Investigation of Watson-Glaser critical thinking skills of junior high school students in solving mathematical problems

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Abstract. This study aims to: (1) describe the critical thinking skills of junior high school students in solving mathematical problems and (2) identify the components of students essential sub-skills of thinking in assumptions, argument evaluation, deduction, information, and inference. This is a descriptive study with a qualitative approach. Data collected through tests and interviews, triangulation is done by comparing the test and interview. This study involved eight research subjects taken by random sampling from class VII, one of the junior high schools in Pidie Jaya Regency. The test used in this study consisted of eight problems representing five critical thinking skills sub-skills. The results of data collection analyzed through data reduction, data display, and conclusion drawing. The results showed that: (1) junior high school students critical thinking skills were in a low category; (2) deduction, information, and inference are the lowest critical thinking sub-skills mastered by students compared to other critical thinking sub-skills.

1. Introduction

The purpose of Education is not only to be able to understand the subject matter that has been arranged in the educational curriculum but also needs to develop thinking skills, analyze a problem through meaningful learning. As stated in the graduation competency standard that students need to have critical thinking skills [1]. Critical thinking is a widely accepted educational goal [2]. Critical thinking today is widely viewed as a basic competency, as is reading and writing, which must be taught [3].

Some definitions of critical thinking from various journals, among others, according to defining critical thinking as an active, persistent, and careful consideration of a belief or form of knowledge that just taken from the perspective of the reasons that support it and further conclusions the tendency [4]. In line with Dewey opinion, Glaser put forward the definition of critical thinking as: (1) an attitude of wanting to think deeply about issues and things that are within reach of one experience; (2) knowledge of logical examination and reasoning methods; (3) a skill to apply these methods [5].

Watson-Glaser provides the view that critical thinking is a set of skills that is very fundamental to student success in learning [6]. Watson-Glaser has researched and developed critical thinking skills. This development based on encouragement in combining existing attitudes, knowledge, and abilities formed from critical thinking skills. The steps of Watson-Glatzer examine how students critically think when they solve problems explained as follows: 1) Inference making, namely the ability of students to distinguish between right or false conclusions from the data provided; 2) recognition of Assumptions, namely the ability of students to recognize assumptions statements given verbally or in writing; 3)
deduction, namely the ability of students to determine decisions on conclusions that must follow from the information provided; 4) interpretation (Induction), namely the ability of students to consider and decide whether the evidence and obtained findings can be generalized; 5) evaluation of arguments, namely the ability of students to provide more precise and relevant cases through specific questions of a given problem. The steps above are tools developed by Watson-Glaser that can be used widely in measuring and assessing students critical thinking skills. This instrument considered as a tool for evaluating success to improve critical thinking skills.

After 85 years of developing the work of Watson-Glaser with the trust of several educational institutions and companies, Watson-Glaser introduced a change in their work, namely Watson-Glaser II [7]. They transformed five structures into three inseparable structures without reducing the essence of need in the goal of critical thinking abilities. Interference, Deduction, and Interpretation that are interconnected can be entered and linked to concluding (Draw Conclusions) while the Recognition of Assumptions and Evaluation of Arguments is as an independent factor. The model proposed by Watson & Glaser is as follows:

![Figure 1. The model proposed by Watson & Glaser](image)

From the new RED model, Rahmy et al. try to develop some RED Watson-Glaser indicators above, which have modified from several other sources [4]. The following signs of RED Watson-Glaser critical thinking skills from Rahmy al et can be seen in Table 1 below:

| Critical Thinking Skill | Sub skill | Description |
|------------------------|-----------|-------------|
| Recognize Assumptions  | (Recognize) Assumptions | Giving comments with the correct information Information and facts about the problem Is there substantial evidence to support the given assumptions |
| Evaluate Objective Arguments | Analyzing Arguments | Analyzing arguments to evaluate, analyze information objectively and accurately Being objectively to sort through the validity in drawing more accurate conclusions Identifying conclusions |
| Deduction              |            | Giving information through a list of decision-making Defining the problem Formulating the possible alternatives |
| Draw Conclusion        | Information | What information is still needed to be added Interpreting the information found to draw a conclusion The reason to think that it is the right answer or the accurate solution Analyzing how it will be done |
| Conclusion             | (inferential) Conclusion | Giving the best judgment with quality decisions Is there any new evidence that will impact a decision What are the conclusions that can draw? The Decisions be based on the given information |

