Analysis of students' Higher Order Thinking Skills (HOTS) ability in matrix subjects

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Abstract. Higher Order Thinking Skills (HOTS) has become the focus of learning mathematics at all levels, especially for prospective math student-teachers because their abilities are not limited to themselves only. However, when they become teachers in the future, they have a tough task of making students to have HOTS. The study aimed to analyze HOTS of students studying mathematics in Matrix subject. The research method used was qualitative descriptive that analyzed and described students' midterm exam answers based on indicators of HOTS to analyze (C4), evaluate (C5), and create (C6). The research subjects were Mathematics students of teacher training education at Lambung Mangkurat University that were taking Matrix subjects in 2018/2019 even semester involved in the Matrix lecture process. The result of the study was concluded that the thinking skills of students in the Matrix subjects in faculty of teacher training education, Lambung Mangkurat University, were in sufficient category. The results of the study should be a reference for the lecture process where students are familiarized with giving HOTS-oriented questions during exams and in lecture practice to help in developing them.

1. Introduction

In this era of industrial revolution 4.0, the use of digital technology in learning processes, task assessment, and evaluation, by increasing the competence of educators cannot be separated from the flow of information and technology developments. Facing these challenges, educators play an important role in building a generation that are competent, charactered, with new literacy skills and high-level thinking. Recently, the educational world is required to equip students with 21st century skills such as creative, critical, communicative, and collaborative skills [1,2]. Educators are required to explore the students' abilities for creativity and critical thinking in solving problems.

HOTS is interpreted on higher level than memorizing facts [3]. It encompasses critical and creative thinking skills, problem-solving abilities, and a wider use of the mind to challenge the information stored in memory and to draw conclusions to find a solution to difficult problem [4]. It increases students' understanding and mastery of learning materials. Therefore, children will think critically, creatively, to solve problems and making decisions in difficult situations [1,5,6].

According to revised Bloom's taxonomy cognitive processes was divided into lower and higher order thinking skills. The skills contained in LOTS are the ability to remember, understand, and apply, while in HOTS include the ability to analyze, evaluate, and create [7,8]. LOTS focuses more on the ability to implement formulas in problem solving, while HOTS is more directed at strategy and manipulation: [9]. There are 13 types of thinking activities in HOTS such as: (1) comparing, (2) classifying, (3) inducing, (4) deducing, (5) error analysis, (6) constructing support, (7) analyzing perspectives, (8) abstracting,

(9) decision making, (10) investigating, (11) problem solving, (12) experimental inquiry, and (13) inventing. However, they are grouped into three important things, namely, (1) critical thinking, (2) creative thinking, and (3) self-regulated learning skills that are called as the habits of the Minds [10]. Based on the revised Bloom's taxonomy, the levels of analyzing, evaluating, creating are categorized in creative thinking, namely Higher Order Thinking Skill [11–14].

Thinking ability affects learning, speed, and effectiveness. Therefore, in the learning process, it is better to consider students' thinking abilities. Thoughtful learners show positive impact on their educational development [10]. Kincaid and Duffus [15] stated that student only thought critically to high degree and carefully examined experiences, assessed the knowledge and ideas, and considered previous arguments. Therefore, HOTS becomes the focus of learning mathematics at all levels. Especially for students who are prospective teachers in mathematics, it is certainly not enough to only have this ability for themselves because in the future they will have a tough task when becoming teachers, that is to make their students have higher order thinking skills. Considering the importance of a prospective mathematics teacher student having the ability to think at high level, learners of Mathematics need to be given questions that measure their higher order thinking skills by providing illogical questions that contain contradictions. Hence, it makes students act more carefully in dealing with problems [16,17]. Although the HOTS is important, the research in this area that specially focus on pre-service math teacher are rarely found. Therefore, the research focuses on how to develop higher order thinking skills for prospective teacher students by providing HOTS-oriented questions. Giving HOTS-oriented questions improves higher-order thinking skills in learning mathematics [3] and one of questions is regarding the Matrix subject [18].

