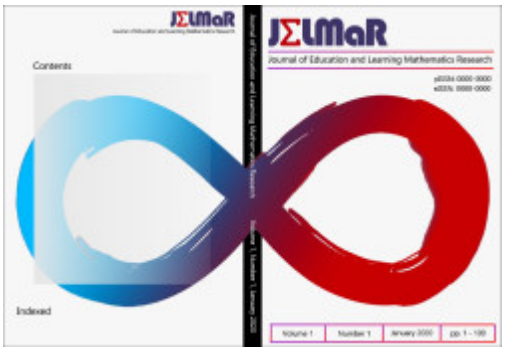

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Watson's Error Category: Analysis of Student Errors in Solving Algebraic Calculation Operation Problems

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***Abstract**: Algebra material is the initial material in mathematics learning for junior high school students, which is a transfer from real material to abstract material, especially for the material for algebraic arithmetic operations is the basic material that students must master before studying higher-level algebraic material. This research is motivated by the presence of several students who still make mistakes in solving algebraic arithmetic operations. Therefore, this research aims to describe the forms of errors made by students in solving algebraic arithmetic operations based on Watson's error category. This research is a qualitative descriptive study. The subject of this research is 4 students of class VII A of MTs Muhammadiyah 2 Jenangan. Data collection techniques were conducted by giving written tests and interviews. The instruments used in this research were test questions and interview guidelines. Research subjects were selected based on the test results of students who made the most mistakes according to Watson's error category, and have good communication skills based on teacher recommendations. Data analysis was conducted with the stages of data reduction, data presentation, and data verification or concluding. The research results show that in solving algebraic arithmetic operations, the students made an error based on Watson's error category, including inappropriate data, inappropriate procedure, omitted data, omitted conclusion, response level conflict, and skill hierarchy problem. Besides the errors made by students, there were errors according to Watson's error category that were not made by students, namely undirected manipulation and other.*
Keywords: Error Analysis, Algebraic Arithmetic Operation, Watson's Error Category

INTRODUCTION

Mathematics is an important subject to be given to all students. According to Anggari & Rufiana (2020), mathematics can be said to be a universal science that can be included in various sciences. Apart from that, the knowledge taught in mathematics is also very necessary because it is closely related to everyday life. As argued by Hernadi, et al. (2020) which states that in everyday life, people cannot be separated from numbers which are used for various purposes such as counting, measuring, comparing, or labeling. Af-idah & Suhendar (2020) also stated that mathematics can be implemented to make it easier for people to live their daily lives. As for learning, mathematics is abstract, where students are required to have the ability to manipulate and visualize real objects. With its abstract nature, it cannot be denied that there are still many students who consider mathematics to be a difficult subject.

One of the mathematics materials that junior high school students find difficult is algebra. This is because algebra can be said to be the initial material for junior high school students, namely a change from real material to abstract material (Afifaturrohmaniyyah & Malasar, 2021). Students need to master algebra, because it is the initial foundation or prerequisite for studying further mathematical material, such as systems of linear equations, linear functions, quadratic functions, function limits, and so on. As a result of these difficulties, new problems emerge for students. The problem in question is that there are still many students who often make mistakes when working on algebra questions.

From the results of preliminary research conducted on 6 junior high school students, researchers also found several forms of student errors when solving algebraic calculation operations problems. From the results of students' answers in the preliminary research, most students made mistakes in the process of operating algebraic multiplication. After the

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interview, the error occurred because the students were not careful when reading the questions and did not understand the distributive property to operate algebraic multiplication. Apart from that, student errors are also caused by students not understanding the elements of algebra correctly, namely variables, coefficients, constants, and terms.

The number of mistakes students make in working on questions is a measure of the extent to which students understand the material. This is also by the views of Dewi and Kusrini (2014) who state that mistakes made by students can be used by teachers to filter students' level of understanding in teaching and learning activities, making it easier to find out the difficulties experienced by students. To find out the types of errors made by these students, conducting an analysis is very important. In detail, error analysis can be used to detect forms of student error, so it is hoped that it can minimize errors and help overcome low student mathematics achievement.

To narrow the breadth of types of student errors, error analysis can be classified according to certain categories. One theory that can be used to classify these types of errors is using Watson's Error Category. There are eight categories of student errors according to Watson's perspective (2006), including inappropriate data, inappropriate procedures, omitted data, omitted conclusions, and response level conflicts. (response level conflict), indirect manipulation, skills hierarchy problem, and other than the seven categories above (above other). Researchers used Watson's classification of errors because these eight categories were felt to be more detailed in describing the types of student errors, compared to other classifications of errors. Apart from that, according to Suriani (2019), students' errors in solving algebraic calculation operations problems are very suitable if analyzed using Watson's error categories.

