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Higher Order Thinking Skills of Students in Solving Linear Programming Problem Based on Bloom's Taxonomy

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Abstract. Higher order thinking skills (HOTS) was one of the important competencies in 21st century learning, so it must have for every student. To respond this statement, the researcher conducted a study aimed to describe how students used higher-order thinking skills based on Bloom's taxonomy in solving mathematical problems. This study was a qualitative-descriptive research. The study was followed by 17 students of class XI MIPA 3. The problem was given in the form of a HOTS's type linear programming problem. The results of this study showed that the majority of students were still unable to use higher-order thinking skills by well. It was seen that most students were only able to reach the level of analyzing (making mathematical models based on the problem). For the next level of evaluating (determining the minimize cases) was only achieved by one student. There was only one student who can reach the HOTS level up to the creating level (finding solutions through graph and mathematical procedures and conclusion). The lack of students 'skill to solve HOTS's type linear programming problem needs to be followed up by students practice through giving problems with HOTS-oriented in order to improve students' thinking skill in solving mathematical problems.
Keywords. *Higher Order Thinking Skill, Bloom's Taxonomy, Linear Programming Problem, and HOTS Problem*

Abstrak. Keterampilan berpikir tingkat tinggi merupakan salah satu kompetensi penting dalam pembelajaran abad ke-21, sehingga wajib dimiliki oleh setiap siswa. Untuk menanggapi pernyataan tersebut maka peneliti melakukan penelitian yang bertujuan untuk melihat bagaimana siswa menggunakan keterampilan berpikir tingkat tinggi (HOTS) yang berdasarkan pada taksonomi Bloom dalam menyelesaikan masalah matematika. Jenis penelitian yang dilakukan adalah penelitian kualitatif-deskriptif. Penelitian diikuti oleh 17 siswa kelas XI MIPA 3. Masalah yang diberikan berupa satu item masalah program linier tipe HOTS. Hasil penelitian menunjukkan bahwa sebagian besar siswa masih belum dapat menggunakan kemampuan berpikir tingkat tinggi dengan baik. Hal ini terlihat sebagian besar siswa hanya mampu mencapai pada tingkatan analyzing, yaitu membuat model matematika yang sesuai dengan masalah. Untuk tahapan selanjutnya yaitu evaluating (menentukan kasus minimum) hanya dicapai oleh satu siswa. Hanya ada satu siswa yang dapat mencapai tingkatan HOTS sampai dengan level creating (menemukan solusi masalah melalui grafik dan prosedur matematika serta dapat memberikan kesimpulan dari pertanyaan masalah). Kurangnya kemampuan siswa dalam menyelesaikan masalah program linier tipe HOTS ini perlu ditindaklanjuti dengan melatih siswa melalui pemberian soal-soal yang berorientasi *HOTS* agar dapat meningkatkan kemampuan berpikir siswa dalam menyelesaikan permasalahan matematika.
Kata kunci. *Keterampilan Berfikir Tingkat Tinggi, Taksonomi Bloom, Masalah Program Linier, dan Masalah HOTS*

1. INTRODUCTION

The development of an increasingly advanced era requires better education. Therefore, the quality of learning and the quality of graduates need to be improved. To deal with this, 2013 curriculum is expected be able to train students to have four important competencies. That competence is known as 4C, which are critical thinking and problem solving, creativity, collaboration, and communication (Widana et al., 2019:1). Furthermore Ariyana, et al, (2018:2) added that in order to form the four competencies, an assessment instrument in the form of international standard is needed, namely Higher Order Thinking Skills (HOTS). Higher Order Thinking Skills (HOTS) is a person's ability to get knowledge through complex thinking processes (Rosyida, et al, 2018). In other words, HOTS is known as the highest level of person's cognitive level (Abdullah, et al, 2019; Anderson & Krathwohl, 2001; Brookhart, 2010). These thinking skills do not just remember facts or concepts but have more ability than that namely analyzing, linking facts and concepts, manipulating information, utilizing new information with existing knowledge to get solutions (Yuliati & Lestari, 2018; Ngah, et al., 2017). Thus, HOTS can train students to improve their thinking ability in solving a problem. In addition, higher-order thinking skills are needed for every student to face challenges in the modern era (Widana et al., 2019:4).

