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Analysis of Critical Thinking Ability in Solving Linear Programming Problems in terms of Students' Self-Concepts

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Abstract

The complex internal process of learning is very closely related to thinking because complex activities and closely related to one another is a way of thinking to solve problems and produce something. This article aims to analyze critical thinking skills in solving linear program questions in terms of students' self-concept. This type of research is qualitative research with a case study method. The research subjects were five students of IPA vocational high school. The instruments used were tests, interviews, and questionnaires. The results showed that students with high self-concept, the ability to think critically in solving linear program questions were still low, the low ability to think critically of students in solving questions was still a lot of errors including: (1) Writing incorrect, incorrect and unsystematic concepts, (2) The picture is incomplete, (3) on the student's answer sheet, (4) write down the reasons for the arguments that are still unclear, while the results of the interview show the students can verbally convey answers in solving linear program problems.

Abstrak

Proses internal yang kompleks dalam belajar sangat erat dengan adanya berpikir, karena kegiatan yang kompleks dan berhubungan erat satu dengan yang lain merupakan cara berpikir untuk memecahkan masalah dan menghasilkan sesuatu. Artikel ini bertujuan untuk menganalisis kemampuan berpikir kritis dalam menyelesaikan soal program linear ditinjau dari konsep diri peserta didik. Jenis penelitian ini adalah penelitian kualitatif dengan metode studi kasus. Subjek penelitian adalah lima peserta didik SMA jurusan IPA. Instrument yang digunakan adalah tes, wawancara dan angket. Hasil penelitian menunjukkan bahwa peserta didik dengan konsep diri positif kemampuan berpikir kritis dalam menyelesaikan soal program linear masih rendah, rendahnya kemampuan berpikir kritis peserta didik dalam menyelesaikan soal masih banyak kesalahan diantaranya: (1) Penulisan konsep yang tidak tepat, tidak benar dan tidak sistematis, (2) Gambar yang kurang lengkap, (3) pada lembar jawaban peserta didik, (4) menuliskan alasan argumentasi yang masih kurang jelas, sedangkan hasil wawancara menunjukkan peserta didik mampu menyampaikan secara lisan jawaban dalam menyelesaikan masalah program linear.

Kata Kunci: *Critical Thinking Ability, Self-Concept, Program Linear*

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INTRODUCTION

Education is a need that must be met in the life of society, nation, and homeland. In line with the quote from Maskur et al., (2020), education is one of the national development sectors to educate the nation's life to produce quality human beings. Through education, whether formal or non-formal, students will experience a process of change in themselves both in knowledge and in behavior, this process of self-change is called learning (Rista & Ariyanto, 2018). Learning is not only limited to reading, listening, writing, doing assignments and tests but also changes in behavior from the results of the learning process activities, where there is active interaction with the environment and these changes are permanent (Setiawati, 2018).

Ennis (1989) defines critical thinking as a thoughtful and reasonable process whose main goal is to make reasonable decisions about what to believe or what to do. (Bassham, et al., 2011) consider critical thinking as a variety of cognitive skills and intellectual dispositions to analyze arguments and overcome individual prejudices (Uribe-Enciso et al., 2017). According to Vincent Ruggiero's book entitled *The Art of Thinking: A Guide to Critical and Creative Thinking* in Murawski, (2014), that critical thinking means reviewing the ideas generated, making tentative decisions about what actions are best to solve problems, or what beliefs about the most plausible problem, and then evaluate and refine that solution or belief. So critical thinking is more about thinking that occurs to solve problems, analyze problems, or make decisions.

Ennis in Yunita et al., (2018) stated that critical thinking indicators in detail are as follows: (1) focusing on questions, (2) analyzing and explaining questions, answers, and arguments, (3) considering reliable sources, (4) reducing and analyzing deductions, (5) inducing and analyzing induction, (6) formulating explanations, hypotheses, and conclusions, (7) compiling valuable judgments, (8) interacting with others. Rahma summarizes the indicators of critical thinking in (Ennis, 1989) into five stages in the Table 1.