METHOD

This research uses qualitative descriptive research, which is used to describe a symptom, phenomenon or object, which begins by understanding the symptom, then the researcher analyzes information from various sources to compare until the researcher feels satisfied and confident that the information obtained is correct, then presents it narratively. Thus, this research can describe students' errors in solving algebraic calculation operations problems which are categorized according to Watson's Error Category. This research was carried out at MTs Muhammadiyah 2 Jenangan which is located on Jl. Raya Jenangan No. 68 Ponorogo. This research was conducted on class VII A students in the even semester of the 2021/2022 academic year. As for the subjects, they were selected purposively, namely based on the objectives and consideration of the criteria for students who made the most mistakes based on Watson's error indicators, and had good communication The indicators for each category of error are:

Table 1. The Most Mistakes Based on Watson's Error Indicators

1	Inappropriate data	Students write information that does not match the information contained in the algebra form questions.
2	Inappropriate procedure	1. Students use inappropriate methods or steps in solving problems. 2. Students add or subtract unlike terms.
3	Omitted data	1. The student loses one or more data from the student's response and thus the solution becomes incorrect. 2. Students ignore the operation signs "+" and "-" which separate algebraic terms.
4	Omitted conclusion	1. Students do not make conclusions from the problem solutions that have been obtained.

		2. Students do not complete the answer until the end.
5	Response level conflict	Students only write conclusions without any logical completion steps in completing algebraic calculation operations.
6	Undirected manipulation	The reasons used by students are not ordered, but the conclusions obtained are correct and in general all data is used
7	Skills hierarchy problem	Students are less careful in carrying out calculations and make mistakes in producing calculation results in addition, subtraction, multiplication, division in algebraic forms.
8	Above other	1. Students only rewrite algebraic questions without any solutions. 2. Students do not answer questions.

RESULT AND DISCUSSION

This research was carried out by giving 4 test questions containing material on algebraic calculation operations adapted from Suriani (2019) & Dellani (2016). From the test results, 4 subjects were obtained by the previously determined subject selection criteria. Next, the researcher conducted interviews with the four subjects to get clarification of the mistakes made. The list of subjects in this research is as follows:

Table 2. List of Research Subjects

Subject initials	Subject Codes
DPK	S-1
JAA	S-2
DQH	S-3
SYA	S-4

Based on the test results and interviews of the 4 subjects above, several errors were obtained based on Watson's error categories which are presented in the following table:

Table 3. Subject Errors Based on Watson's Error Category

No.	Subjek	Nomor Soal	Jenis Kesalahan							
			ID	IP	OD	OC	RLC	UM	SHP	AO
1	S-1	1	-	-	-	-	√	-	-	-
		2	-	√	-	-	-	-	√	-
		3	√	√	-	-	-	-	-	-
		4	-	√	-	-	-	-	√	-
2	S-2	1	√	√	-	√	-	-	-	-
		2	-	√	-	-	√	-	-	-
		3	-	√	√	-	-	-	-	-
		4	-	√	-	-	√	-	-	-
3	S-3	1	-	√	-	-	√	-	-	-
		2	-	√	-	-	-	-	√	-
		3	√	√	-	-	-	-	-	-
		4	-	√	-	√	-	-	-	-
4	S-4	1	-	-	-	-	√	-	-	-
		2	-	√	-	-	-	-	√	-
		3	-	-	√	-	√	-	-	-
		4	-	√	-	-	-	-	-	-

Based on Table 3 above, a description of the analysis of the results of the work of subjects who made errors will be presented based on Watson's error category in each of the following question numbers.

Analysis of Question Number 1

Problem number 1 is to determine the simple form of $4P+3Q$ if it is known that $P = 2x^2 - y$ and $Q = x^2 + y$. The following are the results of the subject test on question number 1 which are presented in figure 1, figure 2, figure 3, and figure 4.