Remember of the importance of higher-order thinking skills that must be satisfied by each student, the teacher need to train students through giving HOTS questions or problems. However, based on preliminary studies conducted by researchers at one private school in Malang district, students are still not accustomed to working on HOTS questions or problems. The teacher gives a statement that most students still have difficulty if solving math problems that are different from the examples's given. However, based on the average results of students' mathematical scores can be said "good" because they have achieved the KKM's value. This is the background of researchers to further study how students' thinking skills are given HOTS mathematics problem. It's important to be realize so that educators and researchers know whether students have higher order thinking skills and how students can solve HOTS problems.

There are indicators to measure students' higher-order thinking skills. According to Krathwohl (2002) in A revision of Bloom's Taxonomy, states that there are three indicators can be used to measure higher-order thinking skills, including analyzing (C4), evaluating (C5), and creating (C6). Analyzing is the ability to separate concepts into several components and connect with each other to gain an understanding of the concept as a whole. While evaluating is the ability to determine the degree of something based on certain norms, criteria or benchmarks. Then, creating is the ability to combine elements into something new, complete and broad, or make something original. In this study, researchers use indicators of higher order thinking skills based on Bloom's taxonomy. The indicators used by the researcher are adjusted to the study's require. The following table 1 indicator of higher order thinking skills.

Table 1. Indicator of higher order thinking skills

Classification HOTS	Indicators	Description
4. Analyzing	4.1 Differentiating	• Identify and determine the appropriate facts of the problem • Determine "analogy" in accordance with the problem
	4.2 Organizing	• Determine mathematical models in the form of the system of inequalities • Determine objective function from the problem
5. Evaluating	Evaluating/Checking	• Determine what is asked of the problem/question of problem • Determine the minimum case that correspond of the problem
6. Creating	6.1 Producing	• Produce/draw graph that representing the mathematical models • Graph the feasible set
	6.2 Formulating	• Find problem solution that is to minimize objective function
	6.3 Giving a Conclusion	• Make decision based on facts and valid calculation

There are several research that have discussed the ability of students to solve HOTS-oriented mathematical problems including Wiwin, et al., (2019); Yuliati & Lestari, (2018); Rosyida et al., (2018); Bakry & Bakar (2015); Dewanto, et al., (2018); and Tong & Loc (2017). Most of the research was conducted to measure students 'high-level thinking skills in solving mathematical problems based on students' mathematical abilities, namely high category, medium category, and low category. Theoretically it has been proven that students who have high mathematical abilities will be able to reach higher levels of thinking and otherwise. However, this research did not look at students' mathematical abilities, meaning that researchers would measure the higher-order thinking skills of students who have heterogeneous abilities. This will show how higher order thinking skills of students with heterogeneous abilities in solving HOTS problems.

In addition, previous studies gave several (more than one) mathematical problems. Therefore researcher tried to focus on one problem so that students remain enthusiastic and focused on the given problem. In accordance with the teacher's opinion that if students are given too many problems will cause saturate and students are not optimal in solving the problem. In addition, the results of the study will also be more focused and detailed in analyzing each student's high-level thinking ability.

From previous studies, there are also not many or even none that have examined the students' higher order thinking skills in solving HOTS problems in linear programming subject. While the linear programming subject

is one of the subjects whose its applications often related in daily life. This is consistent with the writing of Parameswari, et al., (2018) that the application of linear programming subject is often used in real life. In addition, this subject is also not too difficult for students. Therefore, researchers want to find out how students use their higher order thinking skills when solving HOTS-oriented linear programming problems.

Based on the description above, the researchers formulate the problem "How Higher Order Thinking Skills students' to solving linear programming problem based on Bloom's Taxonomy?" From this formula, this study aims to analyze higher order thinking skills students' in solving linear programming problem based on Bloom's Taxonomy. This analysis is determining how far the achievement of students' skills to use their higher order thinking skills based on Bloom's Taxonomy namely analyzing, evaluating, and creating. From this study is expected to be able to provide knowledge and information to educators or readers in order to provide appropriate learning models for both students who have higher order thinking skills or not.