Matrix is one of the compulsory subjects for Mathematics students in the faculty of teacher training education, at University of Lambung Mangkurat. Based on the material characteristics in Matrix subject, an assessment of students' HOTS was carried out and it was used as a reference to determine the level of HOTS of the students [5]. Furthermore, the questions used during the Mid-Semester Examination (UTS) and Final Semester Examination (UAS) were specially designed to determine students' HOTS. Therefore, the aim of the study was to analyze the higher order thinking skills of math education students by providing midterm exam questions that were HOTS oriented.

Varied learning has major impact on the outcome, especially by encouraging students to take HOTS [19] and giving mathematical problems that is related to HOTS is believed to be an effort to overcome student dependence on the formulas used in solving math problems. By getting used to questions that are oriented towards higher order thinking processes, students are trained to develop their creativity and logical thinking by finding solutions to the given problems [20].

2. Method

This study used a qualitative descriptive method [3,11–13], that analyzed students' midterm exam answers. The research subjects were seventy-five students of Mathematics Education FKIP ULM that joined Matrix course in the 2018/2019 semester and took part during the Matrix lecture process. Below are the details of the research steps.

The first step was to provide HOTS-oriented Mid Semester Exam (midterm) questions. The aim of the step was to determine the extent to analyse (C4), evaluate (C5), and create (C6) students. There were three HOTS questions given to the midterm, including.

(1) Can the following matrix be multiplied according to the partition? Give reasons to support your answer. (C4)

$$PQ = \left[\begin{array}{ccc:c} -1 & 2 & 1 & 5 \\ 0 & -3 & 4 & 2 \\ \hdashline 1 & 5 & 6 & 1 \end{array}\right] \left[\begin{array}{c:cc} 2 & 1 & 4 \\ -3 & 5 & 2 \\ 7 & -1 & 5 \\ \hdashline 0 & 3 & -3 \end{array}\right]$$

(2) If M is the involutory matrix, I is the identity matrix, and the matrix $N = \frac{1}{2}(I - M)$ then prove that N is the idempotent matrix. (C5)

(3) Create a matrix with the order of 5x5 whose determinant is −6 and give examples of its complementary algebra. (C6)

The second step was for the students to work on these problems with their respective thinking skills and they were free to find solutions to the questions given based on their knowledge.

The third step was to analyze the students' answers on the Mid-Semester Exam in Matrix course. The analysis was carried out by examining the stages described by students in finding the solution to each question based on indicators of HOTS. The rubric criteria for scoring student HOTS are presented in Table 1 below [1].

Table 1. High order thinking skill scoring indicators

Score	Scoring Indicator
	Indicator 1: Analysing
4	Able to examine and parse information, be able to formulate problems, and provide precise troubleshooting steps.
3	Able to check and parse information appropriately, be able to formulate problems, and provide almost correct solution steps or there are slight errors in answering questions.
2	Able to check and parse information appropriately, be able to formulate problems, but there are still errors in solving steps and final answers.
1	Not being able to check and parse information appropriately, not being able to formulate problems, therefore the final solution and answer steps are not correct.
0	Not able to do analysis at all
	Indicator 2: Evaluating
4	Able to assess, deny, or support an idea and provide reasons that can strengthen the answers obtained correctly.
3	Able to provide reasons that can strengthen the answers obtained correctly, but do not provide a final decision / conclusion.
2	Not being able to provide reasons that can strengthen the answers obtained correctly, therefore they are not able to provide the final decision / conclusion correctly.
1	Not able to provide reasons that can strengthen the answer obtained correctly, but the answer is almost leading to the right solution.
0	Not being able to judge, deny, or support an idea and provide reasons that can strengthen the answers obtained at all.
	Indicator 3: Creating
4	Able to design a way to solve problems or combine information into the right strategy.
3	Able to design a way to solve problems or combine information into a strategy with almost accuracy or there are still a few errors in writing answers.
2	Able to design a way to solve problems but not yet able to integrate information into the right strategy.
1	Not yet able to devise a way to solve problems or combine information appropriately, but the design of the answers has almost headed in the right way.
0	Not being able to devise a way to solve a problem or integrate information into a strategy at all.

