



Review of Critical Thinking Ability as an Indicator in Solving Mathematical Problems Based on Representation

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ABSTRACT

This study aims to describe student's critical thinking ability in solving mathematical problems based on the type of representation used when solving the given problems. The study was conducted in 9th grade in junior high school in Kefamenanu, Timor Tengah Utara, NTT, Indonesia. Three respondents were selected from 28 students who were given a critical thinking ability test based on the completeness of their answers and then interviewed to clarify their answers. The instruments used in this study were test questions and interview guidelines. Test data obtained, has been analyzed based on Facione's critical thinking ability indicators which include interpretation, analysis, evaluation, inference, explanation, and self-regulation. The results showed that student with symbolic representation, fulfilled 4 indicators of critical thinking ability, namely interpretation, analysis, evaluation, and inference. Which means that symbolic representation tends to support deeper critical thinking indicators than visual or verbal. Where student with visual representation fulfilled the critical thinking skills indicators, namely analysis and evaluation. Meanwhile, student with verbal representation fulfilled 1 indicator, namely interpretation.

Keywords: Mathematical Representation, Critical Thinking Ability, System of Linear Equations in Two Variables



ABSTRAK

Penelitian ini bertujuan untuk mendeskripsikan kemampuan berpikir kritis siswa dalam menyelesaikan masalah matematis berdasarkan jenis representasi yang digunakan saat menyelesaikan masalah yang diberikan. Penelitian ini merupakan penelitian kualitatif deskriptif. Penelitian dilaksanakan pada kelas 9 di SMPN 1 Kefamenanu Timor Tengah Utara, NTT, Indonesia. Tiga responden dipilih dari 28 siswa yang diberi tes kemampuan berpikir kritis berdasarkan kelengkapan jawaban kemudian diwawancarai untuk mengklarifikasi jawaban. Instrumen dalam penelitian ini adalah soal tes dan pedoman wawancara. Data tes yang diperoleh, telah dianalisis berdasarkan indikator kemampuan berpikir kritis menurut Facione yang meliputi interpretasi, analisis, evaluasi, inferensi, penjelasan, dan pengaturan diri. Hasil penelitian menunjukkan bahwa siswa dengan representasi simbolik memenuhi 4 indikator kemampuan berpikir kritis, yaitu interpretasi, analisis, evaluasi, dan inferensi. Hal ini berarti bahwa representasi simbolik cenderung mendukung indikator berpikir kritis yang lebih dalam dibandingkan visual atau verbal. Di mana siswa dengan representasi visual memenuhi indikator kemampuan berpikir kritis, yaitu analisis dan evaluasi. Sementara itu, siswa dengan representasi verbal memenuhi 1 indikator, yaitu interpretasi.

Kata Kunci: Representasi Matematis, Kemampuan Berpikir Kritis, Sistem Persamaan Linear Dua Variabel.

INTRODUCTION

The mathematical ability defined by NCTM (2000) include: problem solving, reasoning, mathematical communication, mathematical connection, and mathematical representation. These five mathematical abilities are crucial for students to master and develop in mathematics learning. This is because these five abilities are highly relevant to the abilities students must possess to face competition in the 21st century. First, representational ability is a fundamental part that must be developed and possessed by students. Why is it important? because by having mathematical representation ability, students can organize ideas, communicate mathematical ideas into understandable information, and involve mental activity in the form of thoughts that can be expressed verbally, visually, or symbolically.

Mathematical representation ability serve as a bridge, connecting students to understand other mathematical ability. It's means, when students have mastered and can develop mathematical representation ability effectively, they will easily understand other mathematical ability, such as the process of modeling something from something concrete into abstract concepts and symbols (Hwang et al, 2007). In other words, mathematical representation ability is a key to master other mathematical ability. However, the reality is that some students when communicating between what is written (external representation) and what is thought (internal representation) is still not appropriate (Santia, 2015). Furthermore, student's representation ability will impact the ability to communicate ideas or objects as well as the students take strategies when solving mathematical problems (Hijriani et al, 2018; Lingefjård & Ghosh, 2016). Therefore, the ability to understand a problem and the ability of mathematical representation in solving mathematical problems is considered necessary when students are involved in the mathematics learning process.