Sumarmo et al., (2012) explained that critical thinking ability includes the ability to: (1). Analyzing and evaluating arguments and evidence, (2). compiling clarification, (3). making value judgments, (4). compiling explanations based

Table 1. Critical Thinking Indicators

No	Stages of Critical Thinking Ability	Indicators
1	Elementary Clarification	• Focusing or formulating questions • Analyzing arguments • Clarifying by asking and answering questions
2	The Basis for the Decision	• Considering the truth of the source • Conducting observations and assessing reports of observations
3	Inference	• Making deductions and considering the results • Making inductions and considering the results • Making and determining value judgments
4	Advances Clarification	• Defining and considering • Identifying assumptions
5	Supposition and Integration	• Considering reasons • Combining information or integrating it in decision making

on relevant and irrelevant data, and (5). identifying and evaluating assumptions. Critical thinking abilities in this study include: (1). Elementary Clarification, (2). The Basis for the Decision, (3). Inference, (4). Advances Clarification, and (5). Supposition and Integration.

According to (Sulthoniyah, 2017), the questions that are suitable for developing students' critical thinking ability are story questions in the form of essays. In solving story problems, especially in the form of essay questions, students are expected to be able to write and explain coherently the problem-solving process given by selecting and identifying relevant conditions and concepts, seeking generalizations, formulating solution plans, and organizing skills that have been previously possessed. One of the learning subject matters that can be developed into the form of story questions is linear programming. Linear programming is defined as a problem in choosing real variables that maximize or minimize objective functions with linear constraints on the variables (Affandi, 2011). Linear programming includes planning activities to achieve optimal results, namely a result that best reflects the achievement of certain goals or objectives (Rafflesia, Ulfasari & Widodo, 2014). Linear programming is concerned with the explanation of a mathematical model consisting of a linear objective function and a linear constraint system (Sa'adah, Alfiatus & Suyitno, 2017). This is in line with the statement that linear programming is planning of activities using a general model that can be used in solving problems of allocating limited resources optimally (Rois, 2018).

In addition to critical thinking ability, students' self-concept is closely related to Education Subjects. According to Chaplin, J.P., self-concept is an individual's evaluation of oneself, a judgment or appraisal of oneself by the individual concerned, evaluation, judgment, or appraisal means that the individuals describe themself and give a value about themself. Self-concept is all ideas, thoughts, and beliefs that individuals know about themselves and influence individuals in dealing with others (Prasetyo, 2019). As stated by Burns in Novilita & Suharnan (2013) that a positive self-concept can help a person to increase confidence in oneself so that it can motivate a person to be even better. Mead in Novilita & Suharnan (2013) explains self-concept as the views, judgments, and feelings of individuals about themselves that arise as a result of social interaction. Indications of personal problems and problems with their environment show that many adolescents have a low self-concept or do not understand how their self-concept is. The self-concept of students develops at different times and in different ways and is strongly influenced by the social experiences of students (Handayani, 2017). In line with Pinem (2018), basically, self-concept is formed through a person's learning process from infancy to adulthood.

This self-concept fuses in a dynamic whole and unity. Each part interacts independently-cohesively with the other. The part of the whole interacts with the external aspects of the phenomenal world (Widiarti, 2017). The factors that influence self-concept according to Jalaludin Rakhmat in (Widiarti, 2017) are a) other people; b) reference groups. Furthermore, there are 5 clues for people who have a positive self-concept: having the confidence to solve problems; feeling equal to others; receiving praise from others without shame; having an awareness that everyone has various feelings, desires, and behaviors that are not entirely approved by society; able to improving oneself because individuals can

reveal aspects of their personality that they do not like and change them; and having the confidence to solve problems. Self-concept is not an inborn factor, but a mixed picture obtained from the judgment of oneself, and the views are given by others. In learning mathematics, self-concept is needed to be able to foster positive views and attitudes in solving math problems (Sumartini, 2015).

The ability to know oneself or self-concept and think critically is needed in developing the ability to analyze, solve problems, synthesize, and conclude the problems encountered in everyday life and test or criticize to obtain answers to the problems faced. Previous researchers said that if students have a high level of self-concept in themselves, of course, this will provide encouragement to do things better and solve the difficulties they face in completing their assignments, including completing assignments in mathematics. This proves that self-concept and self-confidence have a good contribution to students, so they must be motivated by teachers and parents to improve their self-concept to improve mathematical critical thinking ability (Rohmat & Lestari, 2019).

The results of previous researchers stated that students who have high self-concept could solve problems given such as the critical thinking ability test (Nurhasah et al., 2021). In addition, there was a significant relationship between students' self-concept and students' critical thinking ability (Barus, Ritonga & Siregar, 2018). Based on the description, the purpose of this research is to analyze critical thinking ability in solving linear programming problems in terms of students' self-concepts.

