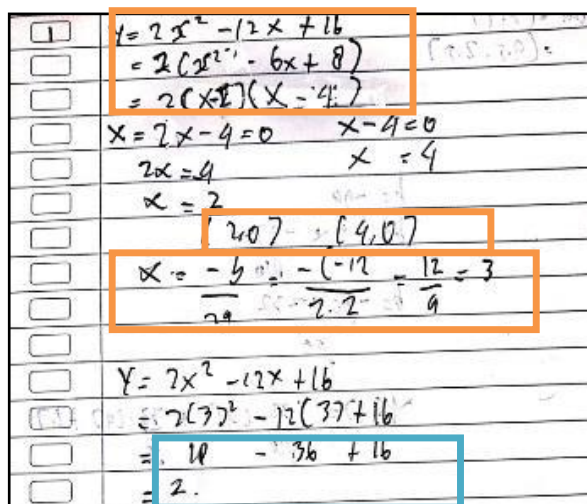


Figure 1. Answer S1 on the interpretation indicator of question number 1

Figure 1 shows that S1 determines the angular points of the triangle i.e. by looking for the x-axis cutoff point as the corner point of the base and the vertex of the triangle. To determine the angular point of the base, S1 solves the quadratic equation by factoring so that the coordinates of the interception point on the x-axis are obtained namely (2,0) and (4,0). Furthermore, the subject determines the coordinates of the vertex of the triangle by using the formula of the axis of symmetry $x = -\frac{b}{2a} = -\frac{-12}{2 \times 2} = 3$. Then, S1 substitutes the value $x=3$ into the quadratic function so that the apex point (3,2) is obtained. In this case, the breaking point obtained by S1 is incorrect. S1 made a miscalculation i.e. on the operation "18-36+16" which should have the answer to -2, but S1 writes with 2. In the interview, S1 just realized that the answer written was incorrect as the answer S1 in the interview, "18-36+16 should be the result -2 yes, I gave less negative signs. The breaking point means (3, -2)." On the subject of S2, in the interview, I also realized that the coordinate points on the y-axis have not been written

in the answer sheet as S2's answer in the interview, "it turns out that I am not looking for the y-axis. So the value $x=3$ is substituted to $2x^2 - 12x + 16 = 2(3)^2 - 12(3) + 16 = -2$ ". Answer S2 shows that in fact the subject can determine the verge of a triangle, but both subjects are less meticulous in performing calculation operations. Thus it can be concluded that both subjects have not fully met the indicators of visual reasoning of interpretation. In the investigation indicators, both subjects were unable to identify a graphic of the problem given in both questions. This is shown in the example of answer S1 related to question number 1 presented in Figure 2.

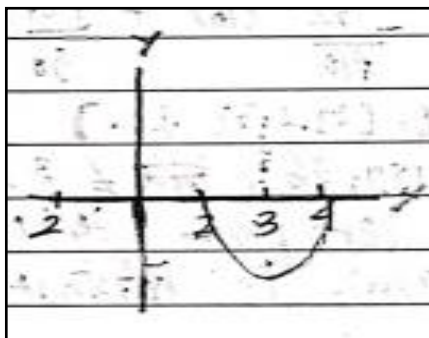


Figure 2. Answer S1 on the interpretation indicator of question number 1

Figure 2 shows that S1 illustrates the graph of the function but is not precise. This is because S1 is not precise in determining the vertex of the triangle as analyzed in the interpretation indicators. Whereas S2 does not describe a graph of functions. In the interview it was revealed that S1 and S2 did not yet understand how to draw a function graph exactly as S1 replied in the interview saying "It seems that it can, but I forgot how. I'm not sure of my answer either." S2's answer indicates that the subject has not been able to correctly identify the picture. In other words, both subjects unable to demonstrate the indicators of the investigation. In the application indicator, both subjects were able to correctly write down the triangle area formula, but both subjects were not precise in determining the base and height of the triangle as presented in Figure 3. This is due to the error of both subjects in determining the vertex of the triangle in cartesian coordinates that occurs at the stage of interpretation, as shown in Figure 3.

Figure 3. Answer S1 on the interpretation indicator of question number 1

Figure 3 shows that S1 is incorrect in determining the base and height of the triangle, causing the area of the triangle obtained to be imprecise. S1 writes the length of the base by 3 units when the base value should be obtained from the distance of the cut point on the x-axis

which is (4.0) and (2.0). In the interview, S1 did not realize that the length of the pedestal written was not as precise as S1's answer in the interview "Furthermore $L = \frac{1}{2} a \times t = \frac{1}{2} (3)(2) = 3$. So the area of the triangle is 3. The base is of the axis of symmetry and the height is from 4-2." Answer S1 indicates that the subject has not been able to determine the exact area of the triangle. In other words, the subject S1 has not met the visual reasoning indicators of the application.