2. METHOD

This study is qualitative-descriptive research. The instrument in this study are HOTS linear programming problem and interviews. The researcher gave one linear programming problem to 17 students of Class XI MIPA 3. From the results of student sheet in solving problems, researchers analyze and determine the research subject. The researcher choose three research subjects based on several criteria, including: (1) students have studied linear programming, (2) student sheet can represent the work of other students who are at the same level of thinking, and (3) recommendation from the teacher. The three chosen research subjects are as follows: (1) students who can only reach the analyzing level which are then referred to as the first subject (S1), (2) students who can reach the evaluating level which are then called the second subject (S2), (3) students who can reach the highest level namely creating level which is then called the third subject (S3). The researcher identify and analyzes students' skills through the guide to higher order thinking skills indicators based on Bloom's Taxonomy in table 1 which was given previously.

The problem given is shown in Figure 1 below.

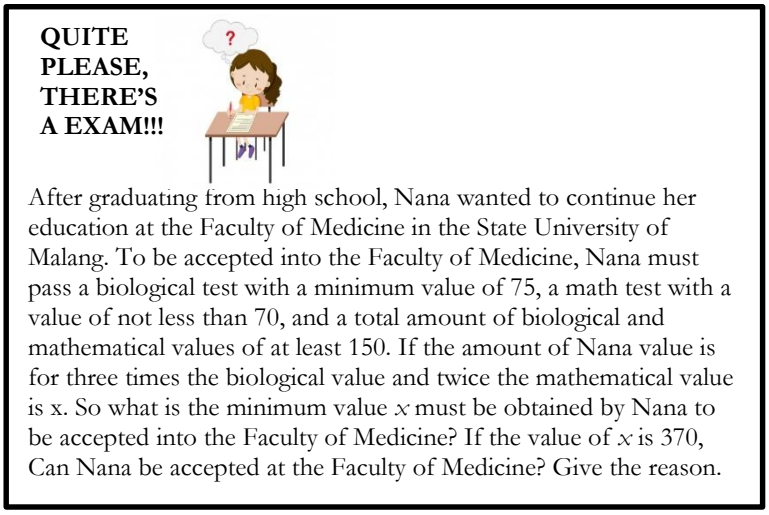

Figure 1. Linear programming problem

3. RESULTS & DISCUSSION

The results of the study are presented by researchers in the form of describing students' higher order thingking skills (HOTS) in solving linear programming problems in Bloom's Taxonomy. The following results are descriptions of each research subject.

3.1. First Subject (S1)

In the initial stages of work, S1 does not write an analogy that presents the facts of the problem given. Writing "analogy" is included in the differentiating indicator. But when asked, students can explain the purpose of the variables x and y are made. This is because S1 can understand what facts are in the problem so that S1 can

make "analogy" correctly. In other words, S1 understand the problem with identifying the facts in the problem and can make "analogy" that are appropriate to the problem. This is consistent with the results of research from Nursyahidah, et al, (2018) which states that students who understand the problem can make an "analogy" with symbolized by the variables *x* and *y*. The results of S1 work can be seen in Figure 2 below.

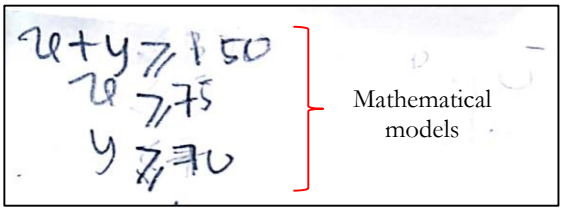

Figure 2. Mathematical models of S1

From Figure 2, S1 directly writes mathematical models, namely: (1) $x + y \geq 150$, (2) $x \geq 75$, and (3) $y \geq 70$. S1 states that x is a biology test value and y is a math test value. The mathematical models written by S1 is in accordance with the given problem. It can be seen that besides being able to make an analogy, S1 can also write/transform information on a problem in the form of the mathematical models. In accordance with Nursyahidah, et al, (2018) that students who can understand the problem well then these students can make an analogy to changes the problem into the form of the mathematical models (in variables *x* and *y*).

