



THE DEVELOPMENT OF THE MATHEMATICAL LOGIC INTELLIGENCE ASSESSMENT INSTRUMENT

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ABSTRACT

Mathematical logic intelligence leads to the ability to think systematically, logically, and scientifically. This intelligence supports learning outcomes not only in the realm of mathematics but also in other fields such as physics, chemistry, statistics, and so on. So far, there has yet to be a valid and reliable mathematical logic intelligence assessment instrument for students in elementary schools or Madrasah Ibtidaiyah. This study aims to develop a valid and reliable mathematical logic intelligence assessment instrument for Madrasah Ibtidaiyah students. The research method is research and development with nine steps: (1) determining the purpose of preparing the instrument, (2) looking for relevant theories or material coverage, (3) preparing indicator items, (4) preparing instrument items, (5) validating the content, (6) revision based on validator input, (7) conducting trials on appropriate respondents to obtain participant response data, and (8) conducting analysis, and (9) assembling the instrument. The research instruments used tests and validation sheets. Instrument validation in the form of content validation and construct validation by three experts in mathematics learning at the Madrasah Ibtidaiyah. The test was conducted on grade V students doing the limited experiment. The study's results produced a test to measure mathematical logic intelligence in as many as nine items, which were valid and reliable items with a coefficient of 0.793. The mathematical logic intelligence assessment instrument consists of five indicators, namely: logical thinking with the ability to organize ideas systematically, abstract thinking with the ability to understand complex mathematical concepts, deductive thinking with the ability to conclude from given premises, inductive thinking with the ability to collect data, and analytical thinking using the ability to analyze and solve mathematical problems.

Keywords: *Mathematical logic intelligence, valid, reliable*

1. INTRODUCTION

Mathematics education is beneficial in everyday life. Mathematics has become essential for understanding and modeling complex natural, technological, and social phenomena. Mathematics is often applied in various disciplines such as science, technology, economics, and others as an instrument.

The importance of mathematics is inversely proportional to the level of students' understanding of mathematics, especially at the Basic Education Level, which still needs to be higher. Many students struggle to learn mathematics (Kholil & Zulfiani, 2020). Delivery of uninteresting material, students' lack of interest in the lesson, or the concepts presented by the teacher are not understood by students (Tyas, 2016). PISA (International Program of Science Assessment) data also states that Indonesian students' mathematical literacy is still low compared to other OECD participating countries, as seen in Table 1.

Table 1. Indonesian Mathematical Literacy 2000-2018 (Hewi & Shaleh, 2020).

Year	Score	OECD Score Average	Indonesia's Ranking	OECD Member Countries
2000	367	500	39	41
2003	360	500	38	40
2006	396	500	50	56
2009	371	500	61	65
2012	375	500	64	65
2015	386	500	63	69
2018	379	500	73	79



Understanding of mathematics must continue to be pursued, considering the position of mathematics as a basic science in the development of other sciences. One of them is looking for various factors that cause elementary school students' low interest and understanding in studying mathematics, which have yet to be explored even though they have relevant relationships (Devlin, 2000).

Mathematical-logical intelligence is a person's ability to think inductively and deductively, think logically, analyze number patterns, and solve problems using abstract and analytical thinking skills (Armstrong, 2003). Individuals with high logical intelligence can analyze situations well, find patterns in information, and make decisions based on facts and logic. Logical intelligence is also related to solving problems and developing effective strategies to achieve specific goals. People with high mathematical-logical intelligence can usually understand mathematical concepts quickly, make connections between these concepts, and solve mathematical problems logically and structured (Pietono, 2015). This intelligence can be measured using indicators, namely, logical thinking with the ability to organize ideas systematically, abstract thinking with the ability to understand complex mathematical concepts, deductive thinking with the ability to conclude from given premises, inductive thinking with the ability to collect data, and analytical thinking with the ability to describe and solve math problems. The research results (Rusmana & Wulandari, 2020) state a positive and significant relationship between mathematical logic intelligence and students' mathematics learning achievement.

