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# The Concept of Quadratic Function Graphs Presented in Singaporean Mathematics Textbooks and Its Potential in Developing Critical Thinking Skills

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**Abstract:** This study describes how the concept of quadratic function graphs is presented in Singaporean mathematics textbooks and its potential in improving critical thinking skills. The research approach used is descriptive qualitative with critical thinking criteria set by Facione (2015), namely interpretation, analysis, evaluation, and inference. Based on the results of the study, it was found that the presentation of the concept of quadratic function graphs in Singaporean mathematics textbooks, the concept of quadratic function graphs is presented deductively and through investigative activities. As for the potential for presenting the concept of quadratic function graphs, it can develop critical thinking skills. This can be seen from the fulfillment of critical thinking criteria.

**Keyword:** concept presentation, quadratic function graph, singapore textbook, critical thinking

## INTRODUCTION

One of the main materials studied in phase E in the independent curriculum is the quadratic function graph. By understanding the concept of a quadratic function graph, students will easily understand other concepts. In addition, we can use the concept of a quadratic function to solve problems in everyday life such as those related to the speed of an object, the construction of a curved bridge and calculating the production cost of an item. However, in reality, students' understanding of the concept of equations and quadratic functions is still very low. This can be seen from the students' answers in solving the following problems:

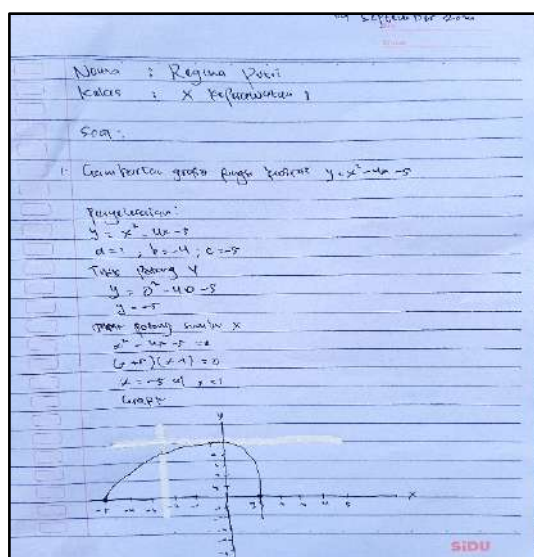


Figure 1. Student Answer Sheet

From the answers, it can be seen that students make many mistakes, namely incorrectly determining the intersection point of the x-axis, not determining the axis of symmetry and the coordinates of the turning point, and incorrectly understanding the

shape of the curve on the quadratic function graph. This results in students making mistakes in drawing function graphs. The lack of understanding of students' concepts about quadratic function graphs is one of the causes of student errors in drawing graphs. In addition, the results of research conducted by Sumarno and Magfirah (2019) found that students' understanding of quadratic equations and functions had not reached the minimum score limit for competency indicators. This is due to students' lack of mastery of the form of quadratic equations and not mastering how to find the roots of quadratic equations.

In general, in mathematics textbooks, the concept of a quadratic function begins by presenting the general form of a quadratic function, namely  $f(x) = x^2 + bx + c; a \neq 0$ , then the steps in drawing a quadratic function graph are presented and followed by examples. This kind of presentation of concepts has been widely applied, so that students are not given space to construct their understanding. In fact, textbooks are one of the supporters of student success in learning. As stated by Tamimi (2018) that student success is supported by good textbooks. In addition, a similar thing was also conveyed by Johar et al., (2018) that student success and activeness are also determined through textbooks.

A good mathematics textbook is a textbook that can encourage students to make discoveries, contains assignments, problems to be solved, and is able to attract children's attention to learn mathematics (Tunde & Gabriella 2011). In addition, Takahashi (2016) said that a good or quality textbook is a textbook that is accompanied by open questions so that it can guide students to develop their understanding, not only containing conceptual explanations and is procedural.