After writing down the mathematical models, S1 should determine the objective function. However, S1 writes the objective function in the calculation table. This calculation table should be at the creating (formulating) level. This can be seen in Figure 3 below.

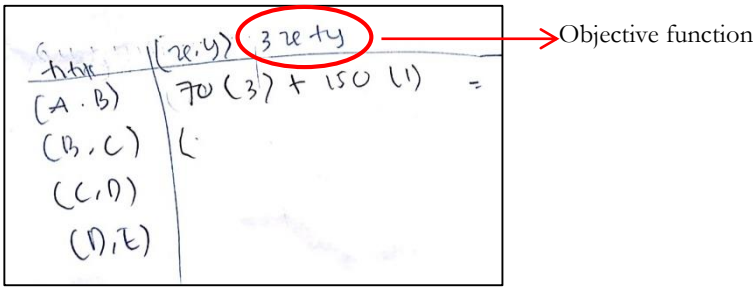

Figure 3. Calculation table of S1

In Figure 3 above, S1 writes the objective function "$3x + y$". If it is adjusted to the problem of "the amount of Nana values for three times the biological value and twice the math value" then the correct objective function is $3x + 2y$. Error in determining the objective function is the concern of researchers. Therefore, researchers conducted interviews with S1. S1 states that she made a mistake in writing and did not carefully read the questions. When confirmed, S1 can determine the objective function which is $3x + 2y$. Researchers conclude that overall S1 able to group information and present it in the form of mathematical symbols. The ability of S1 in determining mathematical models and the objective function indicates that S1 has fulfilled organizing indicators. As written by Anderson & Krathwohl (2001:81) that at this stage of organizing, students can identify and classify important information that exists on a problem to be used in solving these problems.

The next stage S1 makes a graph the feasible set . But at this stage, S1 should be able to determine what is asked for in the problem and determine whether the problem is a maximum or minimum case. On the worksheets, S1 don't write what is asked the problem. When asked, S1 stated that the question of problem is determine value of *x*. But S1 still has difficult to find solution of the problem. S1 still doesn't understand how to solve the problem. S1 only remembers that the process of finding a solution to the problem is to draw a graph and then substitute points into the objective function. Based on the explanation of the S1, it can be concluded that S1 has not yet reached the evaluating level. In other words, S1 don't have higher order thinking skills because S1 only remembers the procedure of working on a problem without knowing how to solve it based on facts. In line with the opinion of Tanujaya, et al, (2017) that in solving HOTS problems not only remember or understand but can also apply information that has been obtained to obtain a solution.

Furthermore Shukla & Dungsungnoen (2016) added that these higher order thinking skills make students able to use their thinking effectively in dealing with problems.

From the explanation above, S1 is only at analyzing level and has not yet reached the evaluating level. In other words, S1 also has not been able to reach the next level, namely creating level. But in the worksheet there is still a graphic feasible set from the mathematical model made previously. The graphic images that have been painted by S1 can be seen in Figure 4 below.