METHODS

This type of research is qualitative research with a case study method. The population in this research were 10th-grade students majoring in science at SMA Negeri 1 Padang Cermin. By using the purposive sampling technique, the researcher took three students based on the consideration of the students' self-concepts and the results of the analysis of the answers to the various students' critical thinking ability test questions. The instruments used are tests, interviews, and questionnaires.

The test is used to find out how students' critical thinking abilities are in solving linear programming questions in the form of essay questions and the number of questions was five questions that were adjusted to indicators of critical thinking ability, namely (1) Elementary Clarification; (2) The Basis for the Decision; (3) Inference; (4) Advances Clarification; and (5) Supposition and Integration. Where the validation results showed that the questions were feasible to use, including the results of the analysis of validity, reliability, level of difficulty, and discriminating power of questions as well as analysis of the specification for mathematics subject teachers at SMA N 1 Padang Cermin.

The interview was conducted to ask students directly, used sound recording evidence of the answers given. The interview used is unstructured. The interview was conducted by giving questions to research subjects related to the results of written answers to obtain the validity of the student's answer data

The questionnaire was conducted to find out how students' self-concepts related to their understanding of concepts. The questionnaire in this research was a self-concept questionnaire compiled based on self-concept indicators including (a) Perceptual (physical): includes students' perceptions of their physical appearance and impressions obtained from other people regarding appearance; (2) Conceptual (Psychic): includes typical self-characteristics, concepts about abilities and disabilities as well as impressions about the family background; and (3) Attitudinal (attitude): includes attitudes

about the current status of students and attitudes towards the future, feelings of pride or shame towards themselves (Hurlock, et al., 1974). The scale used in the questionnaire is a Likert scale in the form of S (agree), CS (Tend to Agree), CTS (Tend to Disagree), TS (Disagree) with a weighted value of S = 4, CS = 3, CTS = 2, TS = 1.

Based on the results of the questionnaire, the researchers then grouped the students' self-concept criteria into two, namely positive self-concept and negative self-concept. Individuals who have a positive self-concept were individuals who know very well who they are so that they accept all the strengths and weaknesses, evaluate themselves to be more positive, and can design goals that are under reality. Meanwhile, individuals with negative self-concepts were divided into two, namely (a) the first type, namely individuals who do not know who they are and do not know their weaknesses and strengths; and (b) the second type, namely individuals who view themselves in a very regular and stable manner (Acocella & Calhoun, 1990).

RESULTS AND DISCUSSIONS

Based on the results of the self-concept questionnaire given to 34 students of class XI IPA 1, it was found that 15 students (44,18%) with negative self-concept criteria and 19 students (55,82%) with positive self-concept criteria. Furthermore, using a purposive sampling technique, five subjects were selected where three subjects were coded A1, A2, and A4 where A1 and A2 with positive self-concept criteria while A4 with negative self-concept criteria to analyze the results of students' answers to critical thinking ability.

Analysis of students' answers to the Elementary Clarification indicator

Following is the student's answer to the Elementary Clarification indicator of the question given to the positive self-concept with the student code being A1.

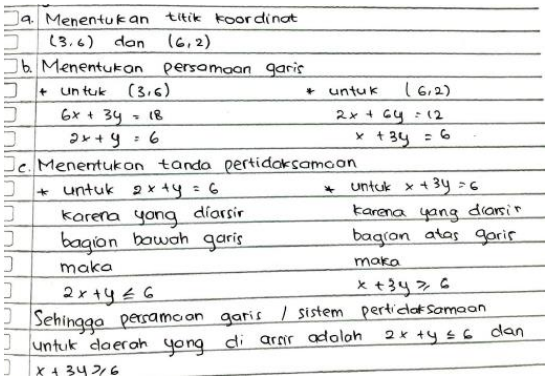
a. Menentukan titik koordinat
(3,6) dan (6,2)
b. Menentukan persamaan garis
* untuk (3,6) * untuk (6,2)
6x + 3y = 18 2x + 6y = 12
2x + y = 6 x + 3y = 6
c. Menentukan tanda pertidaksamaan
* untuk 2x + y = 6 * untuk x + 3y = 6
karena yang diarsir karena yang diarsir
bagian bawah garis bagian atas garis
maka maka
2x + y ≤ 6 x + 3y ≥ 6
Sehingga persamaan garis / sistem pertidaksamaan
untuk daerah yang di arsir adalah 2x + y ≤ 6 dan
x + 3y ≥ 6

Figure 1. A1 Student's Answer to Indicator 1

The student with code A1 explained in detail and each step in determining the system of inequalities for the shaded area of the given graph including (a) determining the coordinates of the point of intersection, (b) determining the line equation from known coordinates of a point, and (c) determine the inequalities model of the system of inequalities. Only in this case, the student is wrong in determining the coordinates of the point of intersection.