Some studies that examine critical thinking skills include Duron, Limbach, and Waugh research, who report that students should have a critical thinking skill in-class learning in the hope of having a pleasant learning experience, more meaningful for students, and also for teachers [8]. Melanie L. Buffington research says that students critical thinking skills can develop if teachers in teaching and learning activities periodically display critical thinking skills in every step of learning that will later be useful for their life provision [9]. The other research on investigating junior high school critical thinking skills in
solving mathematical problems shows the junior high school students critical thinking skills are in a low category for the sub-skills evaluation, analysis, and self-regulation [10].

2. Methods
This type of research is a descriptive study with a qualitative approach. Qualitative research is a study that intended to understand the phenomenon of what is experienced by research subjects, holistically through descriptions in the form of words and language in a unique natural context by utilizing various scientific methods [11]. Descriptive research is research that describes what it is about a variable, symptom or a situation [12]. The sample in this study was one of the Pidie Jaya Regency Junior High Schools. Participants selected by random sampling 8 (eight) VIII grade students of SMP. Research procedures in this study include conducting preliminary activities, compiling tests on critical thinking skills, collecting data, analyzing data, and drawing conclusions. Data collected through quizzes and interviews, triangulation is done by comparing the test and interview. The results of data collection analyzed through data reduction, data display and conclusion drawing. In this study, used test questions consisting of 5 item description items adjusted to 5 (five) of critical thinking subskills.

**Table 2. Mathematical Problems Based on Critical Thinking Subskills used in research**

| No | Subskill               | Mathematical Problem                                                                                                                                 |
|----|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | (Recognize) assumptions| It is that the set of Native numbers is a subset of the Set of Whole numbers. The Set of Whole numbers is a set of parts of a set of integers. Is the Native Number Set a subset of the Round Whole number Set? Give reasons for your answers! (Max score = 4). |
| 2  | Analyzing Arguments    | Safira and Yaya hide two different numbers. Safira said that the number consisted of 6 numbers with the composition of abcd, whereas Yaya noted that the number consisted of 7 numbers with the composition abcd, ef. a) If both numbers owned by Safira and Yaya are positive integers, then whose number is bigger? Give reasons for your answers! b) If the numbers owned by Safira and Yaya are negative integers, then whose number is the greatest? Give reasons for your answer! c) What can you conclude? (Max score = 4). |
| 3  | Deduction              | Given numbers 37, 41 and 51; a) determine the factors of each of these numbers! b) determine the prime factors of each of these numbers! c) what is the difference between a number factor and a prime factor? Explain your reasoning! (Max score = 4) |
| 4  | Information            | Consider the following arrangement of numbers!

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... z^4 z^3 z^2 z^1 ...
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Continue until the 10th row! Determine a) the first number inline 10; b) the number of numbers in the 10th line; c) the pattern of adding numbers above; d) the first number in line 20 using the number addition pattern that you find in point c. (Max score = 4)

| 5  | Conclusion (inferential)| Pak Afdhal is drying the corn so that it can be stored for a long time. He wiped it for two days. Every day \(\frac{1}{5}\) of reduced water content. If corn contains \(\frac{1}{4}\) water content, what is the water content left after the Afdhal pack has to dry the corn for two days? Explain the steps you took to find out the water content! (Max score = 4) |

In addition to the test questions used the rubric of assessment tests are also arranged based on sub-skills developed by researchers following critical thinking skills indicators. Based on this rubric, the researcher can determine the categories of students critical thinking skills in solving problems contained in the issues. The method for calculating percentage values is as follows: In this section, you are asking to describe the process, model, design, subject and location of your research. Please put the procedure of your research clearly so that it is easy to read. The percentage value of critical thinking skills obtained from calculations then categorized according to table 3 below.
The results of the critical thinking skills test of eight grade VII students of one junior high school in Pidie Jaya Regency based on the critical thinking sub-skills of Watson-Glaser are as shown in the following table:

| Students | Assumptions | Evaluate Objective Arguments | Draw Conclusion | Total Score | Percent | Category |
|----------|-------------|------------------------------|----------------|-------------|---------|----------|
|          | Ind 1        | Ind 2                        | Ind 3          | Ind 4       | Ind 5   |          |
| Student 1| 2.5          | 2.5                          | 3.0            | 2.0         | 3.0     | 13.0     | 65.50%   | Moderate |
| Student 2| 2.0          | 1.1                          | 0.5            | 2.0         | 0.5     | 6.1      | 30.50%   | Very low |
| Student 3| 2.0          | 1.1                          | 1.0            | 1.6         | 4.0     | 9.7      | 48.50%   | Low      |
| Student 4| 2.0          | 1.3                          | 1.5            | 1.5         | 0.5     | 6.8      | 34.00%   | Very low |
| Student 5| 1.5          | 3.0                          | 1.5            | 2.0         | 0.5     | 8.5      | 42.50%   | Very low |
| Student 6| 1.5          | 2.0                          | 3.0            | 1.5         | 0.5     | 8.5      | 42.50%   | Very low |
| Student 7| 1.5          | 2.0                          | 1.5            | 2.0         | 1.0     | 8.0      | 40.00%   | Very low |
| Student 8| 2.0          | 2.0                          | 1.5            | 1.5         | 4.0     | 11.0     | 55.00%   | Low      |

Based on Table 4 that the highest score of eight students who were tested for critical thinking skills was 13.00 (65.50%) in the moderate category, and the lowest score was 6.10 (30.50%) included in the very low category. Besides, we can also see that the critical thinking skills of five out of eight students (62.50%) fall into the very low category. Following are the data of each critical thinking subskill achieved by students.

| Subskills      | Stud 1 | Stud 2 | Stud 3 | Stud 4 | Stud 5 | Stud 6 | Stud 7 | Stud 8 | Total Score | Percent | Category |
|----------------|--------|--------|--------|--------|--------|--------|--------|--------|-------------|---------|----------|
| Assumptions    | 2.5    | 2.0    | 2.0    | 2.0    | 1.5    | 1.5    | 1.5    | 2.0    | 15.0        | 46.88%  | Low      |
| Analyzing      | 2.5    | 1.1    | 1.1    | 1.3    | 3.0    | 2.0    | 2.0    | 2.0    | 15.0        | 46.88%  | Low      |
| Deduction      | 3.0    | 0.5    | 1.0    | 1.5    | 1.5    | 3.0    | 1.5    | 1.5    | 13.5        | 42.19%  | Very Low |
| Information    | 2.0    | 2.0    | 1.6    | 1.5    | 2.0    | 1.5    | 2.0    | 1.5    | 14.1        | 44.06%  | Low      |
| Conclusion     | 3.0    | 0.5    | 4.0    | 0.5    | 0.5    | 0.5    | 1.0    | 4.0    | 14.0        | 43.75%  | Very Low |
| Average        | 13.0   | 6.1    | 9.7    | 6.8    | 8.5    | 8.5    | 8.0    | 11.0   | 71.6        | 44.75%  | Low      |

Based on the data listed in Table 5, about the average results of scores and percentages of 5 subskills of critical thinking skills of students is 44.75% classified in the low category. Aspects recognizing assumptions obtained by 46.88% and argument analysis aspect of 46.88% are classified as a low category, aspects of decision making by 42.19% are classified as a deficient category; aspects of information amounting to 44.06% classified as a low category, and finally, the conclusion aspect is 43.75% in the low category. So for the evaluation aspect, the argument reached 44.53% classified in the low class and the decision making aspect reached 43.91% ranked in the low category.

The following are the results of tests and interviews of critical thinking subskills of students of one of the junior high schools in Pidie Jaya in more detail based on indicators and some answers of some students and their analysis. To measure sub-skills (recognize assumptions) indicators are used. Namely,
students can see, know and question information/facts of a problem and can provide ideas/assumptions to support the plan of resolution. Following is one of the answers given by students who are the subjects of this study.

**Figure 2.** Figure drawing student work from problems to measure recognizing assumptions

Based on the results of tests and interviews confirmed students have not been able to distinguish between the concepts of integers, counts and natural numbers as well. Besides, four students were only able to show three types of sets of numbers: the original set of numbers, the collection of integers and the set of numbers. Still, they were unable to provide any arguments other than that. This shows that the student has not been able to provide information and facts about the problem and also includes ideas or assumptions that support a strategy. To measure the sub-skills of evaluating arguments, the following indicators are used "Students can analyze and evaluate arguments and draw conclusions from problems ... related to daily life". Following is the answer to one of the students to answer the problem given related to this sub-skill.