Likewise, Dufour-Janver, Bednarz and Belanger (in Mainali 2021) put forward the reasons for using representation in mathematics education, including: representation cannot be separated from

mathematics, such as the relationship between one topic to another; representation as concrete tool of a mathematical concept, where with the help of various representations students will understand the general properties that allow them to extract the intended concept; representation can help students in understanding a particular concept; presenting contextual problems with various representations.

The representations type what is meant are verbal representation (written text), symbolic representation (mathematical equations or expressions), and visual representation (pictures, graphs, or tables). The representation in this study takes three types of representations because all three are external representations in the form of writing. These allow students to understand how they represent themselves through writing. Verbal representations (written texts) are generated by students to create problem situations based on the data provided, construct stories based on the presented representation, and use written text to solve the given problems. Symbolic representation (equation or mathematical expression) can be in the form of equations or mathematical models to solve mathematical problems. Visual representations generated by students can be in the form of images, graphs, or tables to solve mathematical problems.

When linked to critical thinking ability, mathematical representation and critical thinking ability are two crucial parameters in mathematics learning. Ignoring student's critical thinking ability will result in their inability to solve mathematical problems (Faridah & Nasikhah, 2019). It's means that students with good mathematical ability are indicated to be directly proportional to their ability to solve mathematical problems and have good critical thinking ability, including the ability to use appropriate representations when solving mathematical problems.

But in reality, students critical thinking ability is still low and their ability to use representations effectively are reinforced by initial observations, including discussions with subject teachers, questions and answers sessions with students. Students are accustomed to use common solutions when solving math problems. Therefore, when asked to solve problems using methods that differ from their usual methods, they feel difficulty and confusion. Furthermore, during the problem-solving process, they are not accustomed to reviewing whether their solutions are correct. And this research provides new insights by aligning the representations types that appear when solving problems to see student's critical thinking abilities. Therefore, this research is crucial, so that the results can be used as an input for teachers in designing appropriate learning to improve student's critical thinking ability.

To be able to think critically, students must be able to achieve critical thinking indicators. One indicator of critical thinking according to Ennis (1985) is developing strategies and tactics. Student's ability to develop strategies and tactics when solving mathematical problems require mathematics learning that involves more students actively in the learning process itself. This can be realized through alternative learning forms designed in such a way as to reflect active student involvement that maximizes the use of various representations. Because representation plays a vital role in critical thinking, it enables students to better understand, analyze, and evaluate information and be able to interpret various appropriate mathematical representations of mathematical problem solutions appropriately.

The critical thinking indicators used to describe student's critical thinking abilities in this study, according to Facione (2015), include interpretation, analysis, evaluation, inference, explanation, and self-regulation.

METHOD

This study uses a descriptive design with a qualitative approach. With the aim of the study to describe student's critical thinking ability in solving mathematical problems based on representation used. The study was conducted in 9th grade in junior high school in Kefamenanu which is a state school in the border area (Indonesia-RDTL) in Timor Tengah Utara, NTT, Indonesia. This study involved 28 students who were given test questions, then to see the type of representation used when completing the test, then to see student's critical thinking ability were analyzed using critical thinking ability indicators according to Facione (2015) namely interpretation, analysis, evaluation, inference, explanation, and self-regulation. Additionally, three responders were chosen based on how comprehensive their responses were, and they were subsequently interviewed to get more information. Then the critical thinking indicators according to Facione were adapted by adding details to each stage of critical thinking ability specifically by adding a description to each critical thinking indicator, with the aim of making it easier for researchers to describe the subject's critical thinking abilities completely.

All participants in this study volunteered without any coercion from any party. The classroom used in the study were determined through discussions with the mathematics teacher in those classes. It was noted that the students participating in the study had previously received algebra material.

Data collection was conducted through test questions and interviews. The test questions were first validated by experts. The questions consisted of three types, each adapted to the three types of representations used in this study, there are: question number one used verbal representation in solving, question number two used symbolic representation in solving, and question number three used visual representation in solving. Furthermore, to assess critical thinking ability, each question item contained six indicators of critical thinking ability.