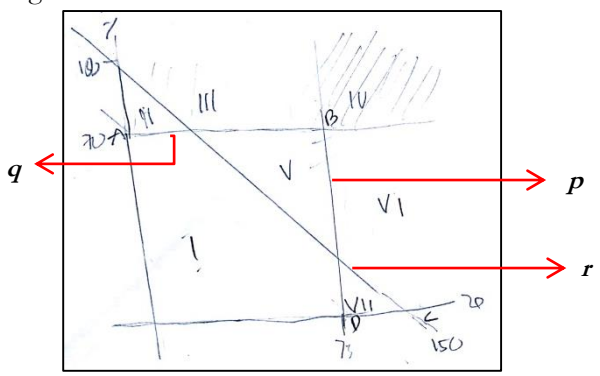

Figure 4. Graph feasible set of S1

From Figure 4, S1 draws the lines $x = 75$, $y = 70$, and $x + y = 150$ each indicated by lines *p*, lines *q*, and lines *r*. S1 made a mistake in determining the point (0.70) where the coordinates (75.0) and (0.70) have the same distance in cartesius coordinates. Its make the wrong graph. Therefore, S1 determines the area of completion of the problem is area IV (the wrong area). If it is adjusted to Figure 4, area IV has an intersection point at B, but when asked S1 cannot determine the coordinates of the point B. In the previous Figure 3 in the calculation table, S1 is also wrong in determining the coordinates of the points (A, B) that is (70,150). From Figure 4, point A should be located at coordinates (0.70) and point B at (75.70). From the results of this work it can be seen that S1 is still having difficulty in drawing the graph feasible set correctly. It's because S1 make error in determining coordinate points. The results of this study are in line with research conducted by Ali, et al, (2018) that students' mistakes in determining coordinate points cause students' difficult in determining the shading area (completion area) on the graph.

Beside that, to answer the last question "Is Nana acceptable to the Faculty of Medicine with a score of 370?", S1 only uses her logic. The answer can be seen in Figure 5 below.

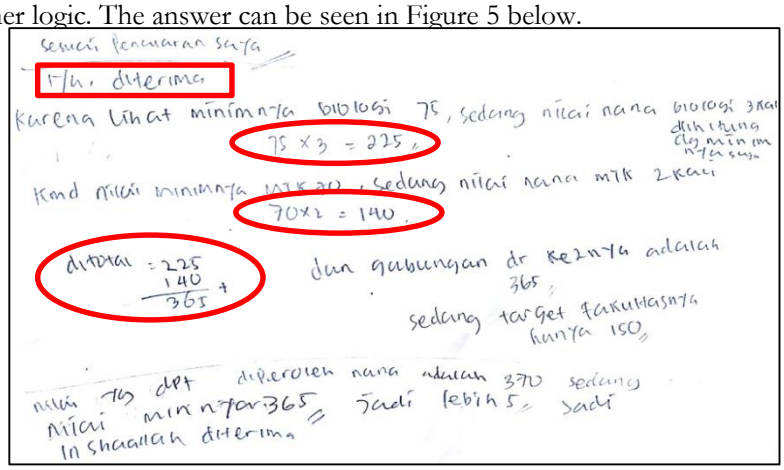

Figure 5. The decision making of S1

Based on Figure 5, S1 determines the minimum score by multiplying the minimum value of a biological test and a mathematical test with an objective function. This can be seen in the red circle that is $75 \times 3 = 225$ and $70 \times 2 = 140$, then $225 + 140 = 365$. S1 considers that the minimum score should be 365 so that S1 concludes if Nana gets a score of 370, then Nana was accepted in the Faculty of Medicine (red box). The S1's answer is of course wrong, to answer the last question on the question S1 should use the concepts and facts

contained in the problem. In addition, to make a decision S1 should not only use her logic but there are logical activities based on the correct statement. This is corroborated by Lithner (2012) that in making an appropriate decision or conclusion a process of reasoning thinking is needed based on a statement that is true or considered true.

3.2. Second Subject (S2)

S2 writes the things that are known to the problem in accordance with the facts. Even though no analogy variable is written, S2 can explain to the researcher that B states the value of a biological test and M states the value of a mathematical test. Following are the results of S2 work in the initial stages.

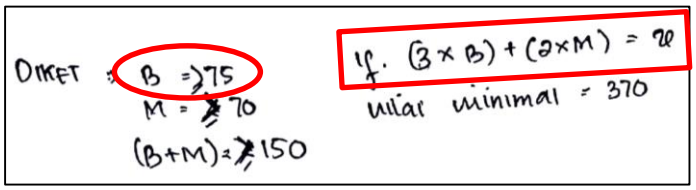

Figure 6. Mathematic models of S2

In Figure 6, S2 write the mathematical models, including: (1) $B \geq 75$, (2) $M \geq 70$, and (3) $B + M \geq 150$. However, if seen from the way of writing the inequality sign there is still an error, ie S2 always starts writing with the sign "=" (red circle). S2 states that the meaning of the "=" sign is the word "is". However, the researcher gave instruction to S2 that the right writing for the sign of inequality is not to include the equal sign "=". In addition to writing the mathematical models, S2 also determines the objective function of the problem, namely $(3 \times B) + (2 \times M) = x$ (red box). Overall S2 can understand the purpose of the problem by well. It proof by the ability of S2 in identifying and connecting information that will be used as the mathematical models (constraint function) and objective function correctly. Therefore, S2 has reached analyzing level. This is in line with the opinion of Brookhart (2010) that at this analyzing level, a person is able to analyze and set important information that has a relationship with each other. Where this information will be used to find solutions the problems.