Furthermore, the acquisition of high order thinking skills score was calculated using the following formula.

$$\text{Final calculation} = \frac{\sum \text{Score Acquisition}}{\sum \text{Total Score}} \times 100 \quad (1)$$

Furthermore, the average value was determined by the following qualifications as presented in Table 2 below [1].

Table 2. Categories of students' high order thinking skills.

Student Score	Rating Category
81,00 – 100,00	Very good
61,00 – 80,99	Good
41,00 – 60,99	Enough
21,00 – 40,99	Less
0,00 – 20,99	Very less

3. Result and Discussion

The analysis of results for student's high-level thinking skills for each indicator are shown in table 3, and it was measured according to high-level thinking capability scoring guidelines [9].

Table 3. The average achievement value of each student's high-level thinking ability indicator

No.	Indicator	Achievement Average	Category
1.	Analyzing	71,96	Good
2.	Evaluating	37,67	Less
3.	Creating	50,34	Sufficient
	Average	53,32	Sufficient

Based on Table 3, the average high order thinking ability of students was in sufficient category. The condition shows that the students' abilities in the class were good enough.

After giving HOTS-oriented Mid Semester Exam questions to Matrix students in the even semester of 2018/2019, the research was performed based on HOTS indicators which included analysis, evaluation and creation in Bloom's taxonomy at the C4 level (analyze), C5 (evaluating) and C6 (creating). Based on the results of the overall data analysis of students who answered these questions, few students reached the C5 level (evaluating) whose average was 37.67 and categorized in the poor category. Meanwhile for level C6 (creating), the average students achieved better results than C5, it gained around 50.34 score and was in the sufficient category. Lastly, at the C4 level (analyzing) students achieved even better results with an average of 71.96 and were in the good category. The level of evaluation (C5) was seen in question number two (2). Most of the students reported wrong solution because it required high-level thinking skills, it was also due to the question which may not be sufficient to be read once or twice, conversely, to understand what the question means. Furthermore, this question demanded high reasoning and imaginative power to describe the clues contained in the problem. In this question, students were asked to prove the N matrix equation given was an idempotent matrix. They were expected to understand problem before determining the requested solution. Due to this problem, it could not be solved by giving example while it required logical reasoning and understanding as keys to finding solutions. However, some students still made mistakes in substituting the equations into questions as shown in Figure 1 below.

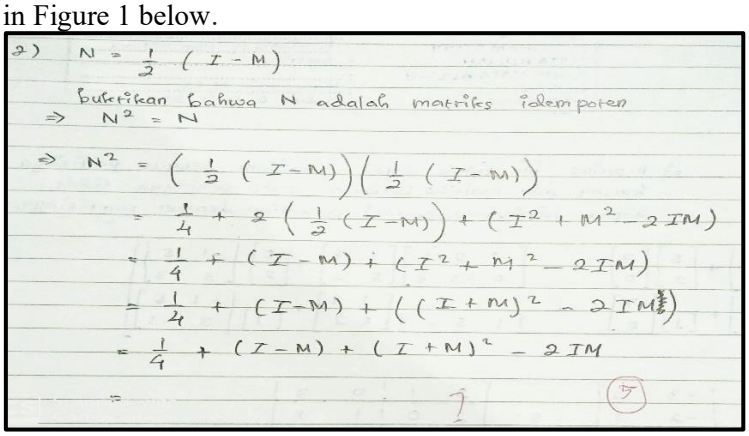

Figure 1. One of the Student Answers in Number 2

In Figure 1, it was seen that students made mistakes when substituting the known equation into the one to be proven. The error lied in the decomposition of the value of N^2, in using the distributive property when extracting from $N^2 = \left(\frac{1}{2}(I - M)\right)^2$. Furthermore, students understood the meaning and the questions given, yet they still had difficulty on imagining, so that the obtained solutions were still inaccurate. Some students proved by giving examples as shown in Figure 2 below.