2. Reflector Students

In the investigation indicators, the two reflector subjects, namely S3 and S4, were able to identify the pictures of the problems given precisely in both questions. This is shown in the example of S3's answer related to solving question number 2 as presented in Figure 4.

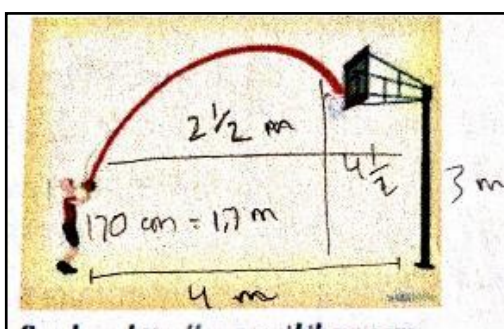


Figure 4. S3 answer to the investigation indicator question number 2

Figure 4 shows that S3 is able to interpret the information in the story in the picture correctly regarding the player's height, basket height, the distance between the player and the basket, and the maximum throw height. In the interview, S3 can explain the information in the picture by saying "basketball player's height = 170 cm = 1.70 meters, basket height = 3 meters, basketball player throws the ball 4 meters away, maximum throw height = 4.5 meters, distance = 2.5 meters." S4 also solves problem number 2 in the same way as S3. This shows that both subjects are able to correctly identify the picture in the question. In other words, both subjects were able to meet the indicators of the investigation. On the indicators of interpretation, both subjects are able to correctly determine the equation of the quadratic function. This is shown in the example of answer S3 in question number 2 as presented in Figure 5.

$$D = ax^2 + bx + c$$

$$= a(0)^2 + b(0)^2 + (1,7)$$

$$c = 1,7$$

$$\text{titik optimum} = (x, y)$$

$$= (4,5, 2,5)$$

$$x = \frac{-b}{2a}$$

$$4,5 = \frac{-b}{2a}$$

$$-b = 4,5 \times 2a$$

$$-b = 9a$$

$$b = -9a$$

$$y = \frac{-b^2 - 4ac}{4a}$$

$$2,5 = \frac{-b^2 - 4ac}{4a}$$

$$-10a = \frac{-b^2 - 4ac}{4a}$$

$$-10a = -9a^2 - 4a(1,7)$$

$$-10a = 81a^2 - 68a$$

$$-100a = 810a^2 - 68a$$

$$810a^2 - 68a + 100a = 0$$

$$810a^2 + 32a$$

$$a(810a + 32) = 0$$

$$a = 0$$

$$810a + 32 = 0$$

$$810a = -32$$

$$a = \frac{-32}{810}$$

$$b = -9a$$

$$b = -9 \times \frac{-32}{810}$$

$$b = \frac{32}{90}$$

Figure 5. S3 answer on the interpretation indicator of question number 2

Figure 5 shows that S3 first writes down the general form of the quadratic function equation i.e. $y = ax^2 + bx + c$. By substitution $y = 0$ obtained value $c = 1.7$ i.e. the player's high coordinates. Based on an understanding of the information in the question, S3 can determine the optimum point of throwing the ball, namely the point $(4.5, 2.5)$. Furthermore, S3 determines the values of a and b using the symmetry axis formula so that the equation is obtained $b = -9a$. then S3 substitutes $c = 1.7$ dan $b = -9a$ in the equation of the axis of symmetry obtained the value $a = 0$ or $a = -\frac{32}{810}$. Value substitution $a = -\frac{32}{810}$ to equation $b = -9a$ obtained value $b = \frac{32}{90}$. In the interview, S3 can explain the step of solving problem number 2 by saying, "The step is to provide for the equation of the quadratic function $y = ax^2 + bx + c$ then it is provided $y = 0$ obtained $c = 1.70$, it is from the height of the basketball player which is 170 cm converted to 1.70 meters (equation 1). Then search for the axis of symmetry of the maximum point coordinates $(4\frac{1}{2}, 2\frac{1}{2})$ i.e. $x = -\frac{b}{2a} \rightarrow 4\frac{1}{2} = -\frac{b}{2a} \rightarrow b = -9a$ (equation 2). Next $y = \frac{-b^2 - 4ac}{4a} \rightarrow 2\frac{1}{2} = \frac{-b^2 - 4ac}{4a} \rightarrow b^2 - 4ac = -10a$ (Equation Three). Equations 1 and 2 substituted to equation 3 are obtained $81a^2 - 6,8a = -10a$. Then multiplied by 10 so that it can be factored. So found $a = 0$ or $a = -\frac{32}{810}$. Continue to look for the value of b by substituting $a = -\frac{32}{810}$ ke $b = -9a$ become $b = -9\left(-\frac{32}{810}\right) = \frac{32}{90}$. So the equation of the quadratic function $f(x) = -\frac{32}{810}x^2 + \frac{32}{90}x + 1,7$ ". S3's answer in Figure 5 and