The test was completed in two lesson hours namely 80 minutes. A preliminary analysis was then conducted to determine the representations types used when completing the test questions. These representations types were verbal, symbolic, and visual. From this initial analysis, three students were selected as research subjects based on the types of representations used when completing the test questions. The three students were given the test, first based on the representation's types used when completing the test questions. The test questions given contain three types of questions, each of which represents three representations in sequence, namely verbal, symbolic and visual. These subjects were coded SR1 for verbal representation, SR2 for symbolic representation, and SR3 for visual representation.

The next stage, analyzing the results of the subject's work related to critical thinking ability by paying attention to the achievement of critical thinking ability indicators that appear according to Facione, which include interpretation, analysis, evaluation, inference, explanation, and self-

regulation. For the last stage was conducted interviews with three research subjects with the aim of exploring the research subjects when the subjects expressed their opinions and ideas from solving the problems that had been created in more depth both in terms of the use of representation and the research subject's critical thinking ability.

RESULT

Before discussing about critical thinking ability and the representations types used by the three respondents in this study, we will first present the general research results based on the written test results. This begins with the representations types used by students when completing the test questions: verbal, symbolic, and visual representations. For question number one, students were asked to create a story problem and problem solution from an existing problem situation using verbal representation. Of the 28 students, only one student used verbal representation to create a story problem from the existing problem situation correctly. Meanwhile, for the problem solution to the story problem that had been created, all students were unable to use verbal representation completely. These results confirm that many students are not yet able to use verbal representation correctly (Mulyaningsih et al, 2020).

Student's critical thinking ability are directly proportional to their ability to use representations, particularly verbal representation, when solving problems. For question number one, only one out of 28 students met the critical thinking ability indicator, interpretation. This indicates that student's critical thinking ability are still relatively low. This finding is reinforced by research findings conducted by Benyamin et al. (2021) that found student's critical thinking ability were in the low category. This indicates a lack of ability in using representations, which can function as a bridge between abstract concepts and individual understanding, both in the form of the ability to problems interpretation and the ability to self-regulation.

Furthermore, for question number two, students were asked to solve the problem using symbolic representation. Of the 28 students, 22 used symbolic representation in solving the problem. Meanwhile, there were differences in student's critical thinking ability. Among them, 5 students met the four indicators of critical thinking ability, namely: interpretation, analysis, evaluation, and inference. Next, 10 students met the three indicators of critical thinking ability, namely: interpretation, analysis, and evaluation. Furthermore, 6 students met the indicators of critical thinking ability, namely: interpretation and analysis. Following this, one student met one indicator of critical thinking ability, namely: analysis, and 6 students did not meet the indicators of critical thinking ability. The critical thinking ability of students at SMPN 1 Kefamenanu are still relatively low. This is reinforced by the findings of research conducted by Anita & Ramlah (2021), which stated that student's critical thinking ability are still relatively low.

Next, to complete the test question number three, students were asked to use visual representation. However, only one out of 28 students used visual representation to complete the test. This finding is supported by research conducted by Harahap & Rahmawati (2020), which stated that students were less able to use visual representations according to the information in the questions. Meanwhile, there were differences in student's achievement of critical thinking ability when

completing the test questions. Among them, one student met two critical thinking ability indicators, namely: analysis and evaluation. Meanwhile, 27 out of 28 students did not achieve the critical thinking ability indicator. Therefore, it can be said that student's critical thinking ability for question number three are relatively low. This is reinforced by previous research findings that stated that student's critical thinking skills are still relatively low (Nuriati et al., 2025; Caswita, 2024; Anita & Ramlah, 2021; Ulva, 2018).

