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(1995) logical mathematics
material of vocational high school
(VHS)
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Submission date: 31-Jan-2021 09:24AM (UTC+0700)

Submission ID: 1497925612

File name: 1. Critical thinking analysis based on Facione (2015) – Angelo (1995) logical mathematics material of vocational high school (VHS).pdf (454.46K)

Word count: 3174

Character count: 17802

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To cite this article: S Y Seventika *et al* 2018 *J. Phys.: Conf. Ser.* **983** 012067

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Critical thinking analysis based on Facione (2015) – Angelo (1995) logical mathematics material of vocational high school (VHS)

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Abstract. The research has purpose to analyze and categorize the critical thinking ability of VHS students based on modified critical thinking indicator according to Facione-Angelo covering: interpreting the problem, analyzing alternative solution, applying the problem, evaluating the solution and concluding the results gained – attached by supportive evidence. The subject of the research is 30 eleventh graders of TKJ in Yabujah VHS, Indramayu in the odd semester 2016/2017. The collected data are critical thinking test and interviews. The result shows 15% is in good category, 30% in fair category, and 55% in low category. The students in “Good” category has accomplished critical thinking steps although imperfect, especially the indicators of evaluating and concluding attached by supportive evidence. The “Fair” categorized students only show partial steps of the indicators. The analyzing, evaluating, and concluding indicators are the most seldom to do, meanwhile the “low” categorized students show all indicators in low quality even to identify has problem to do.

1. Introduction

Human has involved reasoning ability in daily life [1] argues that reasoning is mental process relating and comparing among facts, ideas or events and facts. There are two reasoning abilities, lower order reasoning and high level reasoning. Lower order reasoning only uses limited capability on routine mechanical things, such as memorizing and repeating information given previously. Meanwhile, high order reasoning motivates students to interpret, analyze, or to manipulate given information previously to avoid monotonous environment.

One of high order reasoning is critical thinking. Critical thinking is a term related to high order reasoning signed by careful analysis and consideration. Every people expects any institution to create its students critically think. Based on Conklin [2], critical thinking is a self-guided, that is self-reasoning to accomplish high quality level through fair reasoning. Johnson states that critical thinking is an organized process to allow the students evaluating evidence, assuming, thinking logically, and understanding language underpinning others' though [3]. Critical thinking is also called as convergent thinking, logical thinking and reasoning. Critical thinking is reasonable and reflective thinking emphasizes decision making related to what is believed or done [4].

Beyer [5], states that the ability covers capability to determine a credibility of a certain source, to differ between something relevant and irrelevant, to differ facts and judgment, to identify existing bias, to identify point of view, and to evaluate offered evidence. Critical thinking is also known as metacognitive process, covering numbers of sub skills (analyzing, evaluating, and concluding) used to improve logic concluding creation chance toward arguments or solution [6]. Based on Wade [7],

critical thinking is a skill of asking, defining, testing, and analyzing assumption. Glasman [5] elaborates four field: ability to identify and formulate problems and also to propose and evaluate the solving method, ability to recognize and use inductive and deductive reasoning. Van Gelder argues to improve the ability needs training and actively involved in the ability. Gelder recommends practical activity as the student involvements, learning transfer, theoretical understanding, and identifying ability toward bias and open minded attitude to be considered in improving the ability [8]. Glazer defines the ability as combined attitudes of knowledge and skills [9].

There are six capability of critical thinking emerging in learning process through the ability, (1) *Interpretation*, is an understanding to express meaning or significance from various experience, situation, data, events, assessment, habit, custom, beliefs, rules, procedure, or criteria. (2) *Analysis* is an identification of mutual referential correlation intended to questions, statements, concepts, description or other representation intended to express beliefs, judgments, experiences, reasons, information or opinions. (3) *Evaluation* means reviewing credibility of questions or other representation in form of reports or description from perceptions, experiences, situations, judgments, beliefs or opinions, and interpreting logical power of referential correlation or other intended representation. (4) *Inference* is to identify and get needed elements to logically conclude, creating assumption and hypothesis, considering relevant information and concluding consequences from data, situation, questions, and other representations, (5) *Explanation* is a skill to determine and share reason immediately and logically based on the gained data, (6) *self-regulation* is a skill to monitor one's cognitive activity, elements used in the solving problem, especially to apply skills in analyzing and evaluating [10].