Based on the results of the A1 student interview on the solution of the answer is given as follows.

P : What are the coordinates and why are your answers (3,6) and (6,2)? Aren't there no points on the X and Y-axes?
A1 : Yes, that means the coordinates for the first line (3,0) and (0,6) and the second line (6,0) and (0,2).
P : That means you mean to write the point of intersection of the X-axis and the point of intersection of the Y-axis for these two lines?
A1 : yes.

Based on the interview, it was clear

that the student was able to explain simply in completing the answer, with only errors in writing.

Furthermore, there was a different explanation than code A1. The following is the student's answer to the Elementary Clarification indicator of the question given to the positive self-concept with the student code being A2.

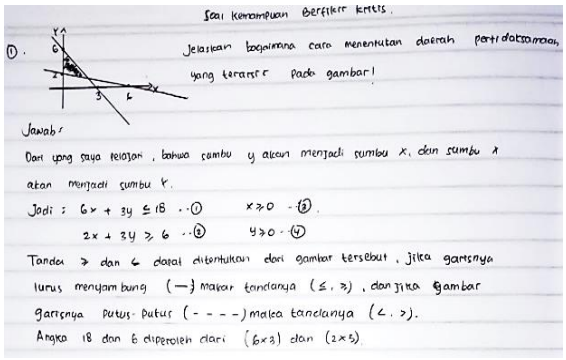

Figure 2. A2 Student's Answer to Indicator 1

A2 student could provide detailed explanations including (1) making mathematical models from the figure presented including $6x + 3y \leq 18; 2x + 3y \geq 6; x \geq 0$ and $y \geq 0$, model results provided answers that match the figure presented; and (2) explain the inequality sign used either in the form of an equal sign or not equal sign. Only for code 2, no detailed explanation has been given, as written by students with code A1. The results of the answer indicated that the initial procedure for obtaining the mathematical model has not been explained.

Based on the results of the interview of A2 students on the solution of the answer given as follows:

P : Why don't you explain the procedure in your answer?
A2 : I only explained the meaning of the equal sign.

Based on the interview, it was clear that the student was able to explain thoroughly in completing the answer, only that the explanation was not explained in detail so that it is easier to understand.

Next, the following is the student's answer to the Elementary Clarification indicator of the question given to the negative self-concept with the student code being A4.

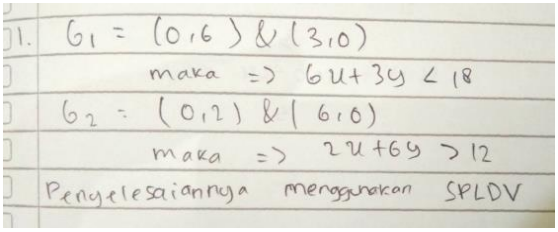

Figure 3. A4 Student's Answer to Indicator 1

A4 student did not explain the results of the answer, the student only wrote 2 inequalities from the results of the two points used in determining the inequality and the answer given was wrong because there is no equal to the inequality requested in the picture. A4 students also did not explain the points taken in determining the linear inequalities.

Based on the results of the interview with A4 students on the solution of the answer given as follows:

P : Why are the inequalities only less than and more than in this answer.
A4 : Because the shaded area is to the left and the right.
P : Then which one to the left and which one to the right?
A4 : This is to the left (shows answer line G1) and this is to the right (shows answer G2).
P : Do you understand the meaning of the concept of inequality to the right and the left.
A4 : No, I only remember when the teacher explained it.

Based on the interview, it was clear that the student was not able to explain thoroughly in completing the answer, the student did not understand the concept correctly and the meaning of the explanations given by the previous teacher.

The results of the analysis of the answer of 3 students with code A1, code A2, and code A4 concluded that students still did not provide simple explanations that were easy to understand, students experienced errors from previously obtained information or even errors in filtering information provided by the teacher. The results of the analysis showed that the writing of concepts is not appropriate, incorrect, and not systematic in conveying information in explaining the answer given. Based on Surya's statement in Fujika, et al (2015), that critical thinking allows an individual to analyze, assess, explain, and restructure oneself thinking. Furthermore, students asked questions to the teacher about the subject matter that has not been understood and asked questions to the presentation group.

