Mathematical reasoning ability of junior high school viewed from logical mathematical intelligence

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Abstract. Mathematical reasoning is crucial especially at school since students need to think logically and be able to draw new conclusion based on evidence. This is a descriptive qualitative research which aims to analyze mathematical reasoning ability viewed from logical mathematical intelligence with 32 eight graders of Junior High School of 01 Jiwan involved. Instrument used is mathematical reasoning ability and logical mathematical intelligence test. The result of the research shows that students with high logical mathematical intelligence were able to present mathematical statement (88.89%), compile evidences or create solution (81.48%), design the characteristic or relationship pattern of mathematical phenomena (74.07%), and describe the logical conclusion related to ideas and their relationship (77.78%). Students with medium logical mathematical intelligence were able to present mathematical statement (60%), compile evidences or create solution (71.11%), design the characteristics or relationship pattern of mathematical phenomena (55.56%), and describe the logical conclusion related to some ideas and their relationship (57.78%). Students with low logical mathematical intelligence were able to present mathematical statement (58.33%), compile evidences or create solution (54.17%), design the characteristics or relationship pattern of mathematical phenomena (50%), and describe the logical conclusion related to some ideas and their relationship (45.83%).

1. Introduction
Mathematics is one of important fields of science that has a role in the improvement of science and technology [1]. It means, mathematics is a potential subject taught in all level of education from low to the high [2]. One of mathematics learning objectives at school is training students’ mindset in the process of reasoning to solve problems and convey their ideas clearly [3]. Mathematics and mathematical reasoning are two interrelated things since mathematics is something that must be understood and reasoning is something that must be trained through learning mathematics [4]. Reasoning ability can help students evaluate their current knowledge and is effective to analyze new situations faced in all aspects ranging from explaining their thinking, compiling evidence, and providing new conclusions [5].

According to NCTM, the standard of mathematics learning process consists of representation, problem solving, reasoning and evidence, connections, and mathematical communication [6]. Reasoning is one of the standards for the NCTM learning process that students must have. Through reasoning, students are expected to consider mathematics as a logical learning that lead them to be confident to understand, think about, prove and evaluate mathematics as well as in doing things related to mathematics that need reasoning abilities [7]. Mathematical reasoning refers to the ability to analyze mathematical situations and draw new conclusions [8]. It is reflected in providing mathematical statements in the form of pictures, diagrams, or others in detail, and compiling evidences according to existing formulas or
theorems [9]. In other words, it is students’ ability to find relationships or patterns to analyze mathematical situations [10].

Reasoning ability shows the level of students’ understanding in processing the information obtained to draw new conclusion [11]. Developing students’ reasoning abilities in mathematics is important in which the teacher should act as a facilitator that assist students in developing their thinking skills started from recognizing mathematical situations to compiling accurate evidences. However, if reasoning ability is not developed, students will only follow learning activity as usual and write down sample questions without knowing the real meaning of them. Students are only able to count without applying it in everyday life either changing problems in the environment into a mathematical model or vice versa [12]. Likewise, students are lack of knowledge about the definition of terms and statements in mathematical form and how to use them to compile evidences [13].

According to a mathematics teacher of Junior High School of 01 Jiwan, students tend to memorize formulas without understanding and reasoning how the formulas are applied in solving problems so that they often forget the material taught. They only listen to the explanation from the teacher without trying to ask questions, and write what the teacher wrote on the whiteboard and work on routine questions that are not much different from what the teacher exemplifies. In addition, students often do not write conclusions or even create their own incorrect conclusion about solving mathematical problems. Therefore, this reasoning ability describes the ability in solving mathematical problems, and will affect student learning outcomes [14]. Teachers also rarely emphasize the learning process that allows students to use their reasoning ability. They also lack of variation in delivering material [15]. Students’ ability in learning can be seen from their arguments proven in drawing new conclusions [16]. Non-routine questions are also able to develop students’ reasoning ability in which they will be better in analyzing problem situations and able to choose good strategies in solving a problem [17].

In addition to the learning process, there are many things that can affect the success of learning objectives. One of which is multiple intelligence. According to [18] multiple intelligences include logical mathematical intelligence, linguistic, musical, visual spatial, kinesthetic, interpersonal, intrapersonal, and naturalist. One of the intelligence related to mathematics is logical mathematical intelligence. It is a person's ability to manage numbers and calculations, patterns and logical and scientific thinking [19]. A person who is able to solve mathematical problems is a person who has good logical mathematical intelligence [20]. One of the characteristics of the person having good logical mathematical intelligence is that they can easily count numbers, recognize relationships and patterns and are related to a students’ mathematical thinking [21]. Based on the statements, logical mathematical intelligence related to mathematical reasoning in the function of managing numbers correctly to solve problems using their reasoning abilities.

