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# MATHEMATICS COMMUNICATION MISTAKES IN SOLVING *HOTS* PROBLEMS

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**ABSTRACT**

Student mistakes in communicating mathematical ideas are still widely practiced. Therefore it is essential to analyze students' mathematical communication errors in solving mathematical problems so that learning planning can be better. This study aims to describe the mathematics communication errors made by students in solving the higher-order thinking skill's problems in linear algebra and matrix subject. The type of research is a qualitative descriptive study. They were 155 students as subject research. The data analysis started by collecting student's answers and then grouped them according to mathematics communication skills criteria. Later identified and analyzed the errors made by students of each mathematics communication criteria. The results showed that mathematical communication errors on the indicators of writing mathematical situations were concept errors and principle errors. The mathematical communication error in the declaring idea is a concept error, principle error, and an operation error. Furthermore, mathematical communication errors on the indicator state the results of solving-problem using the language itself is a concept error and operator error.

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## 1. INTRODUCTION

Learning and communication are integral parts. Kleden (2016) emphasized that in learning activities there was an exchange of information in the form of knowledge and experience between lecturers and students, students and students, also between students and teaching materials, so mathematical communication skills were very much needed. Firdaus & Aini (2019) added that learning activities carried out by students were not limited to memorizing formulas and mastering calculations, but also learning through mathematical communication. Kleden (2016) emphasized that with excellent mathematics communication, students can convey ideas or thoughts appropriately to convince themselves and others. The importance of student mathematical communication is currently a problem that must be considered (Astuti & Leonard, 2015). Therefore, the development of students' mathematics communication skills in problem-solving must master at the lecture level (Fatimah, 2012). It will be useful in social life and good problem-solving results for students (Ruswana, 2019).

Excellent communication skills are essential for students because, through symbolic language, students can communicate mathematically accurately and accurately (Novianti, 2017). Student's ability to solve problems can be influenced by students' written mathematics communication skills through their answer sheets (Ardina dkk, 2016). Umar (2012) emphasized that communication and problem-solving skills are related and essential to have so that mistakes not occurred. Therefore, it is crucial to develop student mathematics communication.

The importance of having mathematics communication skills is not in line with the facts which show that many students make mistakes in communicating their ideas (Pratiwi, 2015). Most of them do not master the concepts but only memorize them (Ruswana, 2019). Students make a lot of mistakes in mathematics communication skills. Therefore mathematics communication conducted through tests will determine the students' ability to master the material (Subekti dkk, 2016). Based on this information, mathematics communication skills are related to mathematical errors made by students.

According to Ardiawan (2015), mathematics errors are systematic errors that occur when the answers are written differently from the real solutions. Firdaus (2019) said that there were some mistakes when solving Matrices about understanding the question of the story, using formulas and concepts, and doing calculations. Besides, Wijaya & Masriyah (2013) said that there were several types of mistakes made, namely concept errors, principle errors, and operating errors. Concept errors are caused by students when misinterpreting or using terms so they cannot understand a given material/problem (Widodo, 2013). Principal error is a mistake made because of the inability of students to connect/link several concepts in the right relationship (Astuty & Wijayanti, 2013). Then Astuty & Wijayanti (2013) said the operation error was an error made due to incorrect calculation. At the same time, Zukhrufurrohmah & Kusumawardana (2019) research states that the types of mathematical errors can be in the form of skills, concepts, and techniques. But in this study, the mathematics errors that be analyzed were concept errors, principle errors, and operating errors.

Agree with Asviangga et al. (2018) that one of the problems that can lead to mathematics communication skills is a matter of high-level thinking. Rahayuningsih & Jayanti (2019) said that improving the quality of learning can obtain by solving Higher-Order Thinking Skills (*HOTS*). Thus when students do problem-solving activities can use a different approach, it will be possible to do so that a high-level thinking process occurs (Rahayuningsih & Jayanti, 2019). *HOTS* questions are questions that require you to use higher-order thinking skills (Pratiwi et al., 2017). The aspects of the *HOTS* problem are analyzing, evaluating, and creating (Rahayuningsih & Jayanti, 2019). Based on some of these aspects in this study *HOTS* Problem indicators in measuring mathematics communication are students can: 1) analyze the mathematical situation by breaking down the information obtained; 2) evaluate by testing against an idea by the procedure to clarify a statement, and 3) create with writing a summary or theory to conclude.

According to the explanation, this researcher is interested in describing mathematics communication errors that students have when completing *HOTS* Questions in Linear Algebra and Matrix subjects.

