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Analysis of Elementary Students' Mathematical Reasoning Using Newman's Error Analysis (NEA)

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Abstract. Mathematical reasoning is one of important abilities for students to develop in learning mathematics. This study aims to describe and analyze problems in reasoning ability of five students in 5th grade using Newman's Error Analysis (NEA). The method used in this research is descriptive qualitative. This research was carried out into three stages, namely the preparation of research instrument, implementation and data collection, and data analysis. Data collection was done by observation, test, and interview. The test contains 3 questions about arithmetic operations on whole numbers which are created based on 3 reasoning indicators, namely constructing mathematical arguments, comparing and ordering, and making mathematical conjectures. The results of this study show that there were 2 students who achieved 3 reasoning indicators, 2 students who achieved 2 reasoning indicators, and 1 student who did not achieve any reasoning indicator. From the three reasoning indicators measured, reasoning to "making mathematical conjectures" is the reasoning indicator most mastered by students because 4 out of 5 students can achieve this indicator, while the other 2 reasoning indicators namely "comparing and ordering" and "constructing mathematical arguments" can be achieved by 3 out of 5 students.

Keywords: mathematical reasoning, newman's error analysis, whole number, elementary school, mathematics

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INTRODUCTION

There are many conditions in students' daily activities that are related to mathematics (Kenedi et al., 2019). To deal with these mathematical situations, it is necessary to have good reasoning ability (Seepiwsiw & Seehamongkon, 2023). Reasoning is the ability to process and find connections from the information that is obtained so that the right conclusion can be made from the situation (Saleh et al., 2018). Students need reasoning ability to make decisions in solving problems. With mathematical reasoning skills, students understand a phenomenon, can prove the answers, and make mathematical conjectures (NCTM, 2000), which are closely related to the problem-solving process. As a subject related to a lot of problem solving, this ability needs to be trained and developed by students in learning mathematics at school (Flegas & Charalampos, 2013). Mathematical reasoning ability has become an important aspect of the curriculum globally. This is supported by the statement of NCTM (2000) which classifies "reasoning and proof" as one of the five process standards in the ability that students must have in acquiring and applying their mathematical knowledge. In addition, the National Research Council (2001) also states "adaptive reasoning" as one of the five standards of mathematical proficiency. No exception to the curriculum used in Indonesia, reasoning is one of the main aspects that need to be developed by students (Kemendikbud, 2020). The Indonesian curriculum combines aspects of reasoning with critical thinking to become critical reasoning. They want student who has critical reasoning can process information objectively, making connections between multiple of information, analyzing information, evaluating and

transform it into a conclusion. Due to the importance of reasoning skills to be developed in elementary school, no wonder that many studies have been conducted to improve students' reasoning. Various strategies are used, from using various learning models, to the use of learning media, games, and technology. (Holisin et al., 2019; Lestariningsih et al., 2022; McFeetors & Palfy, 2018; Siregar et al., 2023).

The low levels of students' mathematical reasoning are shown by many researches that have been conducted, especially at the elementary school level in Indonesia. There are still many elementary school students who have low abilities in mathematical reasoning. It can be seen from research conducted in 10 elementary schools in one of the cities in Indonesia shows that students' reasoning skills are still relatively weak (Setiawan & Dores, 2019). In other researches also show the low reasoning ability of elementary school students on the subject of shapes based on research conducted by Arianto et al. (2019) and Izzah & Azizah (2019). In addition, students also still have difficulty in solving reasoning problems on division and multiplication of math word problems (Khoirina et al., 2023). In fact, many students can only solve problems procedurally based on what is demonstrated without understanding the meaning of the process (Seepiwsiw & Seehamongkon, 2023; Vanutelli et al., 2021). When in reality, students need to understand the connection between mathematical concepts so that the learning process will be more meaningful (Fitriyah et al., 2022).