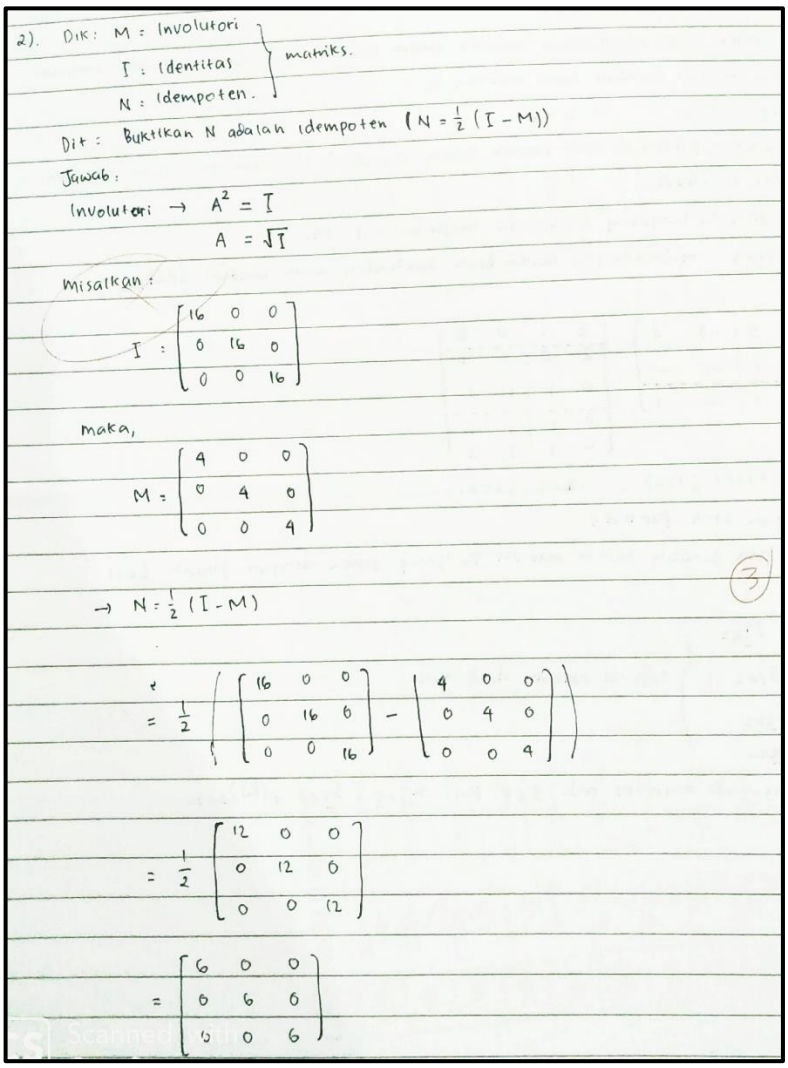

Figure 2. One of the Student Answers in Number 2

By giving the above example, one of the student answers was wrong due to the statement to be proven in question number 2, which was the opposite. Therefore, it was permissible to use counter example [21–23]. Based on the answer, it shows that there was no attempt to find another solution to solve the problem without an example. When it was grouped in the level of thinking ability according to Bloom's taxonomy [11–14], this student only reached the level of understanding and had a little application as well as evaluation because the student was unable to understand the meaning of the question, however he tried to apply knowledge by giving examples as the answer. Even though at the C5 level it was categorized to be less, conversely there were some students who understood the meaning of the question and solved it correctly after analyzing the instructions in the questions as in Figure 3 below.