the interview results show that S3 can interpret the picture as a form of quadratic function equation precisely. Thus, the subject is able to meet the indicators of interpretation. On the application indicators, both subjects are able to solve the equation and give conclusions related to solving the equation appropriately. This is shown in the example of the results of the S3 answer related to question number 2 presented in Figure 6.

$$\begin{aligned}
 y(4) &= \frac{-32}{810}(4)^2 + \frac{32}{90}(4) + 1,7 \\
 &= \frac{-32}{810}(16) + \frac{128}{90} + 1,7 \\
 &= -0,632 + 1,4 + 1,7 \\
 &= 2,5 \neq 3
 \end{aligned}$$

Jadi, lemparan bola tersebut tidak masuk ke dalam keranjang.

Figure 6. S3 answer on the application indicator question number 2

Figure 8 shows that S3 determines the ball into the basket by substituting the position coordinates of the basket (4,3) into the quadratic function equation. S3 answers obtained $y(4) = 2,5 \neq 3$ which means the ball won't go into the basket. In the interview, S3 explained that the thrown ball did not go into the basket as S3's answer said "To prove the throwing of the ball through the position of the basket (4,3). Substituted to $f(x) = y = -\frac{32}{810}x^2 + \frac{32}{90}x + 1,7$; $y(4) = -\frac{32}{810}(4)^2 + \frac{32}{90}(4) + 1,7 = 2,5$. The ball throw does not go into the basket, because it is 2.5 meters \neq 3 meters". S3 answers supported by interviews show that the subject can solve the equation and give the right conclusion. Thus, the subject is able to meet the application indicators.

3. Theories Students

There are two subjects analyzed in the theoretical learning style, namely S5 and S6. Both subjects were able to identify pictures of the problems given precisely in both questions. This is shown in the example of S5's answer related to question number 2 as presented in figure 7.

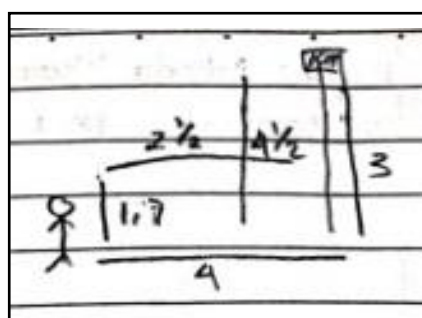


Figure 7. S5 answer results on the investigation indicator Question number 2

Figure 7 shows that S5 is able to interpret the information in the story in the picture correctly regarding the player's height, basket height, the distance between the player and the basket, and the maximum throw height. In the interview S5 said "The picture is like this, basketball player =170 cm= 1.70 meters, basket height = 3 meters, basketball player throws the ball 4 meters away, maximum throw height = 4.5 meters, distance = 2.5 meters." S6 also solves problem number 2 in the same way as S5. This shows that subject S5 is able to correctly identify the pictures in the story question. In other words, the subject of Theory is able to meet the indicators of investigation. On the indicators of interpretation, both subjects are able to determine the equation of the quadratic function completely and precisely. This is shown in the example of the result of answer S5 on question number 2 presented in Figure 8.