Considering the importance of reasoning ability, teachers need to know the level of reasoning ability that each student has (Lestariningsih et al., 2022). Measuring students' reasoning ability can help teachers to make plans about the next steps to improve their reasoning. One method to find out students' reasoning skills is by analyzing their obstacles in solving problems. In analyzing students' obstacles, there is one approach, namely Newman's Error Analysis (NEA). Errors made by students in solving word problems especially in math elementary school can be explained and analized using Newman's Error Analysis (Nurharyanto & Retnawati, 2020; Prasetyaningrum et al., 2022; Sholehah Syawali & Mulyawati, 2024). According to Newman (1977), errors in solving math problems are divided into five types of errors, namely reading errors, comprehension errors, transformation errors, process skill errors, and encoding errors. By using NEA, teachers can find out where students' misunderstandings in answering word problems, so that it can provide guidance to teachers in determining what learning strategies are effective in overcoming these problems.

Therefore, researchers are interested in analyzing students' reasoning skills based on the 5 types of Newman's Error Analysis. There are three indicators used in this study to measure students' reasoning skills, namely constructing mathematical arguments, comparing and ordering, and making mathematical conjectures. By analyzing students' mathematical

reasoning ability, researchers can find out how students think to understand problems and measure their mathematical reasoning ability. This analysis can also help teachers in knowing the students' thinking process and the level of understanding or the misunderstanding of students in processing a problem.

METHODOLOGY

This research used qualitative methods. The results in qualitative research are described descriptively. This research was conducted in one of elementary school in Bandung and used five students in 5th grade as subjects research. There are three stages were applied in this research, namely the preparation of research instrument, implementation and data collection, and data analysis. Data collection techniques in this study were carried out by observation, test, and interview to validate the answers that have been given by students. The test used to measure students' mathematical reasoning ability and contains 3 questions which are created based on the following reasoning indicators:

Table 1. Table Indicator of Reasoning

Indicator of Reasoning	Question in Bahasa Indonesia	Question in English
Constructing mathematical arguments	Ayah mempunyai 40 buku. Ibu mempunyai 45 buku. Jika mereka ingin menyusun semua buku di rak yang terdiri dari 5 baris, berapa banyak buku yang dapat disimpan di setiap barisnya agar jumlah buku di setiap baris sama?	Dad has 40 books. Mom has 45 books. If they want to arrange all of their books on a shelf consisting of 5 rows, how many books should be stored in each row so that the number of books in each row is the same?
Comparing and ordering	Ani memiliki 3 kotak kelereng, setiap kotaknya berisi 15 kelereng. Andi memiliki 3 kotak kelereng, setiap kotaknya berisi 10 kelereng. Beni memiliki 4 kotak kelereng, setiap kotaknya berisi 5 kelereng. Urutkan nama anak dari yang paling banyak memiliki kelereng hingga yang paling sedikit!	Ani has 3 boxes of marbles, each of the boxes contains 15 marbles. Andi has 3 boxes of marbles, each of the boxes contains 10 marbles. Beni has 4 boxes of marbles, each of the boxes contains 5 marbles. Sort the children's names from the most to the least having marbles!
	Topi: Rp42.000,00 Boneka Rp55.000,00	Hat: Rp42.000,00 Doll: Rp55.000,00

Making mathematical conjectures	Gantungan kunci: Rp19.900,00 Tumblr: Rp38.500,00 Edo pergi ke toko suvenir dengan membawa uang Rp100.000,00. Edo ingin membelanjakan lebih dari Rp60.000,00 tetapi kurang dari Rp90.000,00 karena ia akan menggunakan uang kembaliannya untuk ongkos pulang. Jadi, barang apa saja yang bisa dibeli Edo?	Keychain: Rp19.900,00 Tumblr: Rp38.500,00 Edo went to a souvenir store with Rp100,000. Edo wants to spend more than Rp60,000,00 but less than Rp90,000,00 because he will use the change for the cost of going home. So, what items can Edo buy?

The researcher observes students during the test and after students took the test, all of the students' answers from the test became material for the interview, so the researcher could find out how their thinking process. The test results were analyzed using Newman Error Analysis (NEA). The NEA technique is used to analyze the errors of students in solving problems which consist of error: reading, comprehension, transformation, process skill, and encoding. The following is an explanation of each indicator of Newman's Error Analysis:

Table 2. Table Indicator of Newman's Type Error of Analysis (NEA)

Newman's Type of Analysis	Indicator
Reading error	Student can't read key word or symbol written in the problem correctly
Comprehension error	Student can't understand the overall meaning of the word in the problem
Transformation Error	Student can't identify the operation that are needed to solve the problem
Process Skill Error	Student can't process the procedures of the operations corectly
Encoding Error	Student can't give final answer correctly