Critical thinking must cover some characteristics, such as analyzing, synthesizing, introducing and solving problem, concluding and assessing [11]. The explanation of critical thinking based on Angelo is quoted by Santoso [12], elaborates as follows: 1) analyzing, a skill to elaborate the structures into components to find out its organization. In this skills has purpose to understand a concept and to elaborate or classify globally into smaller and detail parts. 2) Synthesizing, a contrast skill to analyzing, it is a skill to combine separated parts into new structures. 3) Recognizing and solving problem is an applicative concept toward numbers of definition. The skill demands readers to understand main idea of reading text, until being able to pattern a concept. 4) Concluding is human reasoning activity based definition or knowledge gained, can be moved into newest definition. 5) Evaluating or to judging demands challenging though to determine values of something and various existing criteria.

The previous research about critical thinking were done by Sahin, Tunca, Altinkurt, & Yilmaz [13] and Li & Payne [14] in relation to professional values of teachers and disposal values of science, technology, and mathematics teachers or STEM shows that there is existing correlation meaning between the professional values of the teachers to disposal level. Critical thinking is part of compulsory thinking synthesizing various critical thinking and knowledge and then apply it to solve and use the concept and computer technique [15]. The conclusion of the research of GoMath program to improve the ability done by Brown [16] shows that critical thinking in mathematics is important to help students exploring and solving problem differently.

From various arguments can be concluded that critical thinking is a skill to review and analyze certain information, identifying supportive evidence, identifying and evaluating assumption, applying various strategies to conclude based on the judgment standards. The indicators used in the research is the modification from Facione's [10] and Angelo's [11] indicators, those are to interpret problems, to analyze alternative solution, to apply solution, to evaluate solution, and to conclude gained results attached by supportive evidence. Below is the detail of the indicators of the research with the sub indicators used as basis to determine critical thinking ability in Table 1.

Table 1. The modified indicators and sub indicators of Facione – Angelo critical thinking

Indicators	Sub Indicators
1. Interpreting problems	1) Mapping the information based on the problems 2) Determining the known and the unknown 3) Identifying similarity and dissimilarity patterns 4) Re-review the information
2. Analyzing solution of the problem	1) Correlating information gained with solving concepts and strategies. 2) Finding relevant evidence to find solution. 3) Describing or illustrating problems through exemplifying or modelling
3. Applying gained solution	1) Applying solution and using gained strategy to solve problems. 2) Carefully and systematically working.
4. Evaluating the gained solution	1) Rechecking each solving step 2) Re-reviewing identified information 3) Verifying the referential and supportive evidence.
5. Concluding the results attached with supportive evidence	1) Creating right conclusion 2) Attaching supportive evidence. 3) Explaining logic reasons.

The research is a preliminary research purposed to find out the students' critical thinking ability in logic mathematics material. The material is a basic material in learning programming language and as one requirement to muster. When the skill has been known, it will be easy to design the learning plans to improve the ability.

2. Methods

The methodology is qualitative with 30 eleventh graders as subjects taken from the school. The students consist of 9 males and 21 females. The data is collected through interview and critical thinking test. The test result is used this formula:

$$P = \frac{\text{Score gained}}{\text{Maximum Score}} \times 100$$

It is categorized into good, fair, and low.

Table 2. The criteria of average scores

Average Scores	Criteria
$75\% \leq P < 100\%$	Good
$60\% \leq P < 75\%$	Fair
$0\% \leq P < 60\%$	Low

3. Results and discussion

The preliminary test of the students is categorized into three are: 15% good, 30% fair, and 55% low. Then the critical test result is recapitulated from each data stage with gained scores as follow:

Table 3. The Students' Critical Thinking Test Data Recapitulation

Indicators	Percentage	Categories
Interpreting Problems	60%	Fair
Analyzing alternative solution	40%	Low
Applying solutions	45%	Low
Evaluating used solution	5%	Low
Concluding the results attached by supportive evidence	10%	Low

Then a deeper interview is done towards each steps of the being problematic problems on good (B), fair (C), and low (K) categories, gained the following results.