Based on further analysis through written tests and interviews, the three students who were the subjects of this study will be discussed individually based on the representations type they used when solving the test questions, as well as a more in-depth analysis of their critical thinking abilities.

a. Subject with Verbal Representation (SR1)

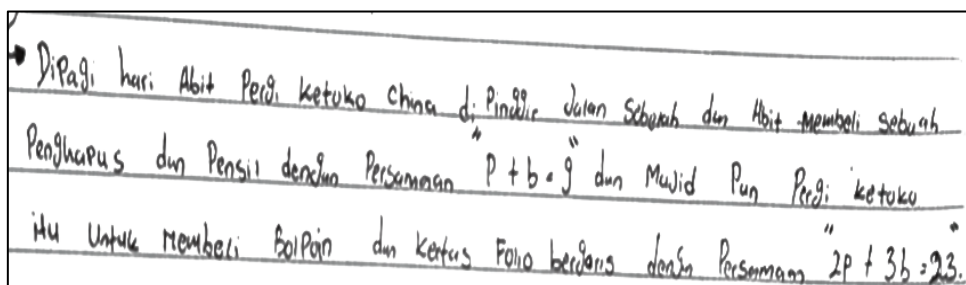


Figure 1. Verbal Representation Subject Work Results

The answer from subject in Figure 1 can be translated as follows in the morning Abit went to the Chinese shop on the side of the Road and Abit bought an eraser and a pencil with the equation $p + b = 9$ and Mujid also went to the shop to buy a ballpoint pen and lined folio paper with the equation $2p + 3b = 23$.

Based on Figure 1, the subject with verbal representation, was able to create story problems based on the given problem situation. Therefore, the subject met the critical thinking ability indicator, namely Interpretation. SR1 was unable to use a good strategy to solve the test questions, resulting in inaccurate answers. The solution to the problem should be made in the form of a story. Therefore, SR1 has not met the analysis and evaluation indicators. Likewise, SR1's inability to draw conclusion from the problem, so SR1 has not met the inference indicator. SR1 has also not been able to create logical reasons for the problem given so SR1 has not met the explanation indicator. SR1 has not been able to double-check whether the answer given is correct or not, so SR1 has not met the self-regulation indicator. Furthermore, based on the interview results, SR1 does not have experience in creating problem solutions based on the given problem situation using words or stories. Therefore, SR1 has difficulty in solving problems using stories based on the story problems that have been created.

b. Subject with Symbolic Representation (SR2)

Penyelesaian:

- Satu gelas Susu dan Satu donat = 7.000
- Tiga gelas Susu dan dua donat = 19.000

Jika x = Satu gelas Susu
 Jika y = Satu donat.

Persamaan 1 $x + y = 7.000$
 2 $3x + 2y = 19.000$

$$\begin{array}{r} x + y = 7.000 \quad (x2) \quad 2x + 2y = 14.000 \\ 3x + 2y = 19.000 \quad (x1) \quad \underline{3x + 2y = 19.000} \\ -1x = -5.000 \\ x = 5.000 \end{array}$$

$x + y = 7.000$
 $5.000 + y = 7.000$
 $y = 7.000 - 5.000$
 $y = 2.000$

Jadi, Harga Satu gelas Susu = 5.000
 Harga Satu donat = 2.000

Figure 2. Symbolic Representation Subject Work Results

Based on the results of SR2's work (see Figure 2), can be translated "The price of one glass of milk and one donut is IDR 7.000, and the price of three glasses of milk and two donuts is IDR 19.000. For one glass of milk, the variable x is assumed to represent one donut, and the variable y represents one donut. Then, a mathematical model is created in the form of an equation as shown in Figure 2, with the solution to the problem being the price of one glass of milk is IDR 5.000 and one donut is IDR 2.000".

Based on Figure 2, this shows that the subject has capability in rewriting information from test questions and being able to create mathematical models correctly, so that SR2 met the interpretation indicator. Furthermore, SR2 is able to determine what strategy should be used to solve problems and perform calculations correctly, so that SR2 met the analysis and evaluation indicators. Next, SR2 met the inference indicator, this can be seen from SR2's ability to draw conclusions from the problem solutions found. However, SR2 has not met the explanation and self-regulation indicators because SR2 cannot write logical reasons for the results of his work and cannot review the answers given whether they are correct or not.