There has been a lot of research related to mathematical logic intelligence at the elementary school level, along with the development of instruments for mathematical logic abilities. However, this research only targeted lower-class elementary schools as per research results (Magdalena et al., 2023; Manggena et al., 2017; Putra et al., 2017). So far, no research has been found related to this in students in the upper classes with increasingly complex characteristics of questions and student abilities. Therefore, this research intends to examine mathematical logic intelligence in upper elementary schools, starting with developing an instrument to measure mathematical logic intelligence. This research is essential not only to measure the logical intelligence of elementary school students at the upper level, but also to complement previous research at the elementary school level. In this way, studies related to the logical intelligence of elementary school students become comprehensive.

2. METHODS

This is research and development (R & D). The R & D model was developed by (Retnawati, 2017) with 9 stages. The research steps are: (1) determining the purpose of preparing the instrument, (2) looking for relevant theories or material coverage, (3) compiling indicators for question items, (4) compiling instrument items, (5) validating content, (6) revising based on validator input, (7) conducting trials on appropriate respondents to obtain participant response data, (8) conducting analysis, and (9) assembling the instrument.

This research included three mathematics education experts at the elementary school level or Madrasah Ibtidaiyah (MI) and 28 grade V elementary school students at one MI in Purbalingga Regency, Central Java, Indonesia.

The data was collected through test sheets. The questions consist of 10 items from the description of 5 indicators of mathematical logic intelligence. The test questions are in the form of descriptions, with each item having a maximum score of 5.

Data analyzed through expert judgment. Data analysis resulting from expert assessment was analyzed using the V Aiken formula.

$$V = \frac{\sum s}{n(c - 1)}$$

Description:

S : The sum of the scores given by experts– the lowest validity assessment score

V : Item validity index

$\sum s$: The sum of S

n : The sum of expert

c : The highest validity assessment score



The results of the Aiken V calculation were then analyzed using the Aiken V criteria guidelines (Table 2).

Table 2. Interval Criteria of V Aiken.

Interval	Criteria
$0,80 < V \leq 1,00$	Very high
$0,60 < V \leq 0,80$	High
$0,40 < V \leq 0,60$	Enough
$0,20 < V \leq 0,40$	Low
$0,00 < V \leq 0,20$	Very low

Questionnaire items that passed expert assessment were then tested on fifth-grade students to determine the fulfillment of empirical validation and instrument reliability using SPSS.

3. RESULT & DISCUSSION

The mathematical logic intelligence test instrument is prepared through instrument development stages with nine stages, namely: (1) determining the purpose of preparing the instrument (2) looking for relevant theories or material coverage, (3) compiling question item indicators, (4) compiling instrument items, (5) content validation, (6) revision based on validator input, (7) conducting trials on appropriate respondents to obtain participant response data, and (8) conducting analysis, and (9) assembling the instrument. The following is a detailed description of the steps.

Step 1. Determining the purpose of preparing the instrument

The purpose of preparing the instrument is to measure mathematical logic intelligence, an assessment in the cognitive domain. Therefore, the instrument prepared is in the form of a test.

Step 2. Looking for relevant theory or coverage of the material

Logical intelligence is the ability to think logically and systematically. Individuals with high logical intelligence can analyze situations well, find patterns in information, and make decisions based on facts and logic (Armstrong, 2003). Logical-intelligence is also related to solving problems and developing effective strategies to achieve specific goals.

Mathematical-logical intelligence is understanding and using mathematical principles logically and systematically. People with high mathematical-logical intelligence can usually understand mathematical concepts quickly, make connections between these concepts, and solve mathematical problems logically and structured (Pietono, 2015). Mathematical-logical intelligence uses numbers effectively and precisely, as a tax accountant, mathematician, or statistician does. This intelligence includes the ability to recognize logical patterns, relationships, statements, and propositions, as well as various other types of functions and related abstractions. The processes involved in mathematical-logical intelligence include categorization, classification, inference, generalization, calculation, and hypothesis testing.

Indicators of mathematical-logic intelligence include several five things, namely being able to organize ideas systematically and understand cause-and-effect relationships, being able to describe and solve mathematical problems, being able to understand complex mathematical concepts and generalize these concepts to different situations, being able to conclude from the premises given, being able to collect data and make generalizations based on patterns. Based on various studies, mathematical-logic intelligence is thinking logically and systematically in managing and using numbers and mathematical principles. Children who have logical-mathematical intelligence show the ability to think logically, analytically, abstractly, deductively, and inductively, which involves logic and is abstract (Widiastuti, 2015).