Logical mathematical intelligence leads people to think mathematically in operating numbers quickly and accurately, calculating complex numbers, and being able to formulate existing problems so that they are able to think rationally [22]. This intelligence also has a significant impact on students’ learning outcomes [23]. In fact, this logical mathematical intelligence has not been fully applied. Students often assume that people who think mathematically and rationally in solving mathematical problems do not necessarily draw the right conclusion. The results of previous research conducted by Sukirwan only focused on analyzing students' mathematical reasoning without looking at other aspects [24]. Furthermore, other researches focus on analyzing mathematical reasoning based on self-efficacy, and then suggests conducting other researches that can affect mathematical reasoning [25]. Therefore, the researcher carried out updates related to analyzing mathematical reasoning abilities based on logical mathematical intelligence.

2. Method
This is a descriptive qualitative research which aims to analyze students' mathematical reasoning abilities based on logical mathematical intelligence. The subjects in this study were 32 eight graders in Junior High School of 01 Jiwan, Madiun Regency, East Java. The sampling technique used was purposive sampling, and the instrument was mathematical reasoning ability test of flat-sided space
material and logical mathematical intelligence test, while for logical mathematical intelligence, it would be grouped into high, medium and low categories with a standard deviation of 4.78 with the average of 67.79. Categories for high logical mathematical intelligence $x_i > 70.18$, medium mathematical intelligence $65.40 \leq x_i \leq 70.18$, and low mathematical intelligence $x_i < 65.40$. The mathematical reasoning ability test instrument used in this research was a descriptive test which contained questions related to mathematical reasoning indicators. The indicators are presented in table 1 below.

| Table 1. The indicator of mathematical reasoning ability |
|-----------------------------------------------|
| Indicator                                    | Descriptor                                                  |
| Presenting Mathematical statement             | Writing correct statement in written, picture, diagram, et al. in detail |
| Compiling evidences and creating solution     | Writing problem solving based on certain mathematical rules or formulas |
| Designing characteristics or relationship     | Finding the pattern or relationship to analyze mathematical situation correctly. |
| pattern of mathematical phenomena             | Describing logical conclusion about some ideas and their relationship |
| Describing logical conclusion about some ideas and their relationship |

3. Results and Discussion

3.1. Results

Based on the calculation results for 32 eighth graders of VIII A, the percentage of logical mathematical intelligence is shown in table 2 below.

| Table 2. The percentage of students’ logical mathematical intelligence |
|-----------------------------------------------|
| Category            | Frequency | Percentage |
| High                | 9         | 28%        |
| Medium              | 15        | 47%        |
| Low                 | 8         | 25%        |

The extent of mathematical reasoning abilities based on the category of students' logical mathematical intelligence can be seen from the test results that have been adjusted to the mathematical reasoning indicators presented in table 3.

| Table 3. The percentage of mathematical reasoning ability viewed from logical mathematical intelligence |
|-----------------------------------------------|
| Indicator                                    | Category of logical mathematical intelligence |
| Presenting mathematical statement             | High       | Medium  | Low     |
| Compiling evidences and creating solution     | 88.89%    | 60%     | 58.33% |
| Designing characteristics or relationship     | 81.48%    | 71.11%  | 54.17% |
| pattern of mathematical phenomena             | 74.07%    | 55.56%  | 50% |
| Describing logical conclusion related to ideas and their relationship | 77.78% | 57.78% | 45.83% |

Based on the data in table 3, the analysis of students’ response related to mathematical reasoning ability in each category of logical mathematical intelligence was conducted.

3.1.1. The Questions of Mathematical Reasoning Ability Test. Mr. Burhan wanted to open a cell phone counter business. To support his business, he ordered someone to make a glass cabinet in the shape of a block with a size of 150 cm x 55 cm x 45 cm. Then, Mr. Burhan gave the down payment to the glass cabinet maker Rp. 500,000.00. The rest will be paid off after the glass cabinet was finished. Furthermore, per 1 cm$^2$ of glass, the maker had to spend IDR 25.00 to buy the material. How much money did Pak Burhan have to pay off?
3.1.2. *The analysis of students with high logical mathematical intelligence.* Groups of students who have high logical mathematical intelligence give good answers, starting from giving mathematical statements to providing conclusions which can be seen in Figure 1.