Based on the interview results, SR2 is accustomed to work on algebra material test questions using the elimination and substitution methods, so for SR2 it is not difficult enough to solve. However, when asked why the price of a glass of milk can be Rp. 5,000 and the price of a donut Rp. 2,000. SR2 has quite a hard time providing logical arguments and SR2 is also not yet able to ensure that the answers obtained are certain to be correct or not. This is because students are not accustomed to solve a problem by restating why the solution obtained is the right solution for the problem given. This statement was obtained during a dialogue between the researcher, the subject teacher and students.

This is indicated by the ability of SR1 and SR2 to write information correctly and are able to create mathematical models of the given problems. However, for SR3, they have not been able to understand the questions well, this is because SR3 did not write down information from the problem that should be the basis for carrying out the process of solving a problem. This shows that SR3's ability to interpret problems from existing situations is still low (Seventika et al., 2018). Furthermore, Seventika said that for students who have not been able to identify problems, habituation actions are needed to determine and map what is known and asked, visualizing problems in real situations given through the answer sheet.

The ability to interpret information in a problem is important because, through interpretation, students are able to write down what is known, asked or are able to make a mathematical model of a problem, in this case reflecting the student's ability to understand the problem then continue to the next stage (Kurniasih et al., 2022; Larsson, 2017; Karim & Normaya, 2015).

Furthermore, the analysis indicator was fulfilled by subjects SR2 and SR3. This is reflected in SR2 and SR3 abilities to determine what strategy to use in solving problems. Meanwhile, SR1 was unable to determine the appropriate strategy to solve the problem. SR1 inability was that the problem should be solved with a story tailored to the type of representation used to solve the problem, namely verbal representation. However, SR1 used the elimination and substitution methods to solve the problem, resulting in incorrect answers. For the next indicator, evaluation, SR2 and SR3 were able to solve the problem correctly until they reached the correct answer. Meanwhile, SR1 obtained an inaccurate result. For the inference indicator, SR2 was able to draw conclusion from the problem solutions obtained. Meanwhile, SR1 and SR3 were not yet able to draw conclusions. The fact that there are still students who are unable to analyze, evaluate problems, and draw conclusions from existing problems indicates that the quality of critical thinking is still low (Seventika et al., 2018).

Explanation is explained as the ability to provide logical reasons for a result (Hayudiyani et al, 2017). However, students SR1, SR2, and SR3 were unable to provide logical reasons for their results, resulting in the explanation indicator for SR1, SR2, and SR3 not being met. Furthermore, students were unable to double-check whether the solution they obtained was correct or not, thus fulfilling the self-regulation indicator. This is because students are not accustomed to ensure the correctness of their solutions. Applied to everyday life, every solution to a problem should first be verified for both its correctness and accuracy. This habit of students not checking the correctness of their solutions is reinforced by research findings conducted by Sari & Adirakasiwi (2021), which found that students tend not to double-check the correctness of their solutions. Critical thinking ability is related to mathematical representation. One of them involves critical thinking ability in solving problems.

CONCLUSION

The representations types used by students when working on test questions are verbal, symbolic, and visual representations. Student's critical thinking abilities differ from one another. Students with symbolic representations better than students with visual and verbal representations, met the critical thinking ability indicators, namely interpretation, Analysis, Evaluation, and Inference.

Student's inability to provide logical reasons and review problem solutions is due to student's learning conditions that are still fixated on memorizing formulas, which can result in students skipping several stages in critical thinking in solving problems. To improve students' critical thinking abilities and their abilities to use appropriate representations when solving mathematical problems, reinforcement in learning such as providing measurable representation-based tasks, explicit instruction in explanation and self-regulation, scaffolding to connect internal and external representations are expected to receive special attention. This includes familiarizing students with mathematical problem solving that engages critical thinking skills, including understanding the meaning of problems, analyzing assumptions, providing rational solutions, evaluating, investigating, and making informed decisions in determining problem solutions. It also includes familiarizing students with solving problems in multiple ways or with multiple solutions. In other words, good representations enable deep understanding & appropriate strategies (critical thinking), while critical thinking helps to bring out existing representations and build deeper conceptual understanding.

DECLARATION OF THE USE OF AI

During the preparation of this work the author(s) used [Google Translate and Grammarly] in order to [check grammar and spelling]. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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