The success achieved by Singapore is inseparable from the textbooks used by Singapore in learning. Many researchers have conducted research or analysis on the textbooks used by Singapore. As conducted by Erbas et al (2012) by examining the ratio or differences of mathematics textbooks in various countries including textbooks from Singapore, the United States and Turkey found that Singapore mathematics textbooks are unique books and can make educators, students or readers in general like Mathematics more than textbooks in Turkey and the United States. Singapore textbooks present more exercises or emphasize more on the problem-solving process and the solution method using an open-ended approach, namely in solving the problem using more than one method.

In addition, there is a widespread view that Singaporean textbooks set high standards in the content of the books used, namely presenting routine and non-routine problems, using a unique approach, namely an abstract approach with concrete illustrations, arranged in a structured, logical manner and focusing on mathematical problem-solving skills (Ahuja, 2005; Hoven & Garelick, 2007). In addition, in the United States, Singaporean mathematics textbooks are used as learning media for several discrete schools (Hoven & Garelick, 2007). In developing students' conceptual understanding, Singaporean mathematics textbooks present them in the form of real illustrations, so that students can easily solve problems through these concepts (Barger, 2013). Yang & Sianturi (2017) explained that Singaporean mathematics textbooks present more exercises and mathematical problems that require students to think critically in solving them.

Critical thinking is a high-level thinking that is an important component in 21st century education (Browne & Litwin, 1987). Miri et al. (2007) stated that critical thinking can help students to succeed in life. Critical thinking is a way for someone to develop their thinking potential through problem analysis, understanding a problem, the process of evaluation and reconstruction or building their understanding (Paul & Elder, 2006). Through critical thinking, someone will be able to choose which correct information to take (Amir, 2015). The importance of developing students' critical thinking skills was also stated by Uzel & Uyangor (2005), namely through mathematical critical thinking skills can help students to solve mathematical problems.

## METHOD

To obtain the required data, researchers use qualitative research methods. Qualitative research is a type of research that describes or depicts the real conditions of a subject that aims to explore and understand the subject in depth.

In this study, the form of presentation of the concept of quadratic function graphs contained in Singaporean mathematics textbooks and its potential in improving critical thinking skills will be analyzed. The critical thinking criteria used are interpretation, analysis, evaluation and inference as proposed by Facione (2015)

## RESULT AND DISCUSSION

Analysis of Presentation of Quadratic Function Concept in Singapore Mathematics Textbooks

Singaporean mathematics textbooks present concepts in a different way than in most textbooks. The presentation of concepts in Singaporean textbooks always begins with an investigation activity. Likewise, the presentation of the concept of quadratic function graphs begins with an investigation activity. However, what is interesting in presenting the concept of quadratic function graphs, students are first asked to analyze a graph. As in the following picture:

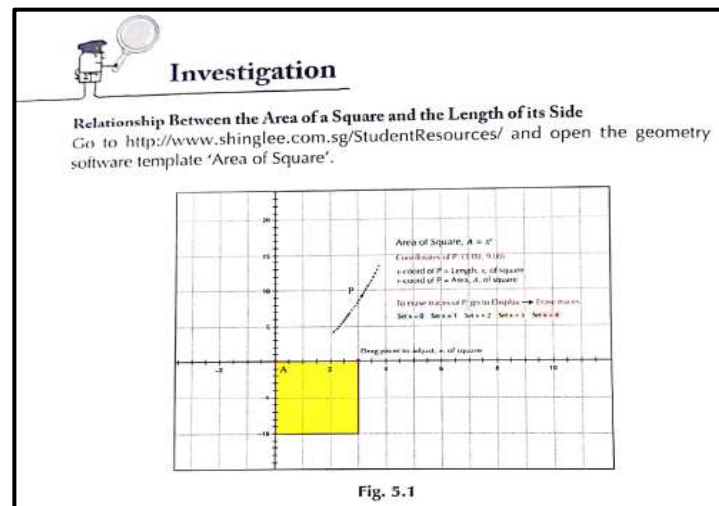


Figure 2. Investigation Activity 1

In the graph above, students are asked to pay attention and input each value of  $x$ , for example  $x = 1, x = 2$  and so on. Then analyze how the shape of the graph changes based on the inputted values. Furthermore, students are asked to explain whether the graph is a linear or non-linear function graph.