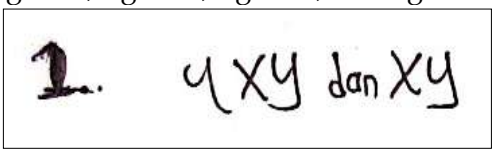

Figure 1. Results of S-1 Question Number 1

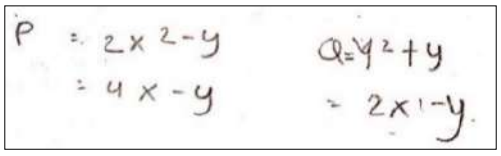

Figure 2. Results of S-2 Question Number 1

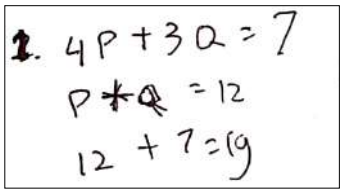

Figure 3. Results of S-3 Question Number 1

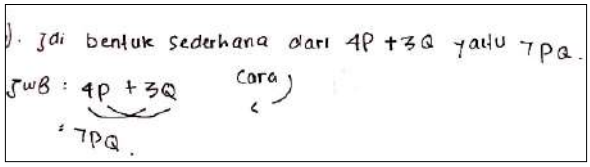

Figure 4. Results of S-4 Question Number 1

Figure 1 is the result of S-1's work, which based on these results and after interviews shows that S-1 has made response-level conflict errors. S-1 immediately wrote down the final results without any process or logical reasoning. This error occurred because S-1 did not know the strategy that should be used to solve problem number 1.

Figure 2 is the result of S-2's work, which based on these results and after interviews shows that S-2 made errors with inaccurate data, incorrect conclusions, and inappropriate procedures. The wrong data error made by S-2 was incorrectly writing the known algebraic terms in the problem. This is because S-2 was not careful in reading and writing the questions again. The incorrect procedural error made by S-2 was carrying out an operation that should not have been carried out. This is because S-2 does not understand the rules for algebraic multiplication using the distributive property. Meanwhile, the mistake in the conclusion was not mentioned by S-2, namely that the final result given did not reach what was asked about the question. This is because S-2 does not know the strategy to continue

Figure 3 is the result of S-3 work, which from these results and after interviews, shows that S-3 made inappropriate procedural errors and the level of response conflict. The incorrect procedural error made by S-3 was that he did not carry out the algebraic multiplication operation correctly, S-3 added dissimilar terms. This is due to S-3 lack of understanding of the distributive property and the rules for adding and subtracting

algebraic terms. Meanwhile, the response level conflict error was several times when S-3 immediately wrote down the results without any flags.

Figure 4 is the result of the S-4 work, which is based on these results and after conducting conflict interviews on response levels. S-4 performs simple operations and then immediately provides the final answer without any reason or logical process. The causes of the error are almost the same as S-1 and S-3 which were explained above.

Analysis of Question Number 2

Problem number 2 is to simplify multiplication in the algebraic form (2x+3)(4x-5). The following are the results of the subject's work on question number 2:

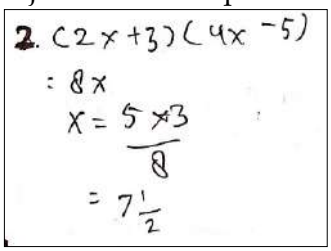

Figure 5. Results of S-1 Question Number 2

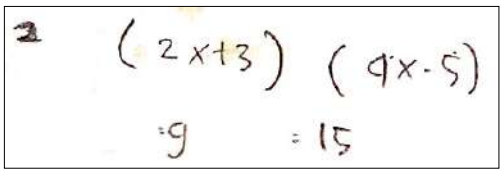

Figure 6. Results of S-2 Question Number 2

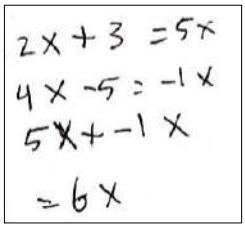

Figure 7. Results of S-3 Question Number 2

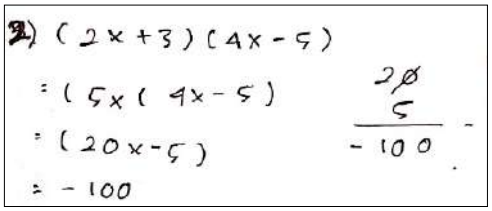

Figure 8. Results of S-4 Question Number 2

Figure 5 is the result of S-1 work, which based on these results and after interviews shows that S-1 has made errors in inappropriate procedures and skills hierarchy problems. The incorrect procedural error made by S-1 was not operating algebraic multiplication using the distributive property correctly, and S-1 instead looked for the x value from the algebraic form. This happens because the undergraduate understanding of the distributive property is still weak. Meanwhile, the error in the skill hierarchy problem made by S-1 was incorrectly calculating both the result of multiplying two algebraic terms and simplifying the fraction obtained. This happens because undergraduate calculation skills in both integers and algebra are still lacking.