## 2. METHOD

This research is qualitative descriptive research aiming to describe the written mathematics communication errors made by students in completing *the HOTS* problem on matrix material. The study begins by conducting field observations with the data obtained is that students make some mistakes in conveying the idea of solving a given problem. Based on this problem, instruments were then arranged in the form of *HOTS*-style test questions to lead to errors and mathematics communication of students. The test questions were validated by two mathematics education lecturers who experts in teaching Linear Algebra and Matrix subjects. The test was given to the students through the lms.umm.ac.id platform. Students collect their answers by uploading handwritten photos or sending typed results to lms.umm.ac.id through their respective accounts. *HOTS* problems that valid were served in Table 1

.

**Table 1. Research Instruments**

| Question | *HOTS* Aspect | Mathematics communication Indicator on the answer to the problem | Mathematical Error that Appears in Problem |
|---|---|---|---|
| 1. Find matrix $A$, matrix $B$, matrix $C$, so $AC = BC$ and $A \neq B$! | Analyze | Understanding the mathematical situation clearly, students write that the matrix $AC = BC$ and matrix $A$ are different from matrix $B$ | Concept errors, principle errors and operating errors |
| | Evaluate | Writing ideas clearly, students will test by multiplying the two matrices to find out whether $AC = BC$ and served matrix $A$ are different from matrix $B$ | Concept errors, principle errors and operating errors |
| | Create | Stating the results of problem-solving using their language, students write the conclusion that matrices A and B are different matrices so that $AC = BC$ and $A$ are different from $B$ | Concept errors, principle errors and operating errors |
| 2. Suppose there is a matrix $A$ with the following components: $A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$ If $A^2 = AA$, $A^3 = AAA, and$ $A^n = \underbrace{AA \ldots A}_{as\ many\ as\ n}$, Is it possible that $A^n$ produces a zero matrix? Provide detailed | Analyze | By understanding the mathematical situation clearly, students write down the information obtained from matrix $A$, matrix $A^2 = AA$, matrix $A^3 = AAA$ and $A^n = \underbrace{AA \ldots A}_{as\ many\ as\ n}$ | Concept errors, principle errors and operating errors |
| | Evaluate | Writing out ideas clearly, students test by calculating the matrices $A^2$and $A^3$ whether they produce a zero-matrix or not, then clarify that the results of the matrix $A^2$ and $A^3$ are not zero-matrices, and then test for the | Concept errors, principle errors and operating errors |

| | | | |
|---|---|---|---|
| explanations of the answers! | | student matrix $A^n$ use each idea to find out whether the matrix $A^n$ will produce a zero matrix | |
| | Create | Using their language, students write the possibility of the matrix $A^n$ to produce a zero-matrix | Concept errors, principle errors and operating errors |

Questions were given to 4 classes that were taking Linear Algebra and Matrix courses. The sample used was 155 students of Informatics Department Muhammadiyah Malang. The results of student work are grouped according to mathematics communication skills of excellent and poor criteria. Excellent mathematics communication skills are intended when all three mathematics communication criteria are fulfilled. While the mathematics communication criteria are less meant when one or more of the three mathematics communication criteria are not filled. The researcher then identifies and analyzes the types of errors made by students on each mathematics communication indicator in each indicator.

Data analysis techniques in this study were carried out through 3 stages: data reduction, data presentation, and concluding. The data reduction stage is carried out by grouping the answers of the two questions based on similar answers into several types of the four classes. This is done to facilitate the analysis based on indicators that have been determined. Then the data obtained are presented in tables and diagrams. And the next step is to conclude the result based on data gathered.

## 3. RESULTS AND DISCUSSION

### 3.1. Results

Data obtained from the four classes were 155 student answers. Figure 1 shows that 148 students have less mathematics communication in the first question, and seven students who have excellent mathematics communication. Judging from the number of answers shows that mathematics communication possessed by students is still lacking. Only 4.5% of the total amount has excellent mathematics communication. It shows that students cannot communicate their ideas well so that they have difficulty in problem-solving.

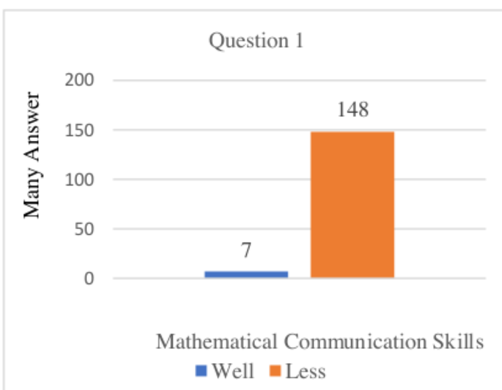


Figure 1. Number of Mathematics communication Questions 1

Whereas in Figure 2, the number of answers to Question 2 does not differ from Question 1. The number of students with communication is more or less compared to students with excellent communication. But for the second question, there is no difference with the distant numbers, namely 85 students with less mathematics communication and 70 students with excellent communication. It means that students are more able to communicate their ideas in the second question than the first question.