Step 3. Arranging indicators for the question items

Mathematical logic intelligence in this research includes five indicators, namely, logical thinking ability, analytical ability, abstract thinking ability, deductive thinking ability, and inductive thinking ability. Each indicator is translated into question item indicators, as shown in Table 3.

Table 3. The Framework of Mathematical Logic Intelligence.

Indicator of Mathematical Logic Intelligence	Question Item Indicators	Total Item
Logical thinking ability	Able to organize ideas systematically	2
Analytical abilities	Able to analyze and solve the mathematics problems	2
Abstract thinking ability	Able to understand the complex mathematical concepts	2
Deductive thinking ability	Able to draw conclusions from the premises given	2
Inductive thinking ability	Able to collect data	2

Step four. Arranging the instrument items

Table 3 is then realized as question items that raise mathematics material in class V, starting with fractions. This can be seen in Table 4.

Table 4. Question Items Based on the Framework of Mathematical Logic Intelligence.

Indicator	The Question Indicator Item	Item	Item number
Logical thinking ability	Able to organize ideas systematically.	Andi bought $2\frac{1}{4}$ liters of cow's milk. A total of $\frac{7}{8}$ liters was given to Nana, $1\frac{1}{7}$ liters were used to make yogurt, and the rest was drunk. How much milk is left to drink?	1
Logical thinking ability	Able to organize ideas systematically.	A bookstore has shelves filled with books. The first shelf contains $\frac{2}{4}$ of the total books, the second shelf includes $\frac{2}{5}$ of the total books, and the rest is for the third shelf. If the total number of books in the shop is 80, how many books are on the 3rd shelf?	6
Analytical abilities	Able to describe and solve mathematical problems.	Sisi bought $3\frac{1}{4}$ liters of cooking oil. The $1\frac{1}{2}$ liter of oil used to fry mendoan. While walking, I accidentally spilled 0.6 liters of oil. Then, the side buys another 0.75 liter. How many liters of Sisi cooking oil are left?	2
Analytical abilities	Able to describe and solve mathematical problems.	Tia has a 30-meter-long ribbon. She will make a flower from the ribbon. Tia will make small, medium, and large flowers. She needs $1\frac{3}{8}$ meter ribbon and $3\frac{5}{6}$ meter large flowers to make tiny flowers. Suppose Tia makes four small flowers and two large flowers. How long is the ribbon Tia needs? Count the rest of the ribbon.	7
Abstract thinking ability	Able to understand complex mathematical concepts.	Rara has 40,000 IDR. $\frac{3}{8}$ of the money was used to buy meatballs, pay 20% in cash, 0.3 part to save, and the rest for snacks. How much of Rara's remaining money is used for snacks?	3
Abstract thinking ability	Able to understand complex mathematical concepts.	Dad bought 24 kg of wheat flour. The wheat flour will be sold at retail by wrapping it in plastic bags weighing $\frac{1}{8}$ kg each. How many plastic bags are needed to package all the wheat flour?	8



Indicator	The Question Indicator Item	Item	Item number
Deductive thinking ability	Able to conclude from the premises given.	Mother has a supply of $4\frac{2}{3}$ kg of sugar. Mother took $1\frac{1}{4}$ kg to make cakes and $\frac{5}{6}$ kg to make pudding. As supplies, Mother bought another $4\frac{7}{8}$ kg. How many kilograms of sugar do you have now?	4
Deductive thinking ability	Able to conclude from the premises given.	Mother has a stock of $5\frac{2}{3}$ kg biscuits. Every day, the mother consumes $\frac{3}{4}$ kg of biscuits. For one week, how many kilograms of biscuits do you have now?	9
Inductive thinking ability	Able to collect data	Order the following fractions from smallest to largest: $\frac{2}{5}, \frac{3}{10}, \frac{1}{2}$, and $\frac{5}{6}$. Include steps in ordering the fractions.	5
Inductive thinking ability	Able to collect data	Raisa wants to make four cakes. To make a Raisa cake, you need $\frac{1}{2}$ kg eggs, $1\frac{1}{4}$ kg flour, and $\frac{1}{4}$ kg granulated sugar. Raisa only has 1kg of flour and $\frac{1}{4}$ kg of eggs at home. How many eggs, flour, and sugar does Raisa need?	10

Determination of student answer scores follows the following provisions.

Score 0 if there is no solution at all or the writing does not match at all.