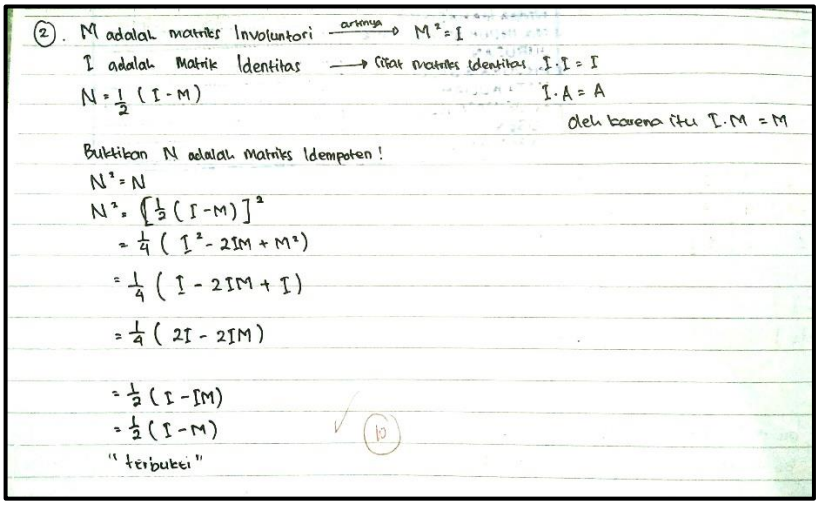

Figure 3. One of the Student Answers in Number 3

In Figure 3, students could evaluate the questions. The student correctly described the equation which was known as the basic concept to prove the Involutary and Identity matrix, then substituted the equation that was to be proven and parsed it correctly, therefore the answer given was correct.

Based on the analysis conducted, some students reached the creating stage (C6). This is shown based on the results of question number 3 which reached an average value of 50.34 in the sufficient category. The students were required to make a 5x5 matrix with the determinant of −6 and asked to make examples of algebraic complement from the matrix. Some students were able to create the requested matrix where the determinant value is −6 and made a correct complementary algebraic as shown in Figure 4 below.

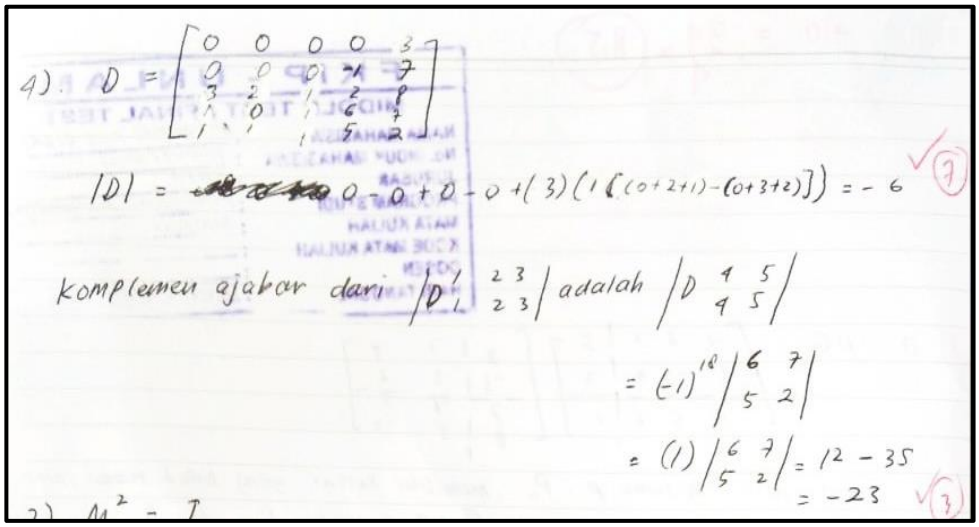

Figure 4. One of the Student Answers in Number 3

In Figure 4, it was seen that the student understood the determinant properties, therefore when being asked to make a matrix with a certain determinant, the student applied the determinant properties then analyzed and evaluated whether the matrix and algebraic complements made were correct according to the questions given. This means that the students were able to find solution to the problems. The thinking ability which was classified as the analysis and assessment phase was achieved, in which the students analyzed and re-examined the description that resulted in finding the correct solution [1,5,6]. However, it was also found that the students' answers were not correct in making the matrix and algebraic complement as shown in Figure 5 below.