<input type="checkbox"/>	2.	$y = ax^2 + bx + c$	
<input type="checkbox"/>		$0 = a(0)^2 + b(0) + 1.7$	
<input type="checkbox"/>		$a = 1.7$ (1)	
<input type="checkbox"/>		koordinat titik optimum = (x, y)	
<input type="checkbox"/>		$= (4\frac{1}{2}, 2\frac{1}{2})$	
<input type="checkbox"/>		$sb = x = -\frac{b}{2a}$	$y = \frac{-b^2 - 4ac}{4a}$
<input type="checkbox"/>		$4\frac{1}{2} = -\frac{b}{2a}$	$2\frac{1}{2} = \frac{-b^2 - 4ac}{4a}$
<input type="checkbox"/>		$2a$	$4a$
<input type="checkbox"/>		$b = -9a$ (2)	$10a = -b^2 - 4ac$ (3)
<input type="checkbox"/>			$b^2 - 4ac = -10a$
<input type="checkbox"/>			$(9a^2) - 4a(1.7) = -10a$
<input type="checkbox"/>			$81a^2 - 6.8a = -10a$) x 10
<input type="checkbox"/>			$810a^2 - 68a + 100a = 0$
<input type="checkbox"/>			$810a^2 + 32a = 0$
<input type="checkbox"/>			$a(810a + 32) = 0$
<input type="checkbox"/>			$a = 0$
<input type="checkbox"/>			$810a + 32 = 0$
<input type="checkbox"/>			$a = -\frac{32}{810}$
<input type="checkbox"/>			$\frac{32}{810}$
<input type="checkbox"/>			$\frac{32}{810}$

Figure 8. S5 answer results on the investigation indicator Question number 2

Figure 8 shows the same S5 completion step as the reflector subject completion step i.e. S3. S5 also uses a quadratic equation model to determine the player's height. It then utilizes the understanding of the optimum point to determine the coefficients a and b of the quadratic equation. In the interview, S5 can also systematically explain the solving steps to find a model of quadratic equations related to throwing a ball into a basket. This suggests that, S5 can determine the equation of a quadratic function precisely. S6 also uses the same solving steps as S5 to find models of quadratic equations. Thus, both subjects were able to meet the indicators of visual reasoning of interpretation. On the application indicators, both subjects were able to identify the equation in order to obtain an exact conclusion. This is shown in the example of the result of answer S5 related to question number 1 presented in Figure 9.

$$y(4) = \frac{-32 \cdot (4^2)}{810} + \frac{32 \cdot 4}{90} + 1,7$$

$$y(4) = \frac{-32 \cdot 16}{810} + \frac{32 \cdot 4}{90} + 1,7$$

$$y(4) = -0,632 + 1,4 + 1,7$$

$$y(4) = 2,46 \neq 3$$

Jadi, bola tersebut tidak masuk kedalam keranjang

Figure 9. S5 answer results on the investigation indicator Question number 2

Figure 9 shows that S5 determines whether a sphere goes into the basket or not by substituting the position coordinates of the basket (4,3) into the equation of the quadratic function so that it is obtained $2,46 \neq 3$ which means the ball doesn't go into the basket. This is supported by an excerpt from the S5 interview which says "Substitution through position from basket (4,3). Substituted to $= -\frac{32}{810}x^2 + \frac{32}{90}x + 1,7 \cdot y(4) = -\frac{32}{810}(4)^2 + \frac{32}{90}(4) + 1,7 = 2,46$. Did not enter, because it is 2.46 meters high \neq 3 meters basket height". This suggests that, S5 and S6 can give conclusions from the equations of quadratic functions precisely. Thus, both subjects were able to meet the application indicators.

4. Pragmatic Students

There are two subjects in the pragmatic learning style, namely S7 and S8. Both subjects are able to pinpoint the cut points and coordinate points. This is shown in the example of the result of answer S8 related to question number 1 presented in Figure 10.

<input type="checkbox"/>	$y = ax^2 + bx + c$	
<input type="checkbox"/>	$y = 2x^2 - 12 + 16$	
<input type="checkbox"/>	$y = 2(x^2 - 6 + 8)$	titik potong = (2,0) (4,0)
<input type="checkbox"/>	$y = 2(x-2)(x-4)$	
<input type="checkbox"/>	$y = 2x^2 - 4 - 0$	
<input type="checkbox"/>	$2x = 4$	
<input type="checkbox"/>	$x = 4 : 2$	
<input type="checkbox"/>	$x = 2$	
<input type="checkbox"/>		
<input type="checkbox"/>	$sb = x = \frac{-b}{2a} = \frac{-12}{2 \cdot 2} = \frac{-12}{4} = 3$	
<input type="checkbox"/>		
<input type="checkbox"/>	$f(x) = ax^2 + bx + c$	sumbu simetris = (3, -2)
<input type="checkbox"/>	$= 2x^2 - 12x + 16$	
<input type="checkbox"/>	$= 2(3)^2 - 12(3) + 16$	
<input type="checkbox"/>	$= 18 - 36 + 16$	
<input type="checkbox"/>	$= -2$	

Figure 10. S8 answer results on the interpretation indicator of Question number 1