Score 1: if the student writes down the question criteria or only knows or is asked or uses a particular procedure, the answers and conclusions are all wrong.

Score 2: if the student uses a specific procedure correctly but the answer is wrong, and the conclusion is terrible, or one of them uses aspects, and one of them is correct.

Score 3: if specific procedures are used correctly, the answers and conclusions are incorrect.

Score 4: if you present the correct sequence of completion steps, accurate answers, and conclusions.

Step five. Content validation

The instrument examination was carried out by three experts, namely lecturers with expertise in mathematics education. Each question item is analyzed from 4 assessment aspects, namely the relevance of the question item to the framework, suitability of question items to indicators, use of language, and clarity of question items. Each assessment aspect uses a range of 1 to 4; the closer to 4, the better.

The results of the instrument assessment by experts were then analyzed using the Aiken V test. The results are in Table 5.

Tabel 5. The Result of V Aiken.

The Item Number	Validator's score			S1	S2	S3	Σ	V	Criteria
	A	B	C						
1	4	3,5	3,5	3	2,5	2,5	8	0,89	Very high
2	3,5	3,5	3,75	2,5	2,5	2,75	7,75	0,86	Very high
3	3,5	3,5	3,5	2,5	2,5	2,5	7,5	0,83	Very high



4	3,25	4	3,75	2,25	3	2,75	8	0,89	Very high
5	4	4	3,5	3	3	2,5	8,5	0,94	Very high
6	4	3,5	3,5	3	2,5	2,5	8	0,89	Very high
7	3,5	4	3,5	2,5	3	2,5	8	0,89	Very high
8	4	4	3,25	3	3	2,25	8,25	0,91	Very high
9	4	3,5	3,75	3	2,5	2,75	8,25	0,91	Very high
10	4	4	3,5	3	3	2,5	8,5	0,94	Very high

Table 5 shows that all question items meet the expert validation test with high criteria. This means that experts have validated all items.

Step six. Revision based on the validator input

This step is only carried out on question items that experts for revision refer to. Based on Table 5, it is known that the V Aiken test results show that all items meet the very high criteria. Therefore, no revisions were made to the test instruments used.

Step seven. Conduct trials on appropriate respondents to obtain participant response data

The eighth step is conducting trials to meet empirical validity and reliability. The test subjects were 28 class V students at one of the Madrasah Ibtidaiyah in Purbalingga Regency, Central Java. The results of instrument testing were then analyzed using SPSS version 25 software.

Table 6. Result of Empiric Validation.

	The Item Number									
	1	2	3	4	5	6	7	8	9	10
Significance	0,000	0,001	0,000	0,013	0,003	0,000	0,085	0,000	0,001	0,001
Criteria	valid	valid	valid	valid	valid	valid	invalid	valid	valid	valid

Based on Table 6, it is known that item 7 does not meet the empirical validation test. Therefore, item 7 was dropped and not included in the subsequent analysis. The next step was to carry out reliability tests on all items that have met empirical validity. The results of the reliability test using SPSS version 25 software on 9 test items show an instrument reliability coefficient value of 0.795. Thus, a total of 9 test items met the reliability aspect.

Step nine. Assembling the instrument.

After completing the empirical trials, Table 6 contained the final mathematical logic intelligence test consisting of 9 items.

Table 7. The Final Test of Mathematical Logic Intelligence.