Based on the presentation above, it can be seen that to instill students' initial understanding of quadratic function graphs, a problem is presented that is related to the previous material with the aim that students can know and distinguish between linear function graphs and quadratic function graphs. At the end of the first investigation activity, it is stated that the quadratic function  $A = x^2$  is a non-linear function or is referred to as a quadratic function that is included in the category of parabolic curves.

In presenting the concept of quadratic function graphs, the general form of the quadratic function graph is then presented, which is then presented again with investigation activities, as in the following image:

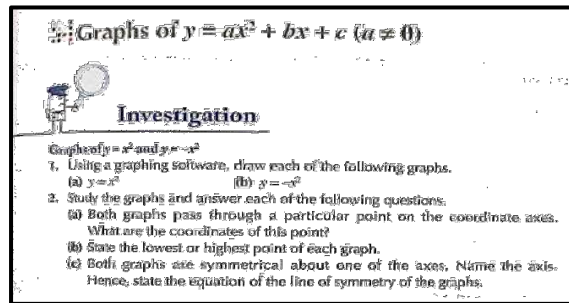


Figure 3. Investigation Activity 2

The investigation activity involves the quadratic function when known  $a = 1, b = 0, c = 0$  and when  $a = -1, b = 0$  and  $c = 0$ . The investigation activity is an activity to guide students to conduct investigations and discover mathematical concepts through problems. With the investigation activity, students can build their own understanding of the function  $y = x^2$  and  $y = -x^2$ . The following is a graph of the function of the equation.

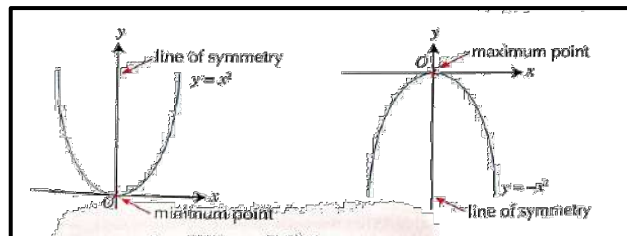


Figure 4. Quadratic Function Graph  $y = x^2$  And  $y = -x^2$

Based on the image we can see some criteria of the function graph  $y = x^2$  and  $y = -x^2$ . The function graph  $y = x^2$  and  $y = -x^2$  passes through the origin  $(0,0)$ , the graph  $y = x^2$  opens upwards without limits and has a lowest point known as the minimum point. While the function graph  $y = -x^2$  opens downwards without limits and has a highest point called the maximum point and the graph  $y = x^2$  and  $y = -x^2$  is symmetrical to the axis  $y$  with the equation of the line of symmetry of the graph is  $x = 0$ .

After knowing the criteria of the generalized quadratic function graph based on investigative activities, the next step is to give a general form of the quadratic function, as shown in Figure 4.15 below:

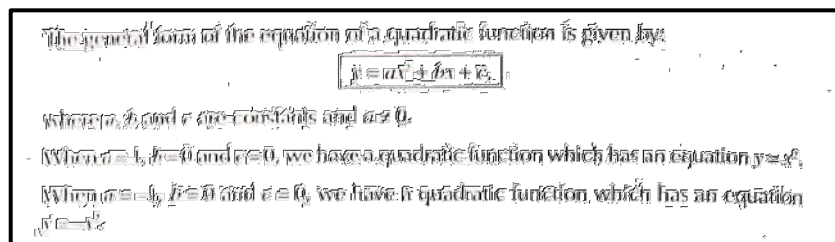


Figure 5. General Form of Quadratic Functions  $y = x^2$  and  $y = -x^2$

In order for students to better understand the concept of quadratic function graphs, questions are given that can guide students in thinking and drawing conclusions related to other forms of quadratic functions.