Figure 10 shows that S8 determines the angular points of a triangle by looking for the x-axis cutoff point and the vertex point. To determine the angular points of the triangle, S8 determines the cut-off points of the x-axis by factoring the quadratic equation so that the cut-off points (2,0) and (4,0) are obtained. Next the subject determines the vertex of the triangle by using the formula of the axis of symmetry $x = -\frac{b}{2a} = -\frac{-12}{2 \times 2} = 3$. Then, S8 substitutes the value $x=3$ to the quadratic function so that an apex point (3,-2) is obtained. Thus, the S8 can determine the cut-off point precisely. In the interview, S8 was able to explain the step of determining the cut-off point and optimum point of the quadratic equation precisely so that the angular points of the triangle could be determined. Subject S7 was also able to explain the steps of determining the angular points of a triangle just like subject S8. This shows that S7 and S8 can pinpoint the cut-off and vertex points of the triangle. Thus, both subjects were able to meet the indicators of visual reasoning of interpretation. In the investigation indicators, the two subjects have not been able to identify graphic pictures on the problems given in both questions. This is shown in the example of the result of answer S8 related to question number 1 presented in Figure 11.

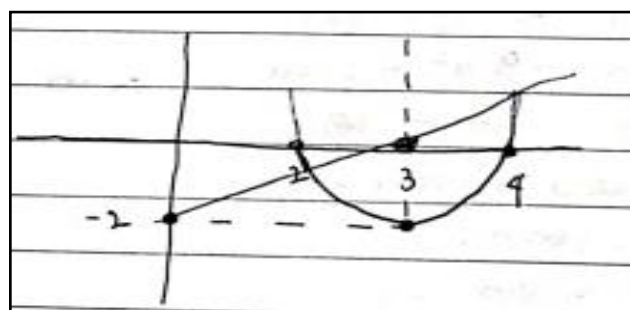


Figure 11. S8 answer results on the interpretation indicator of Question number 1

Figure 11 shows that S8 draws a graph of the function from the quadratic equation of question number 1 but is not precise. This is because S8 does not yet understand how to determine the exact build of a triangle as S8 replied in the interview which said, "This graph can be from the cut point and the coordinate point that has been searched. But I'm less sure of my picture". This shows that the subject S8 has not been able to correctly identify the picture. In other words, the pragmatic subject has not been able to meet the indicators of the investigation. On the application indicator, both subjects can write down the triangle area formula exactly. However one of the subjects was imprecise in determining the base and height of the triangle in cartesian coordinates. This is as shown in the example answer S8 related to question number 1 presented in Figure 12.

$$\begin{aligned}
 \text{Lu} &= \frac{1}{2} \cdot a \cdot t \\
 &= \frac{1}{2} \cdot 2 \cdot 2 \\
 &= 2
 \end{aligned}$$

Jadi, luas segitiga tersebut adalah 2 satuan luas.

Figure 12. S8 answer results on the application indicator Question number 1

Figure 12 shows that S8 is incorrect in determining the base and height of the triangle, causing the area of the triangle obtained to be imprecise. S8 writes the length of the base by 3 units when the base value should be obtained from the distance of the cut point on the x-axis namely (4,0) and (2,0). In the interview, S8 did not realize that the length of the base written was not exactly as a snippet of the interview with S8, "so the base is $2 - 4 = -2$ and the height is -2 from the $f(x)$ axis". Meanwhile, the subject S7 is able to determine the base and height precisely. This is the answer of S7 in the interview which says "the base and height of the point in the graph i.e. the base is from $4 - 2 = 2$ and the height of the y-axis = 2. Thus, the pragmatic subject is still weak on the application indicators.

Based on the data analysis, activist subjects have not been able to optimally meet all three indicators of visual reasoning. On the interpretation indicator, the subject is imprecise in determining the cut-off point of the quadratic equation on the problem due to the lack of accuracy in the calculation operation. Then, on the indicators of investigation, the activist subject has not been able to identify pictures of quadratic equations precisely. Furthermore, on the application indicator, the activist subject has also not been able to correctly determine the area of the triangle at the coordinates of the Cartesian, Thus, students with activist learning styles are still weak in the process of visual reasoning.

Furthermore, the results of data analysis show that reflector and theoretical subjects are able to meet all three indicators of visual reasoning, namely investigation, interpretation, and application. In the investigative indicator, the subject can correctly identify the picture information in the story question. Then, on the interpretation indicators, the subject is able to correctly determine the equation of the quadratic function based on the information in the figure. Furthermore, in the application indicators, the subject is able to carry out settlement steps and provide conclusions related to solving the problem appropriately. Thus, students with reflector and theoretical learning styles already have visual reasoning skills.