**Figure 3.** Figure student work results from problem number 2 to measure the skill of evaluating arguments

Based on the results of tests and interviews students show that students have explained correctly to the questions point a) and point b), but students are able to give the right reasons why they can draw conclusions like that. In addition, students have not been able to draw a conclusion in answering question point c). This shows that the student has not been able to analyze arguments/information objectively and accurately. In addition, he was able to objectively sort out the validity in drawing more accurate conclusions; and also identify conclusions well. Critical thinking sub-skills Conclusions (inferential) are measured by indicators, namely "Students can evaluate all the facts to draw conclusions based on information provided". Following is the answer to one of the students in answering questions to measure this sub-skill.

**Figure 4.** Student work results from the problem to measure the conclusion drawing

Based on the answer number 5 from one of the students as shown in Figure 4 shows that the student has misunderstood the problem given, where he understands if one day the water content decreases by $\frac{1}{20}$, if the corn is dried in 2 days then the water content will decrease by $\frac{1}{10}$. That these students have not been able to provide the best assessment with quality decisions. As a result, he cannot provide evidence that encourages a correct conclusion. Furthermore, the conclusions drawn would certainly not be correct.

Based on the analysis of the results of the study above, the critical thinking skills of students in one Pidie Jaya Regency Junior High School are in a low category. This can be seen from the ability of students in each critical thinking sub-skills to be in a low group. The results of the study are similar to the research conducted by Akgun & Duruk, As’ari et al., Biber et al., And Basri et al., Which states that
the critical thinking skills of students or prospective teachers are in a low category [13]; [14]; [15]; [10]; [16]. The difference between studies is only on the subjects studied.

Recognizing assumptions is one of Watson & Glaser sub-skills critical thinking. In this sub-skill, based on the results of data analysis, the information obtained that students fail because they do not understand the concept well and do not understand the information about the question as a whole. This finding is in line with the results of Phonapichat et al. that students have difficulty understanding the keywords contained in the question. Hence, students are not able to interpret the problem in the mathematical form [17]. Based on the results of the interview, it is known that students who have just received a question for the first time, this is in line with the findings of [18] which states that students are not able to interpret properly because of the problems they face are not accustomed.

Evaluation of arguments is one of the critical thinking sub-skills [19][6]. In Bloom’s Revised Taxonomy, evaluation is the fifth level of the six dimensions of cognitive processes [20]. Evaluation means differentiating values using definite criteria and making comparisons [21]. Based on the analysis of the data obtained, students have not been able to give a strong reason for an argument and draw a conclusion well. The sub-skills analysis of students is still lacking. This finding is in line with the results [22]; [10]; [23] study, which found that the ability of sub-student analysis was in a low category. The inference is one of the critical thinking sub-skills ([24]; [19]; [6]). [25] does not directly state that conclusions are one component in measuring critical thinking skills. However, he uses the term decision making, which means the same as inference. Inference means to identify and secure the elements needed to draw reasonable conclusions [26].

4. Conclusion

Based on the results of data analysis and discussion, it can be concluded that the critical thinking skills of one of the junior high school students in Pidie Jaya Regency are in a low category. From the analysis of five critical thinking sub-skills (assumptions, argument analysis, deduction, information, and conclusion drawing), the critical thinking sub-skills being the lowest are successively deduction, information, and conclusion drawing (inference). Based on the results of this study recommends to teachers and the school to improve critical thinking skills in mathematics through the application of learning models that can improve students’ critical thinking skills. There are several ways to improve critical thinking skills including a) critical reading; b) increase the power of analysis of a problem in a discussion and find the best solution and analyze the worst impacts of the problem; c) develop the ability to observe or observe further mentioning the advantages and disadvantages, the pros and cons of the observed problems are expected to explore students' critical abilities; d) increase curiosity, the ability to ask and reflect, asking quality questions that is questions that do not directly have the right or wrong answers so that students require thinking actively, and critical thinking skills can be improved by implementing student-centred learning (student-centred learning). Future studies are suggested to use indicators of critical thinking skills based on other experts, for example, Ennis, Paul, and others, about strategies and critical thinking processes; and about subject matter and other school levels.