Figure 6 is the result of S-2 work, which based on these results and after interviews shows that S-2 has made inappropriate procedural errors and conflicted response levels. The subject made an inappropriate procedural error, namely not operating algebraic multiplication using the distributive property correctly. Meanwhile, the response level conflict error made by S-2 was that the final result was directly written down without any logical process or reason. This happens because S-2 does not understand the rules of multiplication operations in algebra and does not know the strategy that must be used to solve the problem correctly.

Figure 7 is the result of S-3's work, which based on these results and after interviews shows that S-3 has made errors in inappropriate procedures and skills hierarchy problems. The incorrect procedural error made by S-3 was that he did not solve the problem using the distributive property, instead, S-3 added and subtracted each algebraic form in brackets and then added the two results. However, though this operation cannot be carried out because the algebraic form enclosed is a term that is not similar. This happens because S-2 students still have a weak understanding of the distributive property and the rules for addition-subtraction operations in algebra. Furthermore, the problem with the skill hierarchy problem that S-3 made was not making a mistake in adding up the final results. This occurs due to a lack of calculation skills on positive and negative integers, so it has an effect when adding algebraic terms.

Figure 8 is the result of S-4 work, which based on these results and after interviews shows that S-4 made errors in inappropriate procedures and skills hierarchy problems. Almost the same as the mistakes made by other subjects, S-4 in solving this problem had not operated using the distributive property correctly and there was still an error in multiplying two algebraic terms.

Analysis of Question Number 3

Problem number 3, namely simplifying the division of the algebraic form 24p^3 q^2 :(18p^2 q^3 :3pq). The following are the results of the subject's work on question number 3:

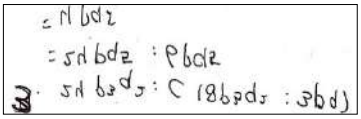

Figure 9. Results of S-1 Question Number 3

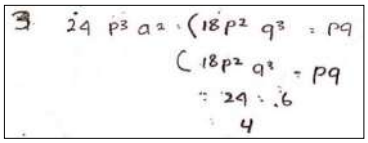

Figure 10. Results of S-2 Question Number 3

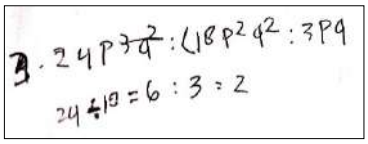

Figure 11. Results of S-3 Question Number 3

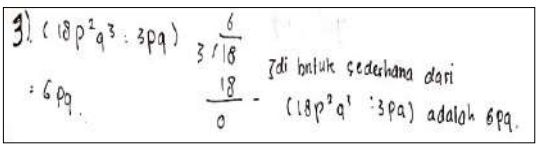

Figure 12. Results of S-4 Question Number 3

Figure 9 is the result of S-1 work, which based on the results of this work and after interviews shows that S-1 made errors with incorrect data and incorrect procedures. The incorrect data error made by S-1 was incorrectly writing the known algebraic terms in the problem. This is because S-1 was not careful in reading and rewriting the questions. Meanwhile, the incorrect procedural error made by S-1 was that he was not correct in operating algebraic division using power rules, S-1 added the powers. This is due to undergraduates' lack of understanding of the rules for division operations in algebra.

Figure 10 is the result of S-2 work, which based on the results of this work and after interviews shows that S-2 made data errors that were not mentioned and procedures were not correct. An unmentioned data error was made by S-2, namely incomplete writing of algebraic terms according to what was known in the problem. This is because S-2 was not careful in reading and writing the questions again. Meanwhile, S-2 made an incorrect procedural error, namely only dividing the coefficients. This is because S-2 does not yet understand how to divide variables into powers in algebra.

Figure 11 is the result of S-3 work, which based on the results of this work and after interviews shows that S-3 made errors with incorrect data and inappropriate procedures. The incorrect data error made by S-3 was the same as the S-1 error, namely the error in writing the algebraic terms according to what was known in the problem. The cause of this error is also the same, namely because of not being careful. Meanwhile, the incorrect procedural error made by S-3 was the same as the S-2 error with the same cause, namely only dividing the coefficients because they did not understand how to divide rank variables.