After writing down the appropriate facts, S2 determines what is asked about the problem. This can be seen from the following S2 work.

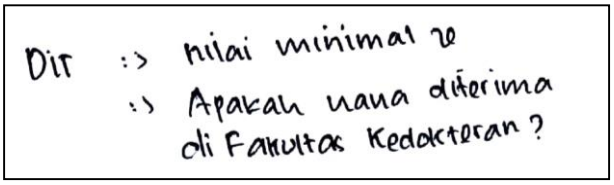

Figure 7. Evaluating level of S2

From Figure 7, S2 can determine the minimum case of a linear programming problem. S2 also states that x is the minimum value of the objective function. So the first step that must be done is to determine the value of x through the graph feasible set. In addition, S2 can also clearly know what is asked about the problem. In Figure 7, S2 writes the thing that is asked besides the minimum value of x is "Is Nana accepted at the Faculty of Medicine?". By knowing what is asked about the problem, S2 is able to determine the strategy or steps taken to solve the problem. Therefore, the ability of S2 to determine the questions of problem and the steps taken to solving the problem indicates that S2 has reached the evaluating level. This is reinforced by the results of research Wiwin et al., (2019) that in the evaluating level, students begin to use their ability to determine, assess, and design steps or strategies that will be used in solve problems.

The next stage S2 begins to draw a graph feasible set. The graph can be seen in Figure 8 below.

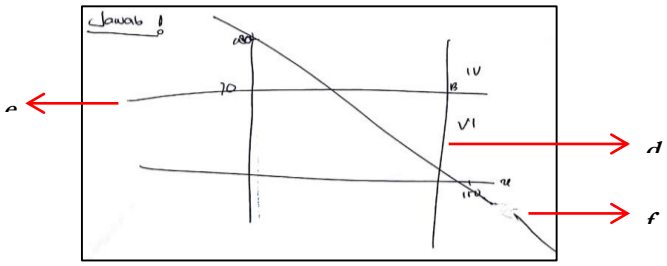

Figure 8. Graph linear Programming of S2

In Figure 8 above, S2 only draws graphs of each of the known lines, namely line d ($B = 75$), line e ($M = 70$), and line f ($B + M = 150$). Similar to S1, S2 is also wrong in determining the points in the Cartesius coordinates. This causes the graph to be made wrong. S2 also has not yet determined the shaded area (completion area). Therefore, S2 cannot answer the problem given until it is finished. One of the reasons why S2 cannot determine the area of completion is that S2 can't to transform mathematical ideas/models that have been previously obtained into graphical representation. In accordance with the results of research by Adityawan, et al, (2016) that students who cannot explain the ideas obtained in the form of geometry/graphs cause incomplete processing and the answers obtained are wrong. The inability of the S2 to draw the graph and determine the area of shading indicates that the S2 has not yet reached the level of creating.

3.3. Third Subject (S3)

In the first stage, S3 writes the analogy with variable x and variable y. x represents the biological value and y represents the mathematical value. This analogy facilitates S3 in determining the appropriate mathematical models. This is consistent with the opinion of (Suh & Seshaiyer, 2017) that by determining the analogy will help students in recognizing problems well. Further explained with this analogy, mathematical models will be made. Therefore, the next step is to write the mathematical models from the analogy created. Following are the results of the initial work of S3.