5. References

[1] Permendikbud, 2016 Peraturan Menteri Pendidikan dan Kebudayaan Republik Indonesia: Nomor 20 Tahun 2016 tentang Standar Kompetensi Lulusan Pendidikan Dasar dan Menengah.
[2] Hitchcock D 2018 Critical Thinking, Stanford Encyclopedia of Philosophy (Stanford: Encyclopedia of Philosophy).
[3] Fisher A 2001 Critical Thinking An Introduction Prist Publ (USA: Cambridge University Press).
[4] Dewey J 1910 How We Think: A Restatement of the Relation of Reflective Thinking to the Educational Process.
[5] Glaser E M 1941 An Experiment in the Development of Critical Thinking (New York : AMS Press)
[6] Watson G and Glaser E 2002 Watson Glaser Critical Thinking Appraisal Test, (USA :Pearson).
[7] Watson G and Glaser E M 2010 Watson-Glaser II: Technical manual and user’s guide (USA: NCS Pearson).
[8] Duron R Limbach B and Waugh W 2006 Critical thinking framework for any discipline Int. J. Teach. Learn. High. Educ. 17, 2 p. 160–166.

[9] Buffington M L 2007 Contemporary Approaches to Critical Thinking and the World Wide Web Art Educ. 60, 1 p. 18–23.

[10] Basri H Purwanto As’ari A R and Sisworo 2019 Investigating critical thinking skill of junior high school in solving mathematical problem Int. J. Instr. 12, 3 p. 745–758.

[11] Moleong L J, 2017 Metode Penelitian Kualitatif Revisi (Bandung: Remaja Rosdakarya).

[12] Arikunto S, 2010 Prosedur Penelitian Suatu Pendekatan Praktek. (Jakarta: Rineka Cipta. Jakarta).

[13] Akgun A and Duruk U 2016 The Investigation of Preservice Science Teachers’ Critical Thinking Dispositions in the Context of Personal and Social Factors Sci. Educ. Int. 27, 1 p. 3–15.

[14] As’ari A R Mahmudi A and Nuerlaelah E, 2017 Our prospective mathematic teachers are not critical thinkers yet J. Math. Educ. 8, 2.

[15] Biber A C Tuna A and Incikabi L, 2013 An investigation of critical thinking dispositions of mathematics teacher candidates Educ. Res. 4, 2 p. 109–117.

[16] Changwong K Sukkamart A and Sisan B, 2018 Critical thinking skill development: Analysis of a new learning management model for Thai high schools J. Int. Stud. 11, 2 p. 37–48.

[17] Phonapichat P Wongwanich S and Sujiva S, 2014 An Analysis of Elementary School Students’ Difficulties in Mathematical Problem Solving Procedia - Soc. Behav. Sci. 116, February p. 3169–3174.

[18] Jimenez P K, 2010 Students’ interpretations of mathematical statements involving quantification. Math. Educ. Res. J. 22, 3 p. 41–56.

[19] Facione P A, 1990 Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction. Research Findings and Recommendations Am. Philos. Assoc.

[20] Anderson L W et al., 2001 A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.

[21] Omar N et al., 2012 Automated Analysis of Exam Questions According to Bloom’s Taxonomy Procedia - Soc. Behav. Sci. 59, 1956 p. 297–303.

[22] Seventika S Y Sukestiyarno Y L and Mariani S, 2018 Critical thinking analysis based on Facione (2015) - Angelo (1995) logical mathematics material of vocational high school (VHS) J. Phys. Conf. Ser. 983, 1.

[23] Hidayanti D As’ari A R and Daniel T, 2016 Analisis Kemampuan Berpikir Kritis Siswa Smp Kelas IX Pada Materi Kesebangunan 12, Knpmp I p. 276–285.

[24] Ennis R H 2011 The Nature of Critical Thinking : An Outline of Critical Thinking Dispositions p. 1–8.

[25] Halpern D F 2012 Halpern Critical Thinking Assessment [Measurement instrument]. Mödling: Schuhfried.

[26] Facione P a. 2011 Critical Thinking : What It Is and Why It Counts Insight Assess. ISBN 13: 978-1-891557-07-1. p. 1–28.

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