![Figure 1](image)

**Figure 1.** The response of students with high logical mathematical intelligence

Figure 1 shows that the students’ response were quite complete and satisfying on several indicators of mathematical reasoning ability. In the first indicator, students were correct in writing mathematical statements in written form, started from drawing blocks and writing down the size of the blocks in detail accurately. Students already understand the problem and plan strategies that will be used in solving the problem. Furthermore, the second indicator shows that the students wrote the formula for the surface area of the block correctly and got the correct result. In the third indicator, S1 was error in finding patterns and relationships to analyze mathematical situations, namely looking for money to make blocks with the surface area of the blocks multiplied by money per cm² of glass. They had errors in the concepts used. They did not understand the relationship of several mathematical situations contained in the completion done. On the fourth indicator, S1 was correct in writing conclusions but the results obtained are not correct. Based on the results above, it can be seen that high logical mathematical intelligence tends to process numbers systematically and think rationally in solving mathematical problems.

3.1.3. *The analysis of students with medium logical mathematical intelligence.* Groups of students with medium logical mathematical intelligence were not able to connect patterns or relationships gradually in analyzing mathematical situations in order to make it easier to work on problems. In fact, they only need to count the full payment subtracted to the down payment. The answers of the medium logical mathematical intelligence group on indicators of compiling patterns or relationships of mathematical phenomena are presented in Figure 2.

![Figure 2](image)

**Figure 2.** Students’ response to the characteristics pattern or the relationship of mathematical phenomena

Based on Figure 2, students tried to solve the problem using various ideas, but at the final stage they did not find the correct conclusions with inappropriate processing processes. Students still did not understand the mathematical phenomena in finding patterns or relationships of "25.00 × 34,950 = 873,730". This is not the correct result of calculation (calculating the money change). Supposedly, after doing these calculations there is still a further calculation to find the final result, namely "873,750 - 500,000 (down payment)". Students had understood the problem and tried to use solution strategy. Students were also correct in writing the formula for the surface area of the blocks and doing calculation according to the procedure and getting the correct results. However, when looking for the money change (the indicator finds patterns and relationships) an error occurs due to confusion in finding a
relationship between the information in the problem so that they only guess in answering the question. Furthermore, students were good at writing conclusions but there were still errors in their answers. The results of the work done by students with medium logical mathematical intelligence have not been able to make correct steps to solve them. They also do not understand what concepts to use.

3.1.4. The Analysis of students with low logical mathematical intelligence responses. Students with low logical mathematical intelligence have not been able to provide accurate mathematical statements contained in the information presented. Students have not provided proof by using the formula correctly. Students have not found patterns or relationships in analyzing mathematical situations and did not logically draw conclusions correctly. The answer to the low logical mathematical intelligence group on the indicators provides a mathematical statement which is presented in Figure 3.

![Figure 3](image)

**Figure 3.** The response of students with low logical math intelligence about mathematical statement

Based on Figure 3, students cannot write a complete mathematical statement, that is, they have not drawn the blocks and wrote down the sizes of the blocks correctly. Students have not written down the size of the blocks that will be used to perform further calculations. Students do not understand the problem and create appropriate solution. The answers of the low logical mathematical intelligence group on the evidence collection indicator are presented in Figure 4.

![Figure 4](image)

**Figure 4.** The response of students with low logical mathematical intelligence in compiling evidence

Figure 4 shows that students with low logical mathematical intelligence write the large of block surface correctly. The error happened in the result of the calculation "$p \times l = 6250"$. It must be “8250”. Furthermore, the answers of the low logical mathematical intelligence group on indicators compose patterns and logical conclusions are presented in Figure 5.