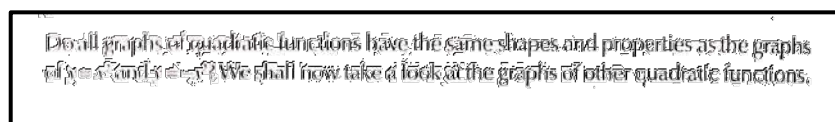


Figure 6. Question Form for Analysis



Next, the investigation activity is presented again. This investigation activity is to see how a graph changes when given the value  $a$ ,  $b$  or  $c$ .

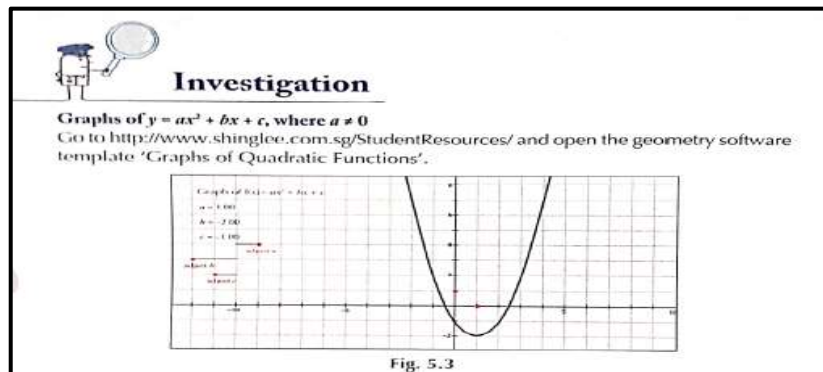


Figure 7. Investigation Activity 3

In this investigation section, four Part questions are presented. In general, it explains how a graph changes when there is a change in the value of the function, either a smaller value or a larger value. Students are asked to analyze how the values of  $a$ ,  $b$ , and  $c$  affect the shape and position of the graph. As seen in the following image:

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Part I: Effect of Value of <math>a</math></b><br/>For this part of the investigation, adjust the value of <math>b</math> and <math>c</math> to 0.</p> <ol style="list-style-type: none"> <li>1. Increase the value of <math>a</math>. What do you notice about the shape of the graph?</li> <li>2. Decrease the value of <math>a</math> but ensure that it is positive. What do you notice about the shape of the graph?</li> <li>3. Decrease the value of <math>a</math> until it becomes negative. What do you notice about the shape of the graph?</li> <li>4. How does the value of <math>a</math> affect the shape of the graph? What happens when <math>a</math> is positive and when <math>a</math> is negative?</li> </ol> <p><b>Part II: Effect of Value of <math>c</math></b><br/>For this part of the investigation, adjust the value of <math>a</math> and <math>b</math> to 1.</p> <ol style="list-style-type: none"> <li>5. Increase the value of <math>c</math>. What do you notice about the position of the graph?</li> <li>6. Decrease the value of <math>c</math>. What do you notice about the position of the graph?</li> <li>7. How does the value of <math>c</math> affect the position of the graph?</li> </ol> | <p><b>Part III: Effect of Value of <math>b</math></b></p> <ol style="list-style-type: none"> <li>8. Adjust the value of <math>a</math> to 1, <math>b</math> to -2 and <math>c</math> to 0 before increasing the value of <math>b</math>. What do you notice about the shape and the position of the graph?</li> <li>9. Adjust the value of <math>a</math> to -1, <math>b</math> to -2 and <math>c</math> to 0 before increasing the value of <math>b</math>. What do you notice about the shape and the position of the graph?</li> <li>10. How does the value of <math>b</math> affect the graph?</li> </ol> <p><b>Part IV: Quadratic Graphs</b></p> <ol style="list-style-type: none"> <li>11. Change the values of <math>a</math>, <math>b</math> and <math>c</math> to obtain each of the quadratic graphs in Table 5.1. Complete the table. The first one has been done for you.</li> </ol> |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Figure 8. Question form