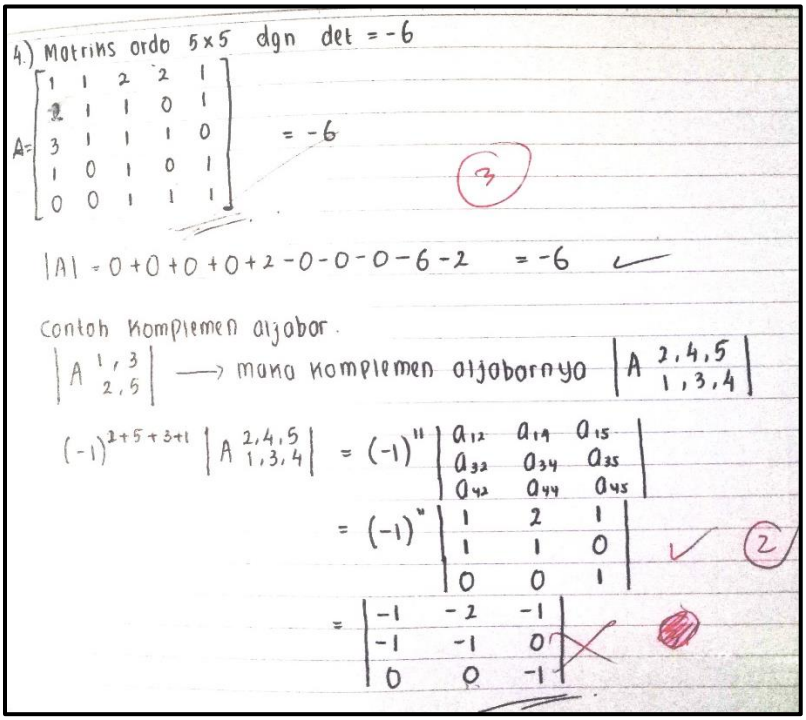

Figure 5. One of the Student Answers in Number 3

Based on Figure 5, the matrix determinant was known to be negative 6, but after being corrected it turned out to be not negative 6, it did not fulfil the required conditions. This means that the students calculated the determinant using the wrong way, the determinant value was wrong; therefore, the complementary algebra was also wrong. The students already understood the meaning of the problem, but when applying the determinant properties to create a matrix with a negative determinant of 6, it was still not correct. Therefore, it appeared that students were still having difficulty in applying and evaluating matters related to the problem. From the thinking skills analysis, this student was still at the analysis stage because he tried to apply his understanding and evaluate it even though the answer given was still not correct because of an error in interpretation.

For the level of analysis (C4), most students have reached this level. This can be seen from question number 1; the obtained average was 71.96 which was in good category. One of the contributing factors was that students in lectures were used to analyzing questions as shown in Figure 6 below.