Figure 12 is the result of S-4 work, which based on the results of this work and after interviews shows that S-4 made unstated data errors and conflicted response levels. The unstated data error made by S-4 is the same as the S-2 error with the same cause, namely not being complete in writing the known algebraic terms in the problem because he was not careful. Meanwhile, the response level conflict error made by S-4 was only carrying out simple operations on the coefficients and then immediately writing down the final results for the variables without any logical process or reasoning.

Analysis of Question number 4

Question number 4 is to determine the area of a rectangle if the length is (5a+3) cm and the width is (6a-2) cm. The following are the results of the work of one of the subjects in question number 4:

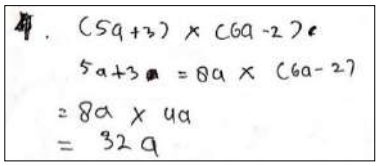

Figure 13. Results of S-1 Question Number 4

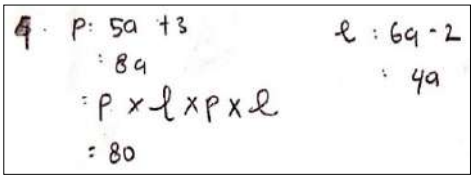

Figure 14. Results of S-2 Question Number 4

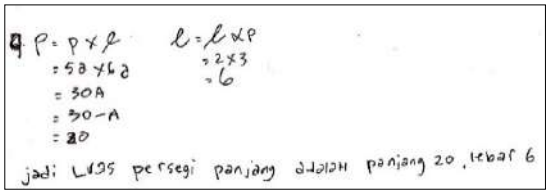

Figure 15. Results of S-3 Question Number 4

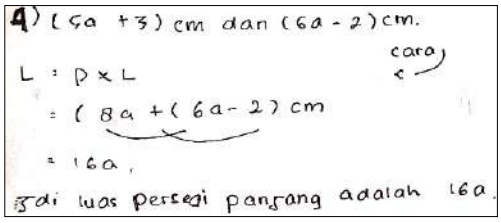

Figure 16. Results of S-4 Question Number 4

Figure 1 is the results of S-1's work, which based on the results of this work and after interviews shows that S-1 made errors in inappropriate procedures and skills hierarchy problems. S-1 uses the formula for the area of a rectangle correctly. However, you still make procedural errors when multiplying the length and width, namely by adding up each length and width and then multiplying the result of the two. Like the previous mistakes, this is because S-1 does not understand the distributive property and algebraic addition rules correctly. Meanwhile, the skill hierarchy problem error made by S-1 was that there was an error in multiplying two algebraic terms.

Figure 2 is the result of S-2 work, which based on the results of this work and after interviews shows that S-2 made inappropriate procedural errors and conflicted response levels. The incorrect procedural error made by S-2 was that he did not correctly use the formula for the area of a rectangle and carried out addition and subtraction operations on unlike terms. Meanwhile, the response level conflict error made by S-2 was to immediately write down the final results in terms of breadth without any process or logical reasoning. This is due to a lack of master's knowledge about the prerequisite material and strategies for implementing algebra.

Figure 3 is the result of S-3 work, which based on the results of this work and after interviews shows that S-3 made inappropriate procedural errors and the conclusions were not stated. The incorrect procedural error made by S-3 is the same as S-2, namely not using the formula for the area of a rectangle correctly. Meanwhile, S-3 did not mention the error in the conclusion, namely that it did not show the results of what was asked in the question, namely the area of the rectangle. This is because there is still a lack of doctoral knowledge regarding the prerequisite material so they are unable to solve this problem correctly.

Figure 4 is the result of S-4 work, which based on the results of this work and after interviews shows that S-4 made inappropriate procedural errors. Just like S-1, S-4 uses the rectangular area formula correctly. However, S-4 still made incorrect procedural errors in multiplying the length and width. This is due to S-4 lack of understanding of the distributive property that should be used to solve this problem.

Discussion

Based on the analysis of the results of the subject's work in solving the 4 algebraic calculation operations questions above, it shows that the number of errors made by the subject in each problem varied. Subjects made one or more mistakes in each question. As in the results obtained above, there are six categories of Watson's error categories made by the subject, namely incorrect data errors, incorrect procedures, data not mentioned, conclusions not mentioned, response level conflicts, and skills hierarchy problems. Meanwhile, indirect manipulation errors other than the seven categories above were not carried out by the 4 subjects.

