International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979
Impact Factor: RJIF 5.72
Received: 03-06-2018; Accepted: 09-07-2018
www.allsubjectjournal.com
Volume 5 Issue 7; July 2018; Page No. 33-37

The critical thinking profile of junior high school students in solving geometry problems

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Abstract
This study aimed to describe the critical thinking profile of junior high schools students in solving geometry problems. This study belonged to a descriptive study with a qualitative approach. Critical thinking in this study refers to criteria suggested by Ennis namely Focus, Reason, Inference, Situation, Clarity, and Overview (FRISCO). There were three students involved as subjects. The data was collected by distributing a written test on geometry issues and conducting an interview based on the results afterwards. The findings have revealed that the critical thinking profile of the students covered the ability to understand the focus of each stage in solving the geometry problems, to decide which strategy should be used to find the solution, and to draw a conclusion based on some rationales. Besides, the students were also able to recognize the situation, explain terms of problem solving, and reexamine their work.

Keywords: frisco, critical thinking, problem solving

1. Introduction

Mathematics is a study underlying the advancement of science and technology. Mathematics is taught at every education level to help students develop their critical thinking ability and to assist them to solve problems they found in life. Department of National Education of Indonesia (Depdiknas, 2006) [6] has outlined that: it is necessary to teach math to all students in order that they can think logically, analytically, systematically, critically, and creatively. In addition, mathematics also allows them to work cooperatively. These competences are required to make the students able to obtain, process, and utilize information from the society.

To think critically is to analyze a mental activity with a systematic thought. Johnson (2006) [11] asserts that critical thinking refers to an organized thought. A critical thinker systematically analyzes a mental activity to test its reliability. S/he cannot accept a thing just the way it is and s/he cannot justify something just because people have justified the thing. According to Fisher (2008) [8], critical thinking is a way of thinking which directs someone to not easily draw a conclusion or merely accept some evidence, demands, or decision without thinking deeply about them. Critical thinking requires careful interpretation and evaluation towards an observation, communication, and any other information.

Ennis (1996) [7] defines critical thinking as a logical thinking focusing on how to make a decision about what to believe and what to do. Critical thinking, therefore, is an aid for someone to make a decision based on facts pertinent to what is being faced at the moment. Furthermore, Ennis characterizes the qualities of a critical thinker as FRISCO (Focus, Reason, Inference, Situation, Clarity, and Overview).

Critical thinking is an ability developed through learning mathematics. Peter Ebiendele (2012) [14] points out that this ability should be embed into the classroom with the students as information users instead of mere information receivers. The students' low critical thinking skills is indirectly caused by the learning process which has not yet empowered the students' thinking skills (Bachtiar, 2014) [1]. It is later required to improve the students' quality of thoughts. Thomas Theda (2011) [17] claims that critical thinking is a skill of which significance for students is to help them give appropriate assessment to information received and to provide rationales of it as well as to solve an unknown problem. He further proposes an argument analysis and feedback evaluation as techniques to improve the students' critical thinking.

The relationship between critical thinking and problem solving is momentous. According to Cottrell Stella (2005) [5], critical thinking is closely related to reasoning or an ability to think rationally. The word 'rational' means 'providing reasons' to find a solution to a prolem. In mathematics, this ability is badly needed by the students. A Board for National Standards in Education or BSNP (2006) [4] states that problem solving is a focus in learning mathematics. This includes closed-problems with a single solution, open-problems with multiple solutions and problems with a number of solutions. Besides, the National Council of Teachers of Mathematics or NCTM (2000) [12] divides five basic competences of mathematics-standard of process into problem solving, reasoning and proof, communication, connection and representation. Based on what has been explained earlier, teachers should concern about students' ability in solving the mathematics problems. As a result, learning objectives can be achieved.

1.1 Literature Review

1.1.1 Critical Thinking

Scriven dan Paul (2007) [16] define critical thinking as an active intellectual process which comprises skills to conceptualize, apply, analyze, synthesize, and/ or evaluate information collected or produced through observations, experiences, communication reasoning, reflections, or information used as guidance to beliefs and conducts. Iakovos (2011) [10] explains that critical and creative thinking play a vital role in education. They have become key objectives to learning in which four important components to build them exist. The components cover skills to (a) explain and clarify; (b) ask appropriate questions to clarify or challenge; (c) examine credibility of information; (d) solve problems and draw a conclusion.