![Figure 5](image)

**Figure 5.** The response of students with low logical mathematical intelligence in designing the characteristics pattern or relationship and logical conclusion

Based on Figure 5, students have not found patterns or relationships in analyzing mathematical situations. They do the calculations only to find money for making glass cabinets but the results are not correct, while students have ignored the remaining money that will be paid by Mr. Burhan. On the fourth indicator, students do not write down the conclusions.
3.2. Discussion

Based on the results of mathematical reasoning tests, it was found that students with high logical mathematical intelligence had good reasoning, but in the last step there was a calculation error, namely designing patterns or relationships in mathematical situations. The student incorrectly wrote the down payment number and the result of the surface area of the block. Students were confused when faced with a mathematical situation such as the problem, so they immediately write the result of the surface area of the block and the answer is incorrect. Students were good at writing conclusions but the result was incorrect. This is one of the characteristics of a person having good logical mathematical intelligence, which is to be able to easily count numbers, recognize relationships and patterns and relate to a student's mathematical thinking [22]. Students will think mathematically in operating a number quickly and accurately, calculate very complicated numbers, and be able to formulate existing problems so that someone who has logical mathematical intelligence will be able to think in accordance with rational things [25].

Students with medium logical mathematical intelligence, for the first step they have correctly described the completion steps, but they make error in analyzing the relationship in mathematical situations. Subject two assumed that by multiplying the glass money per meter with the surface area of the blocks, they would find out the price of glass cabinet. The second subject even concluded that doing the multiplication would find the correct result. The second subject was correct in drawing conclusions but the results were wrong. Furthermore, students with low logical mathematical intelligence are unable to demonstrate mathematical reasoning. The subjects seem to lack of understanding about the concept of flat-sided shapes and students have not been able to analyze mathematical situations well. The third subject did not write complete mathematical statement even compiling evidence and looking for patterns, analyzing mathematical situations is not correct. This is a calculation error when calculating the surface area of the beam so that in the next stage an error will also occur. The indicator looking for patterns and relationships also experienced an error, namely calculating the price per meter of glass multiplied by the result of the surface area of the blocks. The third subject assumed that just multiplying would find the correct answer. The third subject did not write down the conclusions correctly.

The lack of mathematical reasoning ability of students with medium and low logical mathematical intelligence is caused by students' poor understanding of problems, low student knowledge of the material being taught, and students tend to have difficulty in modeling the form of mathematics and students are unable to perform calculations according to procedures. This reasoning requires a good arithmetic level, managing numbers well, and experimenting with each problem to be solved [26]. In accordance with the opinion [27] that those who have good logical mathematical intelligence will always carry out experiments in solving problems with their reasoning abilities. To understand the problem, students first understand what sentences are known, and by using the appropriate solution method. After that, students can do calculations correctly and find patterns of properties or relationships of these mathematical symptoms by looking at previous problems. Students can connect various mathematical concepts that have been learned and will form new knowledge easily. One of reasons for the lack of students in understanding a concept in mathematics is the inaccurate learning method in used in delivering material. According to opinion [28] that high logical mathematical intelligence has a good level of reasoning ability, because at the data processing stage it can apply reasoning abilities from understanding problems to conducting experiments in solving problems.

4. Conclusion

Students with high logical mathematical intelligence succeed in presenting mathematical statements (88.89%), compiling evidence or solutions (81.48%), designing characteristics patterns or relationships of mathematical phenomena (74.07%), and describing logical conclusions related to several ideas and their relationships (77.78%). Students with medium logical mathematical intelligence succeed in presenting mathematical statements (60%), compiling evidence or solutions (71.11%), designing characteristics patterns or relationships of mathematical phenomena (55.56%), and describing logical conclusions related to several ideas and their relationships (57.78%). Students with low logical mathematical intelligence
intelligence succeed in presenting mathematical statements (58.33%), compiling evidence or solutions (54.17%), designing characteristics patterns or relationships of mathematical phenomena (50%), and describing logical conclusions related to several ideas and their relationships (45.83%). Students with high logical mathematical intelligence have better mathematical reasoning abilities than students with medium and low logical mathematical intelligence. This is because students with high logical mathematical intelligence have the ability to calculate and manage numbers appropriately, think rationally, and recognize relationships or patterns and are associated with good mathematical thinking. Lack of mathematical reasoning abilities of students who have medium and low logical mathematical intelligence are caused by students' poor understanding of problems, low student knowledge of the material being taught, and difficulty in modeling mathematical forms and performing calculations according to procedures. Choosing the right learning method is one way to improve students' mathematical reasoning ability. Teachers can find out how the students' mathematical reasoning abilities are so that they can easily help the learning process, so that they can easily improve their reasoning abilities. Based on the results of research and discussion, the researcher hopes that there will be other research in schools regarding solutions in solving students’ logical mathematical intelligence problems on mathematical reasoning abilities so that students' ability to solve problems can be improved.

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