RESULTS AND DISCUSSION

Based on the three questions given, students' answers will be analyzed and classified into 5 types of errors according to Newmans type of error of analysis. The following are the results:

Table 3. The number of students who made errors based on NEA

Newman's Type of Analysis	Question - 1	Question-2	Question-3	Total
Reading Error	0	2	1	**3**
Comprehension error	0	1	0	**1**
Transformation Error	0	1	0	**1**
Process Skill Error	2	1	1	**4**
Encoding Error	2	2	1	**5**
Total	**4**	**7**	**3**	-

The data in the table 3 above shows the number of students who made errors based on the types in NEA. From the table above, students made the most mistakes in "encoding" with 5 errors and the least mistakes in "comprehension" and "transformation" with 1 error. From the table 3 also shows that students made the most errors in question number 2, there are 7 errors that students made. the least errors that students made is in question number 3 with 3 errors are made. The explanation of error analysis using NEA when viewed from the lens of reasoning indicators will be explained as follows:

Constructing mathematical arguments

In question with indicators of constructing mathematical arguments, all students can read, comprehend, and transform the problem well. However, students began to find obstacles at the "process skill" stage. There were 3 out of 5 students who could answer correctly and they provided a variety of different ways. At first, all of them had the same way of doing the addition of 40 and 45, but in the division process, students did a variety of ways as shown in Figure 1,2,3.

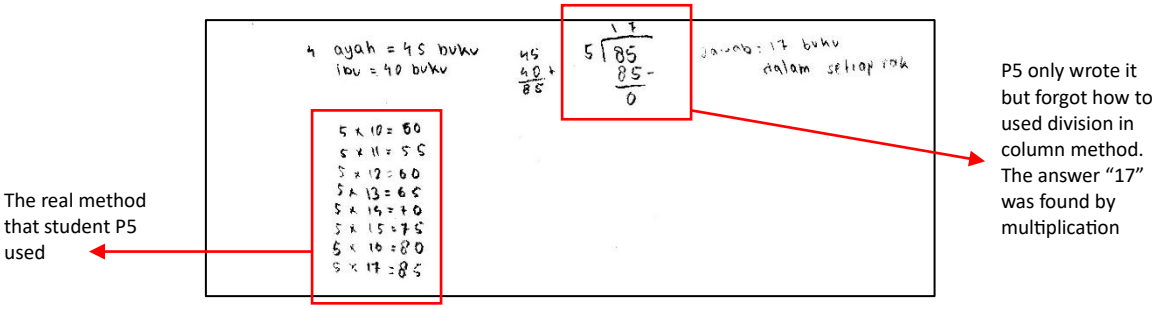

Figure 1. Student's answer Question Number 1 (P5)

The answer in Figure 1 shows that student P5 tried to use multiplication starting from 5x10 until she found the answer 85. After she found the answer and stopped at 5x17, she wrote down the of division with column method in a wrong way. The student told that she forgot how to do the procedure of doing the division with column method, so she just wrote it down randomly and find out the answer with other method which is multiplication.