Ennis (1996) [7] defines critical thinking as a logical thinking focusing on how to make a decision about what to believe and what to do. Critical thinking, therefore, is an aid for someone to make a decision based on facts pertinent to what is being faced at the moment. Furthermore, Ennis characterizes the qualities of a critical thinker as FRISCO (Focus, Reason, Inference, Situation, Clarity, and Overview). (1) F (Focus), First thing to do in understanding a problem is to determine the focus of the problem and decide which strategy will be used to find the solution; (2) R (Reason), The next thing to do is to recognize reasons which support or contradict the issue. Decisions should be made relevant to the existing facts. The reasons could be derived from known information or theorem, attributes, etc. The reasons will background the conclusion drawing; (3) I (Inference), An accurate conclusion drawing should follow a logical step. The most important part of this step is to identify assumption and find a solution. The decision will result from careful interpretation of situation and evidence; (4) S (Situation), To understand the situation and to always keep it during the process of thinking will help clarify the issues (in F) and help recognize key terms as well as relevant parts as an assistance; (5) C (Clarity), Clarifying terms used in oral or written expression will lead to a clear description of the issues to avoid ambiguity, and (6) O (Overview), The last is to review and reexamine the decision made thoroughly.

Based on some definitions of critical thinking by the experts, the researcher concludes that critical thinking is a mental activity to create a conclusion supported by reliable proof, valid information sources, reasonable explanations which refer to FRISCO (Focus, Reason, Inference, Situation, Clarity, and Overview) to find a solution to a problem. A critical thinker should be able to recognize the focus, reasons, situation and appropriate conclusion to a problem before making a decision. Besides, s/he has to clarify terms in every opinion expressed. The last criterion of a critical thinker is to always review every conduct performed. So, evaluating final thoughts is also essential.

1.1.2 Problem Solving

To face a life full of problems, learning at school should be designed to equip students with an ability to solve the problems. Solving mathematics problems requires advanced mental activities which can stimulate students' higher order thinking. NCSM (Pehkonen, 2011) [13] further states that "problem solving can be understood as a process where previously acquired data are used in a new and unknown situation".

Similar to what has been written in mathematics curriculum (Depdiknas, 2006) [6], problem solving has been a focus or mathematics learning at school. It is also in line with the standard established by NCTM (2000) [12] which states that "Solving problem is not only a goal of learning mathematics but also a major means of doing so. … In everyday life and in workplace, being a good problem solver can lead to great advantages. … Problem solving is an integral part of all mathematics learning". Problem Solving is considered more effective (Birgili, 2015; Bachtiar, et al. 2018) [3].

In mathematics, problems can be defined as a unique situation in which an individual is faced with some barriers to a solution. Hudojo (2005) asserts that a question can be a problem if there is no certain rule/law used to find the answer. It means that some students might find a question difficult, but some others might not think the same.

Polya (1973) [15] categorizes problems in mathematics into two, they are (1) problems to find, (2) problems to prove. The purpose of the problems to find is to find a certain object (target) or problem to solve. The principles are (a) what is being asked? (b) What data has been known?, (c) what are the requirements? Problems to prove are those which are designed to reveal whether an issue is right or wrong so that it is necessary to find answers to question; "Is the issue right or wrong? Or to draw a conclusion to prove it. The main part of these problems is if they are mathematics problems the hypothesis or the conclusion of a theorem which should be proven.

According to some experts, it can be concluded that solving mathematics problems is a process of thinking, analyzing, and reasoning by utilizing related experiences and knowledge to find a solution to a problem which is not easily solved by an individual. The barrier could be an inability to understand a problem due to its irregular problem-solving procedure. There are steps can be followed to solve this kind of problem. First is to understand the problem and make a plan. Next is to implement the plan and review things that have been done. The FRISCO criteria used at every step of problem solving suggested by Polya can be seen in the following table.

Table 1: Guidance for analysis of students' critical thinking profile based on FRISCO