The Questions	Item Number
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The Questions	Item Number
Andi bought $2\frac{1}{4}$ liters of cow's milk. A total of $\frac{7}{8}$ liters was given to Nana, $1\frac{1}{7}$ liters were used to make yogurt, and the rest was drunk. How much milk is left to drink?	1
Sisi bought $3\frac{1}{4}$ liters of cooking oil. The $1\frac{1}{2}$ liter of oil used to fry mendoan. While walking, I accidentally spilled 0.6 liters of oil. Then, the side buys another 0.75 liter. How many liters of Sisi cooking oil are left?	2
Rara has 40,000 IDR. $\frac{3}{8}$ of the money was used to buy meatballs, pay 20% in cash, 0.3 part to save, and the rest for snacks. How much of Rara's remaining money is used for snacks?	3
Mother has a supply of $4\frac{2}{3}$ kg of sugar. Mother took $1\frac{1}{4}$ kg to make cakes and $\frac{5}{6}$ kg to make pudding. As supplies, Mother bought another $4\frac{7}{8}$ kg. How many kilograms of sugar do you have now?	4
Order the following fractions from smallest to largest: $\frac{2}{5}, \frac{3}{10}, \frac{1}{2}$, and $\frac{5}{6}$. Include steps in ordering the fractions.	5
A bookstore has shelves filled with books. The first shelf contains $\frac{2}{4}$ of the total books, the second shelf includes $\frac{2}{5}$ of the total books, and the rest is for the third shelf. If the total number of books in the shop is 80, how many books are on the 3rd shelf?	6
Dad bought 24 kg of wheat flour. The wheat flour will be sold at retail by wrapping it in plastic bags weighing $\frac{1}{8}$ kg each. How many plastic bags are needed to package all the wheat flour?	7
Mother has a stock of $5\frac{2}{3}$ kg biscuits. Every day, the mother consumes $\frac{3}{4}$ kg of biscuits. For one week, how many kilograms of biscuits do you have now?	8
Raisa wants to make four cakes. To make a Raisa cake, you need $\frac{1}{2}$ kg eggs, $1\frac{1}{4}$ kg flour, and $\frac{1}{4}$ kg granulated sugar. Raisa only has 1kg of flour and $\frac{1}{4}$ kg of eggs at home. How many eggs, flour, and sugar does Raisa need?	9

The research results show that an instrument has been produced to measure mathematical logic intelligence for fifth-grade elementary school students with nine valid and reliable items on fractions. All question items are composed of 5 indicators, namely logical thinking ability, analytical ability, abstract thinking ability, deductive thinking ability, and inductive thinking ability. All mathematical logic intelligence test instruments were produced from a series of instrument tests by experts and instrument trials on respondents, as shown in Table 8.

Table 8. The Series of Instruments from the Beginning of Preparation to the Results of Instrument Testing.

No	Indicator	Total of Item		
		Initial Design	Result of Expert Judgement	Result of Empirical Research
1	Logical thinking ability	2	2	2
2	Analytical abilities	2	2	1
3	Abstract thinking ability	2	2	2
4	Deductive thinking ability	2	2	2
5	Inductive thinking ability	2	2	2
	Total	10	10	9

Mathematical logic intelligence instruments are nothing new. Many instrument formats measure the same thing. However, there are several differences. This research develops an instrument for the mathematical logic intelligence of fifth-grade elementary school students. Meanwhile, previous research has discussed chiefly the mathematical logic intelligence of early childhood (Afandi, 2018; Kristiana, 2018; Siagian, 2021). Other research aims at the elementary school level but in the classroom low, namely class 1 until class three (Firdaus & Nisa, 2020; Magdalena et al., 2023; Putri, 2017). Research at the elementary school level, especially the upper class,



already exists, but only focuses on class IV (Fasha et al., 2019). Other upper classes have not been widely researched.

Regarding indicators of mathematical logic intelligence at the early childhood education level, (Indriati, 2016) includes three dimensions: a person's ability to process numbers well, think logically, and solve problems. At the lower grade basic education level, indicators of mathematical logic intelligence include processing numbers well, thinking logically, and solving problems related to mathematical operations (Magdalena et al., 2023). As for the indicators of mathematical logic intelligence at the upper grade basic education level, (Fasha et al., 2019) states: can do number calculations, problem solving activities, mathematical games or other strategy games, and the existence of cause and effect relationships, and various activities related to statistical data including estimating, rounding, and interpreting. Based on some of the research results above, this research is complementary with more complete indicators of logical intelligence, including logical thinking, abstract thinking, deductive thinking, inductive thinking, and analytical thinking using problem-solving abilities.

4. CONCLUSION

The outcome shows that the pupils must prepare to use digital technology for learning and teaching. Additionally, they stated that while digital technologies were standard, they were not yet at the manufacturing stage. To assess and improve their competencies, they must put their theoretical knowledge into practice while receiving feedback. In order to better equip them to educate students who are digital natives, in-service teachers and course instructors also provide feedback. It is necessary to conduct additional research to determine how well prepared pre-service teachers are to apply their digital literacy knowledge in actual teaching environments. Subsequent studies may also make use of observations of real-world usage or activities where participants are given a challenge to address with digital tools. This might offer a more thorough understanding of the individuals involved.

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