In part IV, tables and several quadratic functions are presented. The types of quadratic functions presented are different, some have positive coefficients, some have negative values. And students are asked to determine the coefficients  $x^2$ , curve positions, maximum and minimum values, axis of symmetry and intercept values of the given functions.

Based on the investigation activities, the general form of the quadratic function graph is obtained or presented, namely:

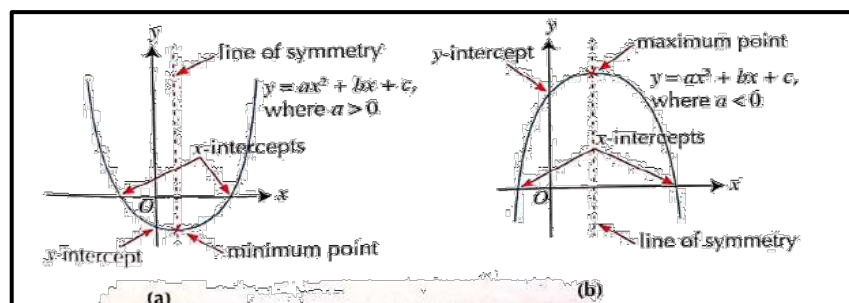


Figure 9. General Form of a Quadratic Function Graph

From the image we can see several criteria of the function graph  $y = ax^2 + bx + c$ . For  $a > 0$ , the curve will open upwards without limit and have a minimum point as in

image (a) while for  $a < 0$ , the graph will open downwards without limit and have a maximum point as in image (b), the smaller the value of  $a$ , the wider the graph opens, the line of symmetry passes through the minimum / maximum point on the graph and the graph may have 0, 1 or 2 intercepts  $x$ , but only has 1 intercept  $y$ .

After presenting the concept of quadratic function graphs, the next section presents examples of questions and applications of the concept of quadratic function graphs in solving everyday life problems.

Based on the analysis, the concept of quadratic function graph is presented deductively and through investigative activities. Through investigative activities, students will be able to construct their own understanding, and students will gain an interesting and enjoyable learning experience because they participate in solving problems to provide conclusions.

The Potential of Quadratic Function Graph Concept Presented in Singapore Mathematics Textbook (New Syllabus Mathematics 7<sup>th</sup> Edition) Book 2 in Developing Critical Thinking Skills.

After conducting a thorough analysis on the presentation of the concept of quadratic function graphs. Next, it will be seen or analyzed how the presentation of the concept has the potential to develop critical thinking. This is shown in the following table 1.

Table 1. Potential presentation of Quadratic Function Graph Concept

|           | Sub<br>Material                | CHAPTE<br>R and<br>page | Critical thinking<br>criteria | Evaluation |   |   |
|-----------|--------------------------------|-------------------------|-------------------------------|------------|---|---|
|           |                                |                         |                               | 3          | 2 | 1 |
| Book<br>2 | Quadratic<br>function<br>graph | Chapter 5<br>h. 129-142 | Interpretation                | √          |   |   |
|           |                                |                         | Analysis                      | √          |   |   |
|           |                                |                         | Evaluation                    |            | √ |   |
|           |                                |                         | Inference                     | √          |   |   |