The data error form is incorrect, the subject incorrectly wrote the known algebraic form in the problem. This is in line with the opinion of Suriani (2019) that the type of data error is inappropriate (inappropriate data), namely writing information that does not match what is contained in the algebraic form question. The inaccurate data errors made by the

subjects in this study were caused by the subjects not being careful in reading the questions and writing the questions back on the answer sheet.

A form of incorrect procedural error, the subject adding or subtracting, unlike terms when what is required is a multiplication operation, or vice versa. Subjects also did not operate algebraic multiplication using the distributive property correctly. Likewise, with the division rules, the majority of subjects carried out the distribution of rank variables using inappropriate procedures, namely by dividing the power number. According to Mavisiuddarojah & Prahmana (2019), the types of errors above are caused by a weak understanding of the concepts of addition, subtraction, multiplication, and division in algebra. Meanwhile, Ramadhani, et al. (2016) make mistakes in adding and subtracting unlike terms because their knowledge is still affected when studying arithmetic, namely, they tend to focus on the result in the form of a certain number. Regarding the weak understanding of the characteristics of an operation, Booth, et al. (2014) argue that if when studying algebra they still misunderstand the operations and properties that they have practiced, this will make it difficult for them to achieve algebra. Thus, it is important to first understand the previous material that can support success in studying algebraic arithmetic operations material.

The form of data error is not mentioned, the subject misses one or more algebraic elements when writing the problem again and/or during the processing process. The errors that occur are in line with Watson's (2006) opinion that errors in inaccurate data (omitted data), namely not finding the right information in the question cause incomplete data entry, or in other words losing data that should be there to non-existent. This error is also caused by the subject not being careful in reading the questions and writing the questions back on the answer sheet, or during the working process. According to Saputri, et al. (2018), this error occurred due to a lack of accuracy, and not fully understanding the function of the known data, as a result, the data entered was incomplete. According to Dellani (2016), this causes errors when the subject reaches the next step, namely calculating and completing the algebraic form.

The form of conclusion error is not mentioned, the subject does not complete the work process to the end, and/or the final result given by the student has not provided an answer according to what was asked in the question. The error that occurred is in line with the form of error in Suriani's (2019) research, namely that this type of error is the absence of a conclusion from the solution that has been obtained. This is because the subject does not understand the strategy that must be used to continue solving the problem, so the subject chooses not to complete the problem until the end. Apart from that, this was also triggered by running out of time to do the work. According to Saputri, et al. (2018), the conclusion error was not stated to occur because the subject had not finished until the final stage due to running out of time to work on it and also not understanding the meaning of the question.

In the form of response level conflict error, the subject performs a simple operation and immediately turns it into the final result, and/or the subject immediately writes the conclusion of the final result without any logical resolution steps. This is the opinion of Suriani (2019) that the response level conflict error is simply writing a conclusion without any logical resolution steps in completing algebraic calculation operations. This is because the subject does not understand the strategy or steps that will be used to solve the problem so the subject tends to choose to write direct results without any logical process. According to Saputri, et al. (2018), the cause of this response-level conflict error is that the steps taken were not precise, failing to get the correct final result. Meanwhile, in Suriani's (2019) research, this response level conflict error occurred due to a lack of understanding of the form of the question, as a result, the subject only operated simply using existing data, then used it as the final result with a procedure that did not comply with the proper rules, or immediately wrote the answer without any logical reasons.

This form of error is a skill hierarchy problem, where subjects make calculation errors such as multiplying two algebraic terms incorrectly and adding or subtracting positive and negative algebraic terms incorrectly. This form of error is in line with the form of error that occurred in Suriani's (2019) research, namely errors involving a hierarchy of skills, namely not being careful in calculating and making errors in producing calculation results in addition, subtraction, multiplication, and division in algebraic forms. Apart from that, a lack of skills in calculating both algebraic forms and whole numbers also causes this error. According to Mavisiuddarojah & Prahmana (2019), it is important to understand whole number operations correctly, so that there are no errors related to negative signs and success when studying the concept of further algebraic arithmetic operations.

CONCLUSION

Based on the description of the results and discussion of research carried out by subjects consisting of 4 students of MTs Muhammadiyah 2 Jenangan, it can be concluded that these students have made errors based on Watson's error category in solving algebraic arithmetic operations problems, namely incorrect data errors, incorrect procedures, data not mentioned, conclusions not mentioned, conflicting response levels, and skill hierarchy problems. The number of errors made in each question varies, namely there is one error or even more. Errors to Watson's error category that were not made by the subject were indirect manipulation errors and other than the seven categories, namely errors in not doing the questions and/or just writing the questions again.

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