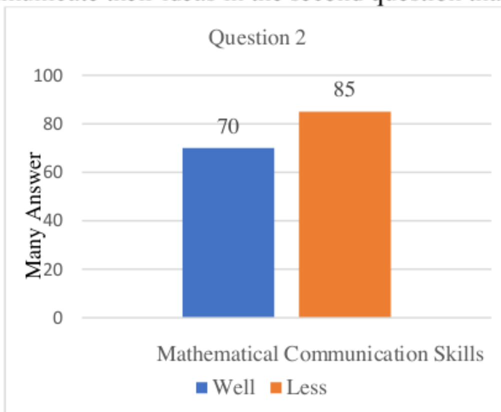


Figure 2. Number of Mathematics communication Questions 2

The percentages of each student's mathematics communication criteria were presented in Table 2.

**Table 2. Percentage of Mathematics communication of Students each Indicator**

| No. | Mathematics communication indicator | Question 1 | | Question 2 | | Average | |
|---|---|---|---|---|---|---|---|
| | | well | less | well | less | less | less |
| 1 | Understand the mathematical situation clearly | 84,52% | 15,48% | 83,23% | 16,77% | 83,86% | 16,13% |
| 2 | Write ideas of problem-solving clearly | 76,77% | 23,23% | 73,55% | 26,45% | 75,16% | 24,84% |
| 3 | State the results of problem-solving using your language | 6,45% | 93,55% | 58,06% | 41,94% | 32,26% | 67,75% |

Table 2 shows that not all students meet the three mathematics communication criteria in solving *HOTS* problems. The third criterion of mathematics communication, declare the answer to solving HOTS's problem using their language, obtain the most significant percentage of 93.55%. This percentage is the highest compared to the other two indicators. It happens because students are incomplete in writing conclusions of problem-solving. The highest rate in the second question for the category lacking was also found in the indicator, stating the solving results using their language that is 41.94%. Most students did not write the conclusions of the calculation that they obtain. Although students are good at understanding mathematical situations or writing their ideas, it did not mean that students' mathematics communication was excellent.

Each rate of mathematics communication

skills showed that not all students fulfilled all criteria of mathematics communication. Students in problem-solving with problems may make mistakes by mathematics communication written owned. The mistakes made by students in completing Problems are presented in Table 3.

**Table 3. Forms of Student Mathematical Errors**

| | Types of mistakes made by students |
|---|---|

| Mathematics communication indicator | Concept | Principle | Operation |
|---|---|---|---|
| Understand the mathematical situation clearly | In Question 1, it is wrong to determine matrix $A, B, C$ | In Problem 2, the concept of an identity matrix and matrix multiplication is wrong | Not found |
| Write ideas of problem-solving clearly | In Question 2, it is wrong to apply the concept of multiplication to the $AA$ matrix | In Question 1, it is wrong to use ideas, so there is no relationship between the matrix $A\ B\ C$<br><br>In Question 2 it is wrong to form the matrix $A^n$ because it does not find a relationship with the matrix $A^2$ and $A^3$ | Not found |
| State the results of problem-solving using your language | In Question 1, it is wrong to conclude that $AC = BC$.<br><br>In Question 2, it is wrong to conclude that $A^n$ will probably produce a zero-matrix | Not found | In Question 1, it was wrong to calculate the $2x2$ matrix multiplication. |

### 3.1.1 Mathematical Errors when Understanding Mathematical Situations Clearly

On the indicators of understanding the mathematical situation clearly, students made mistakes, namely misconceptions and principles, but did not make operational errors. In the second question, students did not make misconceptions when understanding mathematical situations. Students created a mistake in the first question. The mistake made by students were wrong in determining the A, B, C matrices. These errors resulted in students not getting AC = BC. The answers of students who make misconceptions when understanding the mathematical situation are clearly shown in Figure 3. Figure 3 shows that students only determine matrix C and then conclude that AC is the same as AB, while matrix A and matrix B are not explained as components.