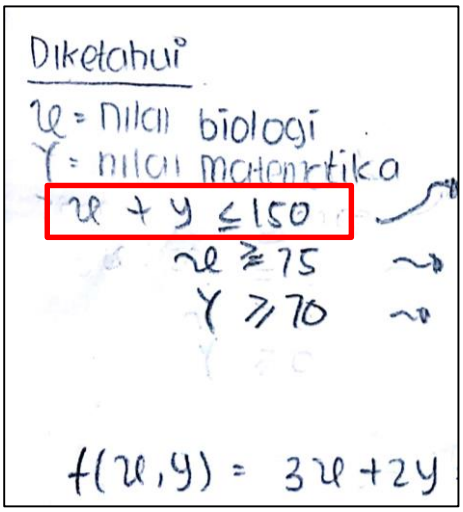

Figure 9. Mathematical models of S3

Based on Figure 9, S3 writes the mathematical models as follows: $x + y \leq 150$, $x \geq 75$, and $y \geq 70$. There is an error in writing the mathematical model that is "$x + y \leq 150$" (red box), it should be "$x + y \geq 150$". To find out more, researchers conducted interviews with S3. S3 explains that she was wrong in writing inequality notation. S3 confirms the correct answer is "$x + y \geq 150$". In addition to the mathematical models, S3 can also determine the objective function correctly ie "$f(x, y) = 3x + 2y$". Because S3 can correctly identify each fact of

the problem, write down the mathematical models and the objective function correctly, S3 reach the analyzing level. This was also made clear by Anderson & Krathwohl (2001:79) through his writings that at the stage of analyzing, students can simplify information to be easier to understand. Simplifying information here means to identify and group the facts of the problem into a mathematical models and objective function that makes it easy for students to solve problems.

The next step to reach the evaluating level, S3 must be able to determine the minimum case of linear programming problem. The results of the S3 work can be seen in Figure 10.

Figure 10. Evaluating level of S3

In Figure 10 above, S3 write what is asked in the problem is the minimum value of x. S3 states that the value of x is not a biological test value but the value of x referred to is the value of the objective function "f (x, y) = $3x + 2y$". S3 added that the minimum score is the smallest value requirement so that Nana can be accepted at the Faculty of Medicine. So to answer the next question, it is necessary to find the value of x using the graph feasible set and the mathematical calculation. The ability of S3 to determine the minimum case of the problem and set solution strategy clearly indicates that S3 has reached the evaluating level. In line with the writings of Brookhart (2010) in her book that evaluating levels indicate a person's ability to determine the strategy or steps to be taken in order to find the right solution.

After determining the minimum case, S3 draw the graph feasible set in accordance with the mathematical models created. The graph feasible set can be seen in Figure 11 below.

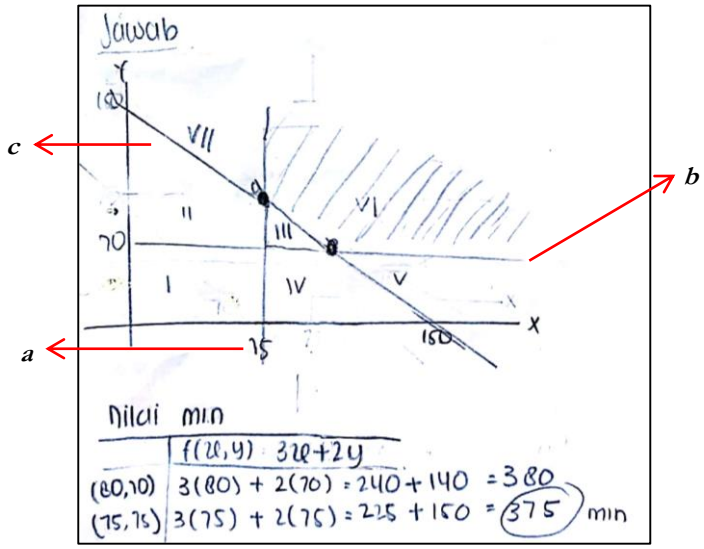

Figure 11. Graph feasible set of S3

In Figure 11 above, S3 draws lines $x = 75$, $y = 70$, and $x + y = 150$ each indicated by lines a, lines b, and lines c. The accuracy of S3 in determining the coordinates of the points causes the graph created is also correct. Then the area of completion that meets the inequality system of $x + y \geq 150$, $x \geq 75$, and $y \geq 70$ is area VI. Area VI is the sliced area of the inequality system. From Figure 11 it can be seen that S3 can communicate mathematical ideas to graph representation so that the results obtained are also correct. The ability of S3 in changing mathematical ideas into other forms (geometrical representation) shows that S3's understanding of linear programming subject is good. Suh & Seshaiyer (2017:8) reinforce these findings through their writings which is said that someone who can translate their ideas into geometrical representations (graphs) then that person has strategic competence and good conceptual understanding.