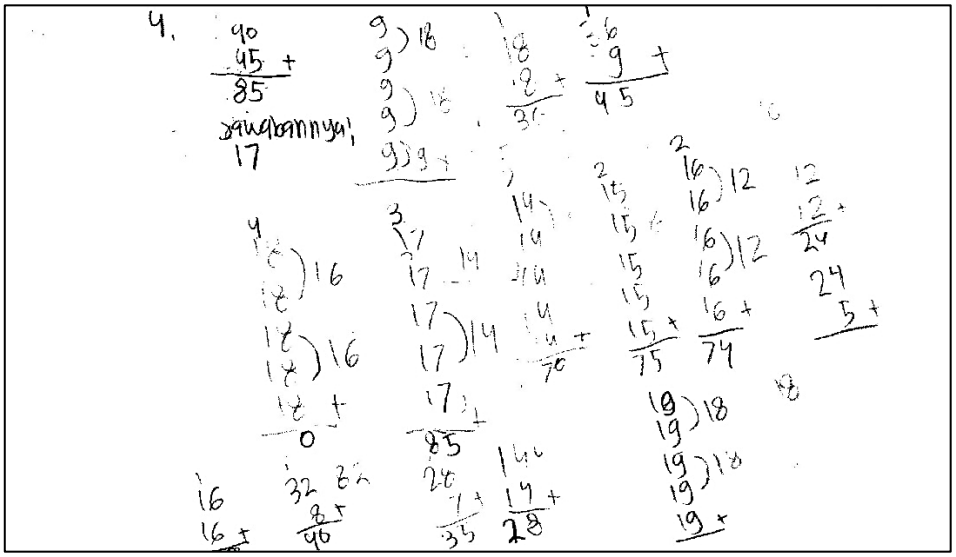

Figure 2. Student's answer Question Number 1 (P3)

The answer in Figure 2 shows that students do a lot of trial and error. Student P3 tried to add up starting from 9+9+9+9+9 until finally found the answer in the sum of 17+17+17+17+17. She forgot how to use division with column method and she also didn't think to use multiple method at all. It can be seen from all the ways she solved all the problems in 3 questions, she only used addition and subtraction.

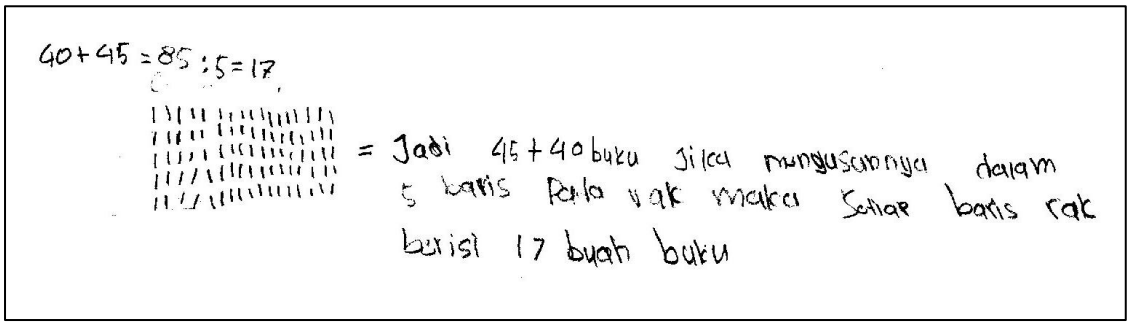

Figure 3. Student's answer Question Number 1 (P2)

The answer in Figure 3, the student tried to visualize the book with lines (|), so he made 5 lines in 5 columns and wrote them one by one up to 85 lines and found that there were 17 rows obtained. From the three students, all of them used a long time to solve this problem. During the observation, students took quite a long time to decide how to solve the problem

because they forgot how to use the divide column method. While the other two gave up until the summation and did not continue the rest.

In this question, there were 3 students who could achieve this indicator. Although the method of solution they used took quite a long time. The three students were considered quite good at reasoning to find answers and dealing with their weaknesses at doing division operator, but the method they chose could make them more confused if the problems contained large numbers such as hundreds or thousands.

On the positive side, their basis for solving the problem can be used to find the answer more easily. For example, instead of checking the multiplication of 5x10 to 5x17, students can be trained to find the closest value. 85 is between 5x10 and 5x20. 85 is closer to 5x20=100, while 100 to 85 is 15 numbers different, which means 5x3. From this, students can find 5x17= 85.

Comparing and ordering

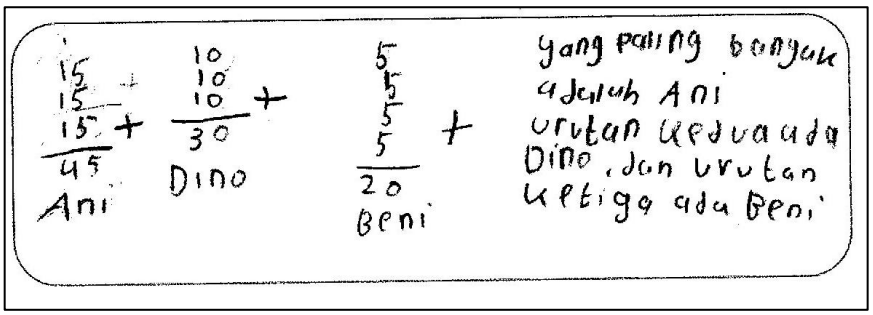

Figure 4. Student's answer Question Number 2 (P2)