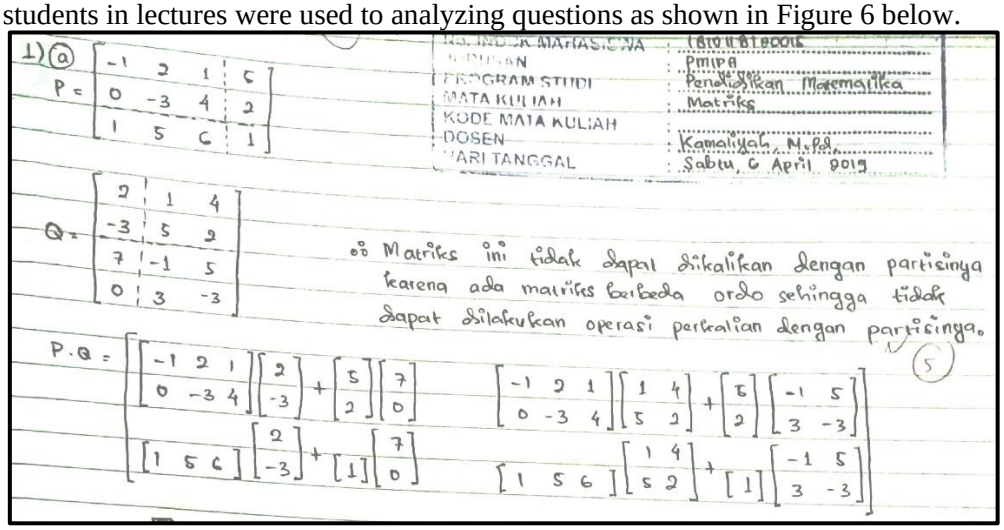

Figure 6. One of the Student Answers in Number 1

In Figure 6, it was seen that students were able to analyze whether the matrix given in the question could be partitioned or not because they had mastered the basic concept of matrix partitioning. However, there were many of the students' answers indicated misconceptions in answering question number 1 as in Figure 7 below.

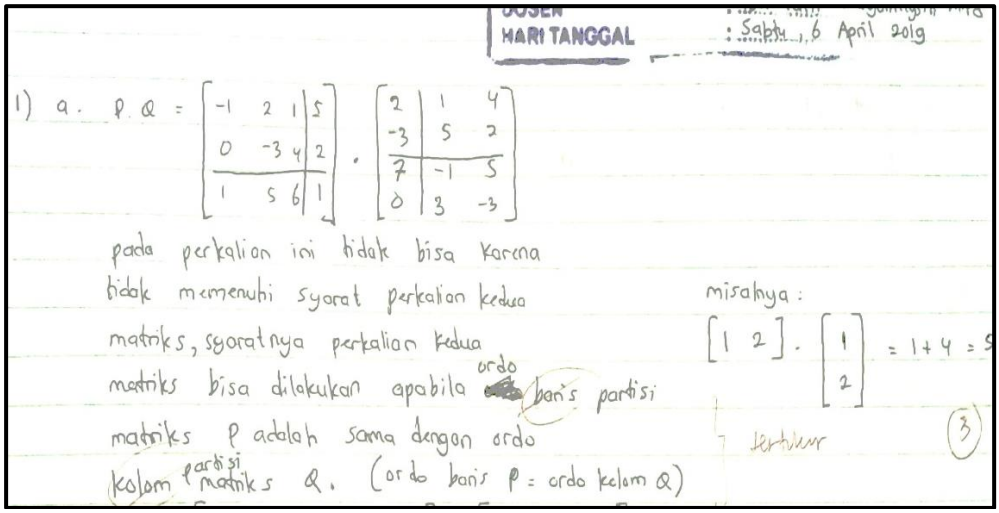

Figure 7. One of the Student Answers in Number 1

Based on Figure 7, it was seen that the students' answers were still containing misconceptions between the rows and columns of the matrix and the basic concept was missing [18]. This means that the students have reached the analysis stage but still inaccurate, therefore the solutions produced were incorrect because there were errors in understanding the basic concepts of the questions given.

4. Conclusion

Based on the research, it was concluded that the Higher Order Thinking Skill (HOTS) of students in the Matrix course of the mathematics education study program, Lambung Mangkurat University, was in sufficient category. The results are expected to be used as reference in lecture process where students are familiarized with HOTS-oriented questions in order to improve their thinking ability, which is limited to knowing the students thinking ability in the HOTS stage. In the future, it is possible to develop on how to apply learning with the support of instruments that refer to HOTS.

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