Based on Figure 11, area VI has corner points, where these corner points will be substituted to the objective function. S3 determines two corner points, point (80.70) and point (75.75). S3 states that the point (80.70) is obtained from the intersection point between the line $x + y = 150$ and the line $y = 70$. While the point (75.75) is obtained from the intersection of the line $x = 75$ and the line $x + y = 150$. S3 can determine the coordinates of the points by well so that the results obtained are correct. Furthermore, the point (80.70) and point (75.75) are substituted to "$f(x, y) = 3x + 2y$" as in Figure 11. S3 determines that the minimum value of x is 375. In other words , the value requirement so that Nana can continue her studies to medical school must obtain a score of 375. The results obtained by S3 are correct. This is because S3's understanding of the problem is good and S3's ability to solve problems through mathematical procedures is good too.

To answer the next question, S3 uses the results of previous calculations, namely the minimum value obtained by Nana to be accepted at the Faculty of Medicine is 375. The results of S3's work can be seen in Figure 12.

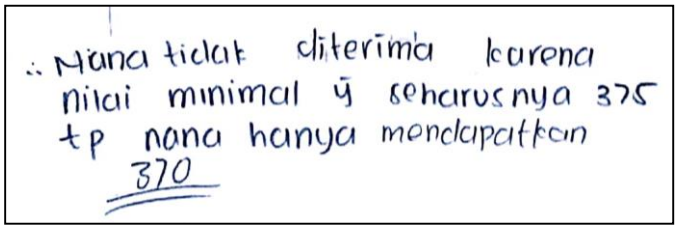

Figure 12. Decision making of S3

In Figure 12, S3 gives the argument that Nana was not accepted at the Faculty of Medicine. This is because the minimum value obtained by Nana is 370 while the minimum value requirement is 375. It is seen that S3 can give the reason properly through decision making based on valid calculations. In the decision making process, a good reasoning ability is needed so that the results obtained are correct. This is in accordance with the opinion of Madu (2017) which states that the ability to reasoning plays an important role in the process of thinking and making decisions/conclusions.

From the results of S3's work it appears that S3 can solve problems well and make decisions based on valid data. Therefore, it can be concluded that S3 has reached the highest level of Bloom's taxonomy namely creating. In other words, S3 has satisfy the indicators of higher order thinking skills. In line with the research of Bakry & Bakar (2015) which states that students who have higher order thinking skills are students who can distinguish ideas or ideas clearly, argue well, be able to solve problems and be able to construct explanations.

4. CONCLUSION

Higher order thinking skills (HOTS) can be measured based on Bloom's taxonomy which consists of three level namely (1) analyzing, (2) evaluating, and (3) creating. Based on the results and discussion it can be concluded that most students still do not have the higher order thinking skills. Students who only reach the level of analyzing are students who are only able to represent their idea to algebra form namely mathematical models. Students who can reach the level of evaluating are students who can determining the minimum case and solution strategy to solve the problem. While students who have reached the level of creating are students who have been able to find solutions to problems through the graph feasible set and use mathematical procedures and can provide conclusions/opinions based on valid arguments.

Remember of the importance of these higher order thinking skills, students need to be given HOTS problem and learning activities that can improve students' thinking skills. Thus students will get used and skilled in using their thinking skills well. In addition, conceptual understanding of the subject needs to be considered by educators so that students can solve the problem by well.

This research still has deficiency namely there's not alternative ways for students who still have not reached the level of creating (HOTS). It is hoped that further research can provide alternative assistance so students can use their higher-order thinking skills (HOTS) in solving mathematical problems.

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