Critical Thinking Criteria of Frisco	Understanding a problem	Planning	Implementing the plan	Reviewing
F	Construct a meaning of the problem to be solved. It can be done through formulating problems in sentences, pictures, charts, and others.	Decide which strategy to use to find the solution to the problem.	Follow some steps to implement the strategy.	Decide to cross-check the answers to the question.
R	Provide reasons underlying the formulation of the problem.	Provide reasons of why the strategy is used.	Recognize reasons of implementing the steps.	Provide reasons of why the answers should be reviewed.
I	Draw a logical conclusion according to the researcher (based on data collected) from a series of stating reasons to making a decision.	Draw a logical conclusion (according to the researcher) from a number of reasons of why to choose a certain strategy and of why to use the strategy.	Draw a logical conclusion (according to the researcher) from a number of reasons of why a decision has been made and of how to implement it.	Draw a logical conclusion (according to the researcher) from a number of reasons of why to review the answers.
S	Recognize what has been stated and being asked by the problem.	Recognize important things in making a plan such as knowing what should be done when the strategy is being implemented to find a solution to the problem.	Recognize important things in implementing the strategy such as steps in solving algorithm.	Recognize important things in reviewing the answer.
C	Clarify terms used (revealed through an interview)	Clarify terms used (revealed through an interview)	Clarify terms used (revealed through an interview)	Clarify terms used (revealed through an interview)
O	Check all activities that have been done (from formulating problems to drawing a conclusion) whether all of them are logical or not.	Check all activities that have been done (from formulating problems to deciding strategy used) whether they are effective or not to solve the problem.	Check all activities that have been done (from formulating problems to implementing the strategy) whether they are logical or not.	Check all activities that have been done (from formulating problems to making final conclusion) whether they are effective or not to solve the problem.

2. Methods

This study was a descriptive qualitative study which involved three students as participants. The participants should be able to communicate or express their thoughts. Data was collected through a mathematics test and interview which elicited clearer view of the students' ability in solving problems in mathematics. Valid data was then analyzed and interpreted. The interpretation contained the students' critical thinking profile in solving geometry problems. Data analysis referred to the FRISCO criteria by Polya in Table 1.

2.1 Instruments

2.1.1 Written test

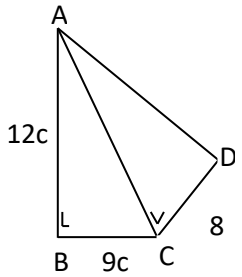
The test conducted was a mathematical ability test and a problem solving test on triangle problems. The problem solving test was used to reveal the students' critical thinking profile in solving geometry problems.

Mathematical Ability Test

- In triangle ABC, the length of the base is 24cm and the corresponding altitude is 15cm, find the area of ABC.

Answer

Look at the following picture!



Find the length of AD!

Problem Solving Test

2.1.2 Problem

If two triangles have the same perimeter, do they have the same area? Explain.

2.1.3 Interview Guidelines

Followings are the interview guidelines used to elicit answers from the participants:

Interview Methods:

- The interview questions were adjusted to the result of the test.
- The interview questions can be used repeatedly, but asked different problems.
- If the students found difficulties in answering a certain question, the interviewer might simplify the language without changing the meaning.

Table 2: Interview Guidelines

Critical Thinking Criteria of FRISCO	Indicators	Questions
F	▪ Formulate the focus of the problem ▪ Decide strategy to be used to solve the problem	▪ What is the focus of the problem? ▪ Which strategy will you use to solve the problem?
R	Provide reasons based on relevant facts/proof to support each stage in making decision and drawing conclusion	What reasons underlie your steps in solving the problem?
I	Draw a conclusion based on appropriate reasons	What steps do you follow to draw a conclusion?
S	Make use of all information related to the problem	What information do you use to solve the problem?
C	Clarify terms used in solving the problem	How do you clarify the terms used to solve the problem?
O	Review all activities that have been done thoroughly (generated at FRISC)	How do you review all the activities thoroughly?

3. Findings and Discussion

This study was conducted to the students of VIII A at Mts Surya Buana Malang. It aimed to describe the students' critical thinking profile in solving geometry problems, especially the triangle problems. There were two stages of the study that are the written test stage and the interview stage. The students were interviewed after they finished the test stage of which purpose was to know the students' problem solving ability.

3.1 Results of the Tests

The results of the written mathematical ability test on triangle conducted to the participant have been described by following pictures:

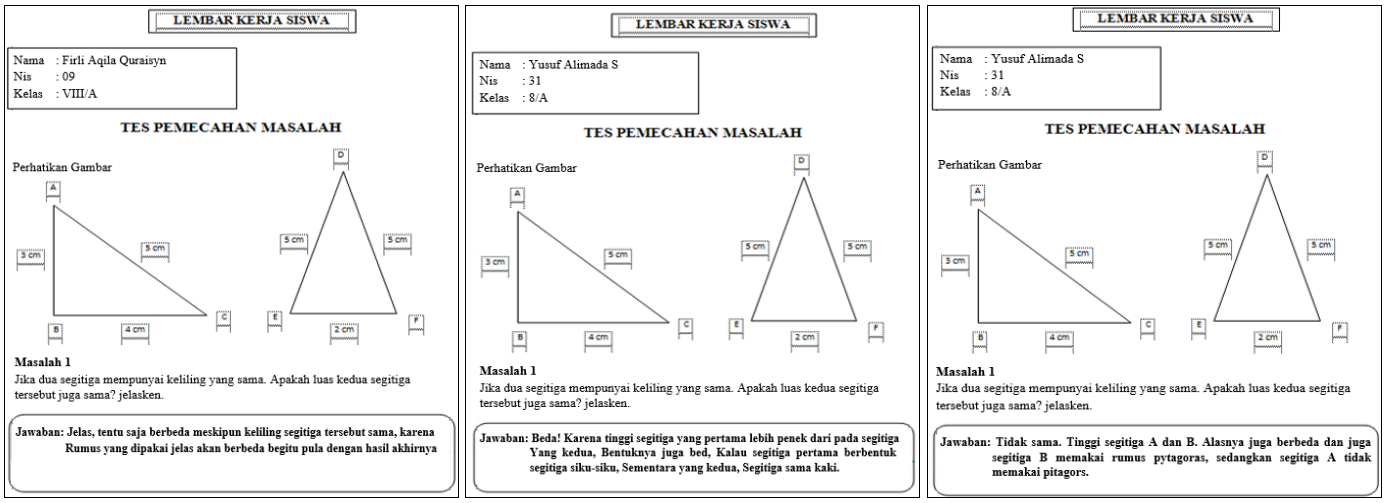


Fig 1

3.2 Results of the Interview

The interview was conducted after the participants finished doing both written tests. Based on the interview, it can be concluded that the students:

- Determined the focus of the problem
- Decided strategy used to solve the problem
- Clarified terms used to solve the problem
- Reviewed their work thoroughly

The results of the observation on the students when solving geometry problems are depicted in the following table. It reflects the students' critical thinking profile in solving the problem.

Table 3: Description of the Students' Critical Thinking Profile in Solving Geometry Problem

Critical Thinking Criteria of FRISCO	Students of VIII A at Mts Surya Buana Malang
F (Focus)	Argued focus of the problem briefly and decided strategy used to solve it.
R (Reason)	Explained reasons of why using a certain formula to solve the problem
I(Inference)	Stated the answer as well as its rationales
S (Situation)	Made use of information relevant to the problem and ignored unimportant information
C (Clarity)	Clarified terms used to solve the problem.
O (Overview)	Reviewed their final work, but not thoroughly

4. Discussion

In Focus, participants argued focus of the problem briefly. They stated that the measure of all sides of triangle A was the same as those of triangle B. Then, they continued to use strategy in calculating the area of triangle A and triangle B; whether they were similar or not. The participants showed things relevant to the case that needed to be solved, in this case. They sought for an effective strategy to find the solution. This finding is in line with Ennis (1996) [7] who argues that first thing to do in understanding a problem is to formulate the focus and to decide which strategy best used to find the solution.

In Reason and Inference, the subjects used a theorem to determine the area of the triangle.After that, they could find answer to the problem together with its rationales. This is similar to Ennis (1996) [7] who stated that it is necessary to look for relevant facts to support rationales before making a decision.

In Situation, the students utilized applicable information that can be used to solve the problem; that the measure of all sides of triangle A and of triangle B was similar, that before calculating the area of triangle A and of triangle B, they needed to recognize the length of the base and of the corresponding altitude. This is supported by Ennis (1996) [7] who asserts that it is important to recognize relevant parts of the problem to find the solution.

In Clarity, the subjects clarified all terminologies found in the problem; that are the base and the altitude of the triangle. This is also similar to Ennis (1996) [7] who argues that clarifying terms can help solve the problem.

In Overview, the participants were convinced with their answer because they had checked it although they only performed it at the end of the process instead of doing it thoroughly. In addition, they also provided rationales to support their answer.

5. Conclusion

Based on the result of the study conducted to the students of VIII A at Mts Surya Buana Malang on their critical thinking profile in solving geometry problems, it can be concluded that the students were able to state the focus of the problem, found s strategy to solve it, provided rationales to support their conclusion, utilized information relevant to the situation, and clarified terms used when finding a solution. They also did review on their answer, but unfortunately they did not perform it thoroughly. Instead, they only checked their final conclusion.

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