In pragmatic subjects, the results of data analysis show that the subject is only able to meet one indicator of visual reasoning, namely interpretation. Whereas in the indicators of visual reasoning of investigations and applications, the subject is still not able to meet optimally. In the investigative indicators, the subject has not been able to correctly identify the pictures in the story question. Then, on the interpretation indicator, the subject can precisely determine the cut-off point and the vertex of the quadratic equation on the problem. Furthermore, in the application indicator, the subject is able to determine the area of the triangle precisely, but one of the subjects has not been able to determine the area of the triangle precisely. Overall, students with pragmatic learning styles are still weak in the process of visual reasoning.

The results of this study show that students with activist and pragmatic learning styles still have relative difficulty in solving problems related to visual reasoning. On the contrary, students with reflector and theoretical learning styles are able to solve problems related to visual reasoning appropriately. The lack of visual ability of students with activist learning styles in solving problems related to visuals was also stated by Sanjaya et al. (2018) which explains that activist students are in the category of sufficient in visual representation ability. In contrast, students with theoretical learning styles have better visual representation skills.

Aljaberi (2015) also concluded that students with reflector learning styles are more successful in solving problems compared to activist students.

The difference in students' mathematical reasoning ability is seen from Honey and Mumford's learning styles also in line with the study by Masuda, Pambudi, and Murtikusuma (2021) which concludes that students with activist learning styles can present indicators of mathematical reasoning but are less complete. Meanwhile, students with reflector and theoretical learning styles are able to present complete indicators of mathematical reasoning on solving arithmetic sequence and series problems. However, in students with pragmatic learning styles, the results of the Masuda's et al. research are different from the results of this study which concluded that students with pragmatic learning styles are still weak in visual reasoning. Meanwhile, Masuda et al. state that pragmatic students are already able to present complete indicators of mathematical reasoning. The difference in the results of this study with Masuda et al. related to reasoning abilities in students with pragmatic learning styles is interesting to study further. Differences in the cognitive abilities of the research subjects, Grade IX in this study and Grade XI in the research by Masuda et al., may be a factor that needs to be studied.

Knowledge of the students' individual differences is very important for teachers to be able to design appropriate learning methods or strategies and prepare appropriate teaching materials for students. The use of methods, strategies, or teaching materials that are in accordance with the students' individual differences will be able to help students' success in learning (Hamdani, 2015; Shinnick & Woo, 2014). Research by Setiana and Jailani (2013) also shows that learning styles have an influence on students' math learning achievement. Student learning styles are one of the individual differences that need to be considered by teachers in designing of the learning. Learning style is the way of students perceive and process the information obtained. Learning style is also a significant variable to student learning achievement (Banas, 2018; Mundia & Metussin, 2018). Teachers' knowledge of student learning styles helps improve the quality of learning in the classroom (Amponsah, 2020). Therefore, teachers need to design learning activities that are in accordance with the characteristics of student learning styles (Pilar et al., 2021).

D. CONCLUSION AND SUGGESTIONS

Students with reflector and theoretical learning styles are able to meet the three indicators of visual reasoning, namely investigation, interpretation, and application. Students in both types of learning styles can identify picture information in word problems correctly, able to determine quadratic function equations based on the information in the picture correctly, and able to carry out solving steps and provide conclusions related to solving problems appropriately. Further, students with a pragmatic learning style, are able to meet only the indicators of interpretation. Meanwhile, in the investigation and application indicators, students have not been able to meet optimally. Meanwhile, students with activist learning styles have not been able to meet the three indicators of visual reasoning optimally. Students are less precise in meeting investigative, interpretive, and application indicators.

This study provides information that there is a link between learning styles and students' reasoning abilities. Nonetheless, the limited involvement of the subject as a consequence of case study research causes the results of this study to be uncontroversial for each student.

The use of quantitative research design is an alternative in order to provide broader conclusions. In addition, this research is also only limited to the topic of quadratic functions. The expansion of studies on other mathematical topics will provide more comprehensive information regarding the influence of learning styles on students' reasoning abilities, especially visual reasoning.