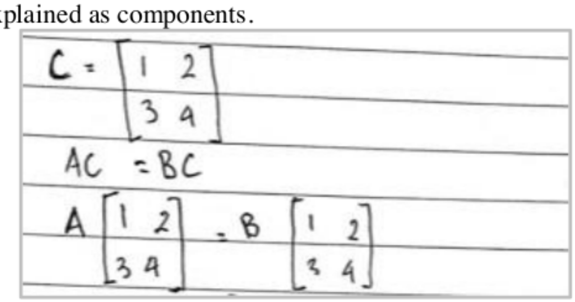

**Figure 3. Misconceptions when Understanding Mathematical Situations in the First Problem**

Students make a principle mistake in the form of incorrectly linking the concept of the identity matrix and matrix multiplication. Figure 4 is the answer to students who earned a principle error when they did not understand the mathematical situation correctly. Students make a mistake when multiplying the matrix and stating that the matrix $A^2$ is the identity matrix.

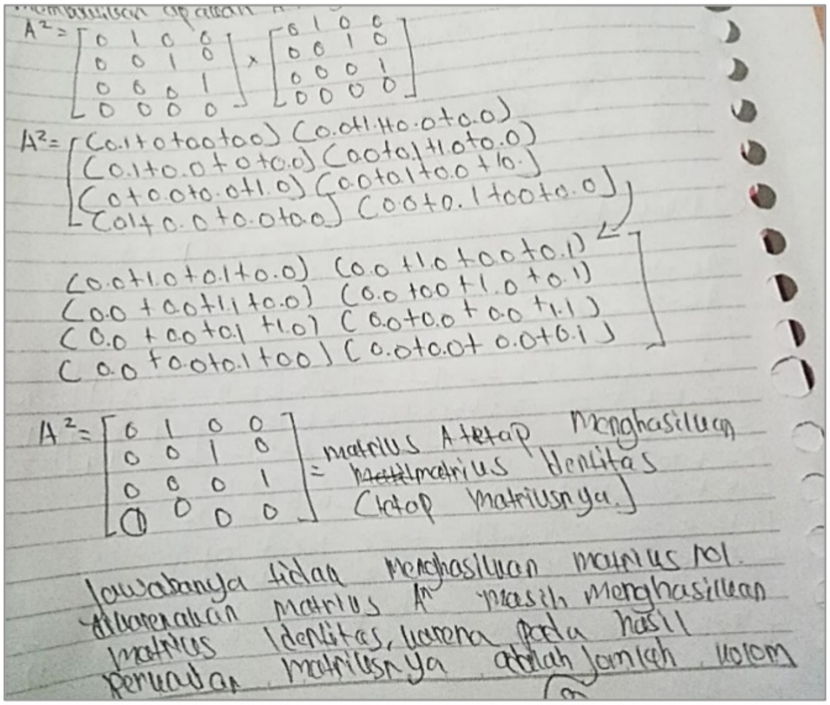

**Figure 4. Mistakes in Principle when Understanding Mathematical Situations Clearly**

### 3.1.2 Mathematical Mistakes when Writing Out Problem-Solving Ideas Clearly

Students make misconceptions, principles, and operations when writing problem-solving ideas on the second problem. But in the first question, no students made mathematical mistakes. In the second problem, students created a misconception, namely not applying the concept of multiplication to matrix A. Students wrote the conclusion that $A^n$ produced a null matrix, but did not test the multiplication against $A^4$ matrix. Figure 5 shows students' mistakes, not doing the calculation concept of matrix A, so that they do not write ideas.

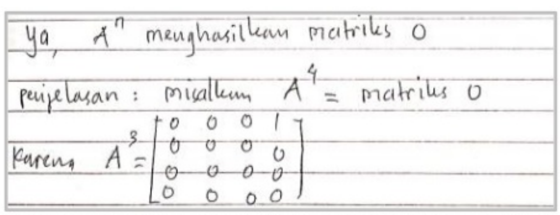


**Figure 5. Misconceptions when Writing Clear Problem-Solving Ideas**

Students made a principle mistake in the second problem by not doing the multiplication concept on the matrix $A^3$. Students only perform calculations on matrix $A^2$ so that they do not find the relationship between the $A^2$ and $A^3$ matrices in finding the An matrix. So it concludes without checking whether An yields a null matrix.