#### Interpretation

The concept of quadratic function graphs presented has the potential to develop critical thinking skills. This can be seen in the Interpretation aspect which meets the value of 3, namely the concept is presented in various forms of mathematical representation such as through equations, graphs, examples, definitions, and classifying objects based on certain criteria according to the concept. Based on the analysis of the presentation of the concept of quadratic function graphs on the functions  $y = x^2$  and  $y = x^2 + bx + c$ , that the concept is presented in the form of graphs, statements, equations, examples and through definitions. This is shown in the presentation of the concept of quadratic function graphs contained in book 2. In addition, the criteria for quadratic function graphs are clearly explained that the quadratic function graph is parabolic. In the function  $y = x^2$  and  $y = -x^2$  function graph passing through the origin (0,0), the graph  $y = x^2$  will open upwards without limits and have a lowest point known as the minimum point. While the function graph  $y = -x^2$  will open downwards without limits and have a highest point called the maximum point. The function criteria  $y = x^2 + bx + c$  are also clearly described, namely when  $a > 0$ , then the graph opens upwards without limits and has a minimum point while when  $a < 0$ , then the graph will open downwards without limits and has a maximum point, so that through these criteria it can be used to distinguish which is included in the quadratic function graph or not.

#### Analysis

In the analysis aspect, the concept presented causes the identification of the relationship between the graphs, statements, images or definitions presented and the process of inferential analysis of the relationship in the representation. So that the

Analysis aspect meets the value of 3. Based on the presentation of the concept of quadratic function graphs, there is a process of identifying the relationship between the concept of quadratic equations, quadratic functions and the concept of quadratic function graphs. In addition, through investigation activities, students will conduct analysis and investigation of several quadratic functions given. In the function  $y = x^2$  and  $y = -x^2$  students will analyze how the shape and differences of the two graphs will be drawn. In the function  $y = x^2 + bx + c$  when  $a > 0$  and when  $a < 0$ , students will also do the same thing, namely analyzing how the shape and differences of the two graphs are so that valid conclusions are obtained.

#### Evaluation

In the evaluation aspect of the presentation of the concept of quadratic function graphs only meets the value of 2 because presenting concepts in the form of graphs, sentences, and images is less able to be assessed for credibility because it does not present methods, evidence and other forms that support the presentation of the concept. Several things are presented to support the evaluation aspect, namely the existence of investigative activities that will guide students in conducting investigations. In addition, through the graphs presented, students can directly see the truth. However, in the presentation of the concept of quadratic function graphs, other things that can be used as evaluation tools in determining student understanding are lacking, such as not presenting thinking time activities and questions to evaluate understanding of the concept.

#### Inference

The concept of quadratic function graphs presented has the potential to develop critical thinking skills by meeting a value of 3 because there are things needed to make conclusions and the results presented are in accordance with statements, procedures or other representations by including logical reasons in justifying conclusions. And the important elements presented in drawing conclusions related to quadratic function graphs are the form of the graph presented, namely the presentation of quadratic function graphs and descriptions and exposures of the criteria obtained based on investigative activities, so that the equation of the quadratic function graph is obtained, namely  $y = x^2 + bx + c$  with  $a, b$  and  $c$  are constants and  $a \neq 0$ .

### CONCLUSION

Based on the analysis results of the presentation of the concept of quadratic function graphs in Singaporean mathematics textbooks, the concept of quadratic function graphs is presented deductively and through investigative activities. Through investigative activities, students will be able to construct their own understanding, and students will gain an interesting and enjoyable learning experience because they participate in finding concepts, solving problems and drawing conclusions.

In the potential of presenting concepts in developing critical thinking skills, there is one criterion that only meets the value of 2, namely evaluation. This is due to the lack of evaluation forms presented such as Thinking Time activities and other forms of evaluation. While for other criteria such as interpretation, analysis and inference each get a value of 3. Based on the results of the analysis, it can be concluded that the presentation of the concept of quadratic function graphs can develop critical thinking skills.

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We would like to express our gratitude to all parties involved in this research until the final stage of the research. and our hope for the future is that research like this will continue to be carried out and developed so that it will later provide a positive impact or good results for the field of education, especially in developing good textbooks.



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