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REFERENCES

- Aljaberi, N. M. (2015). University Students' Learning Styles and Their Ability to Solve Mathematical Problems. *International Journal of Business Environment*, 6, 152–165.
- Amponsah, S. (2020). Exploring The Dominant Learning Styles of Adult Learners in Higher Education. *International Review of Education*, (0123456789). <https://doi.org/10.1007/s11159-020-09845-y>
- Banas, R. A. (2018). Perceptual Learning Styles of Students and its Effect to Their Academic Performance Academic Performance. *International Journal of Trend in Scientific Research and Development*, 3(1).
- Darmadi, D., & Sanusi, S. (2020). Visual reasoning analysis of female students in solving mathematical problems. *Journal of Physics: Conference Series*, 1464(1), 12019. <https://doi.org/10.1088/1742-6596/1464/1/012019>
- Darmadi, Sanusi, Wihardjo, E., Karim, Suprianto, & Prayitno, S. (2020). Male Students' Visual Reasoning in Solving Mathematical Problem. *Journal of Physics: Conference Series*, 1538(1), 12086. <https://doi.org/10.1088/1742-6596/1538/1/012086>
- Darmanta, V. D., & Wrastari, A. T. (2014). Studi Deskriptif Profil Gaya Belajar Guru SMP dan SMA di Surabaya Dikaji dari Faktor Sosiodemografis. *Jurnal Psikologi Pendidikan Dan Perkembangan*, 3(2).
- Debrenti, E. (2015). Visual Representations in Mathematics Teaching: an Experiment With Students. *Acta Didactica Napocensia*, 8(1).
- Fatkhiyyah, I., Winarso, W., & Manfaat, B. (2019). Kemampuan Komunikasi Matematika Siswa Ditinjau dari Perbedaan Gaya Belajar Menurut David Kolb. *Jurnal Elemen*, 5(2), 93–107. <https://doi.org/10.29408/jel.v5i2.928>
- Geçici, M. E., & Türnüklü, E. (2021). Visual Reasoning In Mathematics Education: A Conceptual Framework Proposal. *Acta Didactica Napocensia*, 14(1), 115–126. <https://doi.org/10.24193/adn.14.1.9>
- Hamdani, D. Al. (2015). *Exploring Students' Learning Style at a Gulf University: A Contributing Factor to Effective Instruction*. 176, 124–128. <https://doi.org/10.1016/j.sbspro.2015.01.452>
- Hamid, H. A. (2017). *Visual Reasoning In Solving Mathematical Problems On Functions and Their Derivatives Among Malaysian Pre-University Students*. University Of Malaya.
- Hamid, H. A., & Idris, N. (2014). Assessing Pre-University Students's Visual Reasoning: A Graphical Approach. *International Journal of Assessment and Evaluation in Education*, 4, 24–39.
- Hamid, H. A., Idris, N., & Tapsir, R. (2019). Students' Use of Graphs in Understanding the Concepts of Derivative. *Southeast Asian Mathematics Education Jurnal*, 9(1), 3–16.
- Haryono, A., & Tanujaya, B. (2018). Profil Kemampuan Penalaran Induktif Matematika Mahasiswa Pendidikan Matematika UNIPA Ditinjau Dari Gaya Belajar. *Journal of Honai Math*, 1(2), 127–138. <https://doi.org/https://doi.org/10.30862/jhm.v1i2.1049>
- Honey, P., & Mumford, A. (2006). *The Learning Style Questionnaire, 80-item version* (Revised ed). Maidenhead Berks: Peter Honey Publications Limited.
- Keliat, N. R. (2016). The Profile of Students' Learning Styles and Their Effects on Grade Point Average (GPA) Achievement. *Edutech*, 15(2).
- Masuda, A., Pambudi, D. S., & Murtikusuma, R. P. (2021). Analisis Penalaran Matematis Siswa SMA