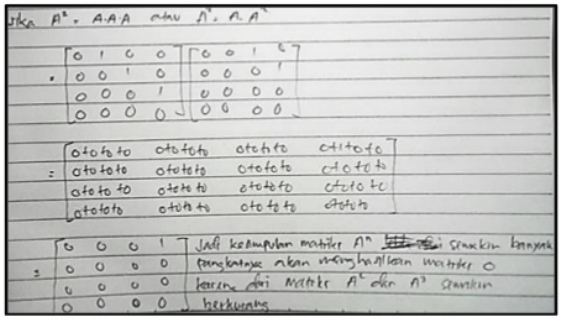

**Figure 6. Principle Mistakes when Writing Clear Problem-Solving Ideas**

### 3.1.3 Mathematical Errors when Expressing Problem Solving Results in His Language

Students make misconceptions and operational errors when clearly stating the results of solving problems. The mistake made by students when reporting the results of solving the problem was that the multiplication matrix did not recognize ranks so that An could not be a zero matrix. In Figure 7 showed that students wrote that An could not be a null matrix because matrix A is not a zero matrix.

Operasi matriks tidak mengenal perpangkatan. Perpangkatan yang dimaksud dalam operasi matriks adalah perkalian berulang suatu matriks dengan matriks itu sendiri. Syarat agar suatu matriks bisa dipangkatkan adalah matriks tersebut haruslah matriks persegi atau matriks bujur sangkar. Dengan demikian, perpangkatan suatu matriks persegi adalah perkalian matriks persegi dengan dirinya sendiri sebanyak jumlah pangkatnya. Jika matriks itu bukan merupakan matriks kosong maka $A^n$ tidak mungkin nantinya akan menjadi matriks 0. Ambil contoh angka 1 jika angka $1^n$ maka berapapun n tidak akan mengubah angka 1 menjadi 0.

**Figure 7. Misconceptions when Expressing Problem Solving Results in His Language**

Operation errors made by students when stating the results of solving the problem in the first problem are wrong to conclude that AC = BC. Students get the same results, but the calculations that have been done are not correct. In Figure 8, students state that the results of problem-solving do not match the calculations obtained.

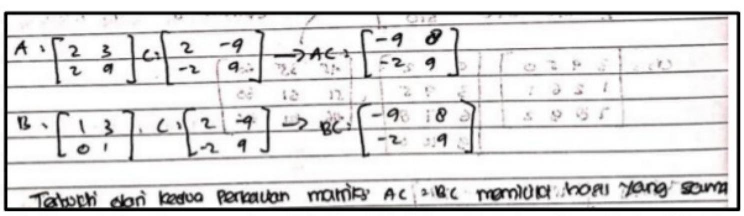

**Figure 8. Operating Errors when Stating Problem-Solving Results in His Language**

### 3.2. Discussion

Figures 1 and 2 show that the number of students who have excellent abilities is less than that of students who have fewer skills. In other words, students' mathematics communication is still low. This finding is in line with research by Firdaus & Aini (2019) and Kleden (2016), which states that mathematics communication owned by students is still in the low category. Firdaus & Aini (2019) noted that this could be caused by indicators of student mathematics communication that have not been achieved. Then Kleden (2016) states that this is caused by students having difficulty communicating their ideas and expressing mathematical expressions in problem-solving.

The second finding, based on Table 2, shows that students' ability to state the problem-solving results using their language is the first indicator that is difficult for students to fulfill. The answers written by students do not give reasons with their language style, so it does not state the conclusions of the given problem. Besides, some students still have difficulty writing ideas and knowing the mathematical situation clearly to make mistakes made by students. So that in this study, students made mistakes in concepts, principles, and operations. The types of errors made by students are in line with Zulfah's (2017) research that students make mistakes in the form of concept, process, and principle errors. This study's findings also indicate that mistakes will arise when students do not have excellent mathematics communication skills. It is in line with the statement of Zulfah (2017) which states that each ability influences the completion step of the problem, it is also by this study that mathematics communication skills affect the errors that might be made. Afifah et al. (2018), in their research, stated that the types of mistakes made by students were concept errors, operation errors, and principle errors. Besides that, Firdaus (2019) research shows that in solving the Matrix Problem, the type of error made is concept and operation error. Likewise, with this study that misconceptions and operations were also carried out by students. However, in this study, students also made mistakes in principle.

## 4. CONCLUSION

Students' mathematics communication errors in completing *HOTS* problem on matrix material are concept errors, principle errors, and operating errors. These errors can occur in every student mathematics communication indicator. In the first mathematics communication indicator that understands the mathematical situation clearly, mistakes made are concept errors and operating errors. The second indicator of mathematics communication is writing ideas clearly; the mistakes made are concept errors and principle mistakes. As for the third mathematics communication indicator that states the problem-solving results using their language, the mistakes made are concept errors and operating errors.

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