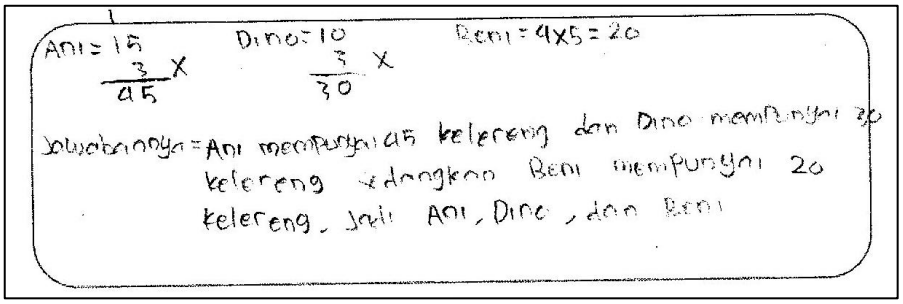

Figure 5. Student's answer Question Number 2 (P5)

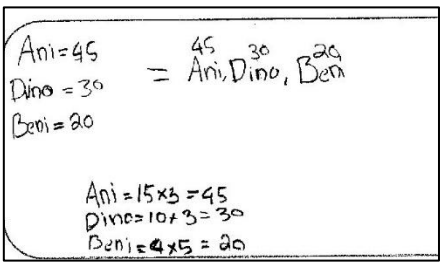

Figure 6. Student's answer Question Number 2 (P1)

Three of the five students were able to read and find the keywords in this problem. From these three students also can understand, transform, process the problem well. There are two ways how they transform the problem into arithmetic operations. As seen in the answers of P2 and P5, the difference can be seen from the operation they chose. P2 prefer to use the addition operator and Q2 prefer the multiplication operator in transforming and processing the problem. Students who chose the addition operator considered that the problem was easier to do with addition and it was more familiar and they more mastered it. Meanwhile, those who chose the multiplication operator assumed that it was shorter way than having to add them up.

In addition, the two students who chose the multiplication operation both had different ways of doing the calculation. As seen at figure 6, student wrote the multiplication form sideways and from the interview it was found that he did not use column multiplication but only reasoned by imagining. While 1 other student used the column multiplication method to find the answer.

From all students, there are 2 students who could not answer correctly had errors in reading and understanding the problem. One student could process the problem well, but she was not careful in reading the problem so she only sorted the number of marbles, not ordering by the names. Meanwhile the last student could not understand the problem at all. She could not find the keywords and was confused about what arithmetic operations she should use. She could understand the problem with the help of the researcher during the interview. When the researcher used some triggering questions such as “How many boxes of marbles does Ani have?”, “How many marbles are in each box?”, “So how many marbles does Ani have?”, she then understood the meaning of the problem and could determine what mathematical operation to use.

Basically, students understand how to compare and order numbers appropriately. However, students can be tricked in answering if it is put into a story problem. Hence, there are three students who have reached the indicators of comparing and ordering without any errors. While the other two had obstacles at the reading and understanding the problem.

Making mathematical conjectures

In the indicator of making mathematical conjectures, Students' answers may be different as long as they match the demands of the question, more than 60.000 rupiah and less than 90.000 rupiah. There were 4 of the 5 who answered correctly. From the 4 students who answered correctly, there were various ways of finding the answer. From the interview, it was found that there was one student who use rounding numbers and estimated first. As shown in figure 6 below, the student explained that he rounded hat price from 42,000 to 40,000 and the keychain price from 19,900 to 20,000 so that he could add them easily without having to write

them down. After he considered his estimation was correct, he then wrote to added them up to find the exact answer.