Table 4. Interview Results

Question 1	<i>What information do you know from the questions above? What is being looked in the task? Please explain!</i>
Answer (B)	: Hasan is 21 years old. Ali is 4 years older, the differences between Sinta and Ali is 3 years. The asked one is how old Sinta is.
Answer (C)	: Ali is Hasan's brother, 4 years older. Sinta is Ali's sister, 3 years older. And Hasan is now 21 years old. How old is Sinta now?
Answer (K)	: Sinta is the oldest one from two brothers.
Question 2	<i>How to solve the problem?</i>
Answer (B)	: It is easier to separate and model its mathematical problem.
Answer (C)	: Counted by using logical thinking. Sometimes also guessing.
Answer (K)	: Get no idea. It is confusing.
Question 5	<i>How is your conclusion?</i>
Answer (B)	: Because Sinta is Ali's brother, 3 years older, meanwhile Ali is 25 years old, then sinta is 28 years.
Answer (C)	: Sinta is the oldest one from the brothers
Answer (K)	: (having no conclusion)

On interpreting step with "fair" category (60%) seen some students have not determined information based on the known problems, being questioned, especially on the low categorized students until having problems on both indicators, analyzing, low category, 40%. Then in applying indicator the problem also has low category, 45%, most of the students choose the guessing as the solving problems, although the answer is correct. In the evaluating step of the solution and concluding results, both of them gain low category with 5% and 10%. There are still many students have not mastered both indicators, most of them are only able to write the result or answer. The students with good category has started to conclude although incomplete and no supportive evidence attached.

The "good" category students is 15% are able to do 3 indicators well, however on evaluating solution used, the students have not done some of sub indicators, rechecking all the identified information. Meanwhile, the concluding indicator, the students are only able to rewrite the answer without supportive evidence attached. The "fair" category students relates information gained with the solving concept strategy, has not appeared. The indicators of evaluating and concluding, only some students are capable of concluding, however not accurate, meanwhile most of the students have not

done evaluation and conclusion. All indicators of critical thinking show low score quality. The indicators to interpret problem, there are still lot of students committing mistake, not knowing what is being asked. The indicator of analyzing is still low especially in sub indicator relating gained information and solving concept or strategy well, creating modelling and description of the problem through mathematics model. The indicator of applying solution gained, is still low seen from various problems, even there are many students gain answers by guessing and in the evaluating and concluding category are not properly done. It is caused because since the beginning the students have not understood the problems, and facing problems, then have not got ability to find solution or problems of the next one. The knowledge gained by the students is not developed based on personal understanding, the students receive given material from the teacher, and then as the result the critical thinking ability is low. According to Snyder & Snyder [17] the memorization promoted learning is not improving critical thinking, contrary the learning should demand the students to analyze, synthesize, and evaluate information to solve problem and decide. From the discussion is known the problems of each parts of the indicator assumed as low category and needed treatment, so that demand solution as follow up to improve critical thinking motivation.

The indicator of interpreting problems, for incapable students to identify problems then needs habitual action to determine and map what is known and asked, to visualize problem in real situation given through answer sheet. The analyzing indicator to correlate information gained with the concept and strategy of solving problem, the students need concept and strategy emphasizing during teaching material, being explained about the benefit of mastering the concept in real life. Giving tasks in the form of simulating or projecting related to the students' real daily life. To illustrate problems in mathematics problem, the students are treated to get used to describe real problem using their imagination, then as if the students really face the problem. The low basic knowledge causes students to have difficulties in solving problem [17-19]. In the indicators of applying solution of the problem, the students will be given not routine practicing task and using various drilling method. Then the students are getting common to solve the problems having higher difficulties. According to Carson [18] although the students know a concept but not always have capability to apply the knowledge and concept to solve it. The evaluating indicators used to treat the students to always recheck all information, reminds the students to systematically and carefully work. Low frequency of practicing to evaluate causes the ability to get lower [17, 19]. In the indicator of concluding attached by supportive evidence, the students are treated to conclude correctly with relevant supportive evidence attached to the answers.

4. Conclusion

Based on the data analysis and discussion, then it can be concluded that the ability of critical thinking of the graders is still low. This is based on the test result. The students fulfill the indicators from the ability is still under 60%. Especially in the analyzing, evaluating, and concluding seen low. The condition causes the students get used to learn and memorize the formula, the students can quickly solve without passing analyzing step, the logical mathematics knowledge is still low, the students cannot apply the concept learnt and have not gotten used to solve the high level difficulty demanding evaluation and analysis. Therefore, the recommendation addressed from the research are: (1) to the future researcher should figure the ability to think critically for each lesson or other material in mathematics, (2) it is suggested to develop critical thinking indicator from other experts to test the students' ability. (3) Designing learning model to improve the ability of the students with low indicator of analyzing, evaluating, concluding, and remembering its importance in mathematics. One of the recommended learning is STEM PJBL learning, which is combined mathematics and science learning, engineering and technology in the form of project. It is expected to improve the students' critical thinking ability.

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