- Kelas XI dalam Menyelesaikan Soal Barisan dan Deret Aritmetika Ditinjau dari Gaya Belajar Honey-Mumford. *Jurnal Riset Pendidikan Dan Inovasi Pembelajaran Matematika*, 5(1), 56–68. Retrieved from journal.unesa.ac.id/index.php/jrpipm%0AAalisis
- Mohammed, Z., Narayanasamy, S., Abdul, H., Kaur, S., & Ariffin, S. R. (2011). Learning Styles Preferences Among Third Year Optometry Students of Universiti Kebangsaan Malaysia. *Procedia Social and Behavioral Sciences* 18, 18, 384–387. <https://doi.org/10.1016/j.sbspro.2011.05.055>
- Mudaly, V., & Narriadoo, D. (2023). Solving Word Problems by Visualising. *African Journal of Research in Mathematics, Science and Technology Education*, 1–13. <https://doi.org/10.1080/18117295.2023.2183612>
- Mumford, A. (2006). Learning styles and mentoring. *Industrial and Commercial Training*, 27(8), 4–7. <https://doi.org/10.1108/00197859510097045>
- Mundia, L., & Metussin, H. (2018). Exploring Factors That Improve Mathematics Achievement in Brunei. *Studies in Educational Evaluation*, 1–9. <https://doi.org/10.1016/j.stueduc.2018.10.003>
- Natsheh, I., & Karsenty, R. (2014). Exploring the potential role of visual reasoning tasks among inexperienced solvers. *ZDM - International Journal on Mathematics Education*, 46(1), 109–122. <https://doi.org/10.1007/s11858-013-0551-1>
- Nurhayati, E., & Subekti, F. E. (2017). Deskripsi Kemampuan Penalaran Matematis Siswa Ditinjau Dari Gaya Belajar Dan Gender. *AlphaMath : Journal of Mathematics Education*, 3(1), 66–78. Retrieved from <http://jurnalnasional.ump.ac.id/index.php/alphamath/article/view/1935/1564>
- Pilar, A., Díaz, R., Granado-Alcón, M. del, Lago-Urbano, R., & Martínez-García, C. (2021). Variability of Higher Education Students' Learning Styles Depending on Gender, Course, Degree and Institutional Context. *Sustainability*, 13, 1659. <https://doi.org/10.3390/su13041659>
- Putri, D. F. P., Ekawati, R., & Fiangg, S. (2022). Kemampuan Penalaran Matematika Siswa Dalam Pemecahan Masalah Matematika Ditinjau Dari Gaya Belajar. *Jurnal Pendidikan Matematika Undiksha*, 13(1), 1–12.
- Ridwan, M. (2017). Profil Kemampuan Penalaran Matematis Siswa Ditinjau Dari Gaya Belajar. *KALAMATIKA Jurnal Pendidikan Matematika*, 2(2), 193–205.
- Sanjaya, I. I., Maharani, H. R., & Basir, M. A. (2018). Kemampuan Representasi Matematis Siswa Pada Materi Lingkaran Berdasarkan Gaya Belajar Honey Mumford. *KONTINU: Jurnal Penelitian Didaktik Matematika*, 2(2), 60–72. <https://doi.org/http://dx.doi.org/10.30659/kontinu.2.1.72-87>
- Setiana, D. S., & Jailani. (2013). Komparasi Metode CTL dan Open-Ended dengan Gaya Belajar Ditinjau dari Prestasi dan Minat Belajar. *PYTHAGORAS: Jurnal Pendidikan Matematika*, 8(2), 135–145. Retrieved from <http://journal.uny.ac.id/index.php/pythagoras>
- Shinnick, M. A., & Woo, M. A. (2014). Learning Style Impact on Knowledge Gains in Human Patient Simulation. *Nurse Education Today*. <https://doi.org/10.1016/j.nedt.2014.05.013>
- Sholihah, U., & Maryono, M. (2020). *Students' Visual Thinking Ability in Solving The Integral Problem*. 5(2), 175–186. <https://doi.org/10.23917/jramathedu.v5i2.10286>
- Sundayana, R. (2016). Kaitan antara Gaya Belajar, Kemandirian Belajar, dan Kemampuan Pemecahan Masalah Siswa SMP dalam Pelajaran Matematika. *Mosharafa: Jurnal Pendidikan Matematika*, 5(2), 75–84. Retrieved from https://journal.institutpendidikan.ac.id/index.php/mosharafa/article/view/mv5n2_4/267
- Utami, I. D., & Masduki. (2023). Student's Visual Reasoning in Solving Linear Equations in Terms of Learning Style. *Prima: Jurnal Pendidikan Matematika*, 7(1), 26–45. <http://dx.doi.org/10.31000/prima.v7i1.7171>
- Wahyudi, I. D., & Walid. (2020). Mathematical Reasoning Ability of Students Based on Learning Style Using Missouri Mathematics Project Learning Model. *Unnes Journal of Mathematics Education*, 9(3), 206–210. <https://doi.org/10.15294/ujme.v9i3.44538>
- Zulfah, N. A. A., Kusumaningsih, W., & Endahwuri, D. (2021). Profil Kemampuan Penalaran Matematis Dalam Menyelesaikan Soal Cerita Ditinjau Dari Gaya Belajar Siswa. *Jurnal Ilmiah Pendidikan Matematika*, 6, 277–284. <https://doi.org/10.26877/jipmat.v6i2.9495>