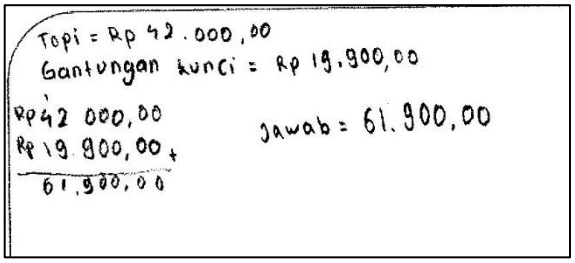

Figure 6. Student's answer Question Number 3 (P2)

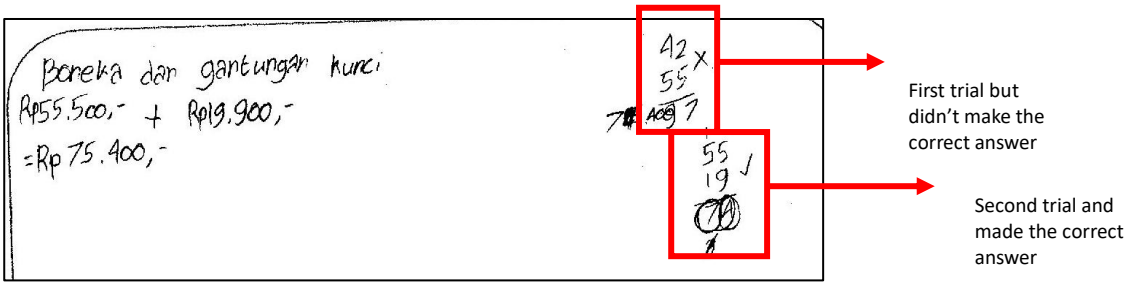

Figure 7. *Student's answer Question Number 3 (P5)*

There was another student who did trial and error first. As shown in figure 7, he did addition of 2 price of items (42 + 55) but it didn't give right answer because the result is above 90.000, then he tried to add up by choosing another item (55+19). While the rest of the students tried by trial and error but immediately found it on the first try.

There was one student who answered wrong because he was not careful in reading the question, he thought that the provision was more than 50,000, so he gave the wrong answer even though he could process the question correctly. So in this indicator there are 4 out of 5 students who can reach the indicator of making mathematical conjectures.

Mathematical Reasoning Indicator

From the analysis on encoding, it can also show how many students are able to solve the problem until the end. So that from the final results of students also obtained the number of students who were able to achieve reasoning indicators which can be seen in the table below:

Table 4. The number of students' correct answer

Subject Research	Constructing mathematical arguments (Q1)	Comparing and ordering (Q2)	Making mathematical conjectures (Q3)	Total of Correct Answer
P1	X	✓	✓	2

P2	✓	✓	✓	3
P3	✓	X	✓	2
P4	X	X	X	0
P5	✓	✓	✓	3
Total	3	3	4	

Based on the result in table 4, it can be seen that students P2 and P5 achieved three reasoning indicators, students P1 and P3 achieved two reasoning indicators, and student P4 did not achieve any reasoning indicators. Meanwhile, when viewed from the mathematical reasoning indicators, 3 out of 5 students can construct mathematical arguments, 3 out of 5 students can compare and order, and 4 out of 5 students can make mathematical conjectures. This means that the most mastered reasoning of the five students is making mathematical conjectures, while students' ability to construct mathematical arguments is the same as students' ability to compare and order.

CONCLUSION

Among the 5 students in 5th grade, there were 2 students who achieved 3 reasoning indicators, 2 students who achieved 2 reasoning indicators, and 1 student who did not achieve any reasoning indicator. From the three reasoning indicators measured, reasoning to make mathematical conjectures is the reasoning indicator most mastered by students because 4 out of 5 students can achieve this indicator, while the other 2 reasoning indicators namely “comparing and ordering” and “constructing mathematical arguments” can be achieved by 3 out of 5 students. Meanwhile, when viewed from the question, the question that contributes the most errors for students is question number 2 with 7 errors, then question number 1 with 4 errors, and the least is question number 3 with 3 errors.

From all the ways of problem solving done by students, students are more proficient in addition and subtraction operations than multiplication and division operations. They need improvement in multiplication and division operations because they still wasted a lot of time in the process of solving that typical question which need multiplication and division. With the variety of problem solving given, it can also become a new idea for teachers to be able to make special sessions for students to present how they find answers so that it can be an input for students to each other to be able to find the most efficient way of solving problems. It also can give teacher reflection for making plan about teaching strategy and material that proper to give to students in order to improve students’ mathematical abilty. Meanwhile, I suggest for

future studies to be able to analyze reasoning on other topics and also make a study to find out a learning model or approach that is suitable according to the problems found.

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