Analysis of students' answers to The Basis for the Decision indicator

The following is the student's answer to The Basis for the Decision indicator from the question given to positive self-concepts with the student code being A1.

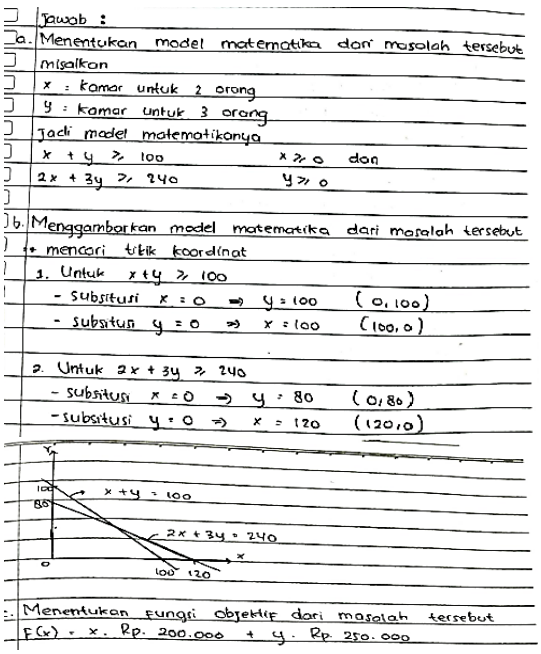

Figure 4. A1 Student's Answer to Indicator 2

Based on the results of the answer from Figure 4, it was found that A1 students wrote the solution procedure of determining the mathematical models of the given problem, drawing the mathematical models, and writing the objective function. A1 student explained in detail/systematically in making basic decisions from determining mathematical models, drawing mathematical models, and determining objective functions. The drawback is that the student did not provide a shaded area from predetermined mathematical models, only illustrated using the arrow direction of the specified line equation and there was an error in determining one of the mathematical models of "*A tour group consisting of 240 people will rent a hotel room for one night*" students write $2x + 3y \geq 240$ which should be $2x + 3y \leq 240$.

Based on the results of the A1 student interview on the solution of the answer given as follows:

P : Please explain the model used in the discourse "A tour group consisting of 240 people will rent a hotel room for one night".
A1 : $2x + 3y \geq 240$.
P : Why did you put a sign greater than or equal to? Does that mean the number of people is more than 240 people?
A1 : o yes, it should be less than right? (confused) because it consists of. Yes, means I was wrong.
P : Did you provide shading on the figure as a solution region?
A1 : (seeing the answer) I just gave an arrow, showing the shaded area.
P : Then how do you determine the objective function of a given problem?
A1 : I review the discourse of "The amount of room rent for 2 people and for 3 people per night is Rp 200.000,00 and Rp 250.000,00 respectively" so that it can be written that the objective function is $f(x) = Rp\ 200.000{,}00x + Rp\ 250.000{,}00y$ *based on the variable example specified earlier.*

Next, the following is the student's answer to The Basis for the Decision indicator from the question given to positive self-concepts with the student code being A2.

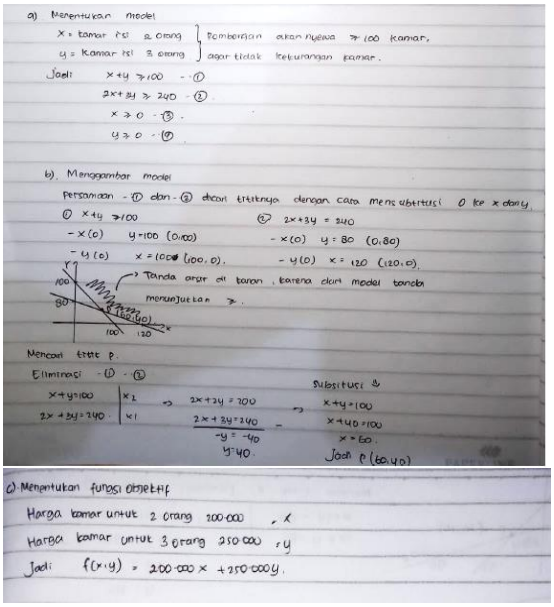

Figure 5. A2 Student's Answer to Indicator 2

Based on the results of the answer from Figure 5, it was found that A2 students wrote the solution procedure of determining the mathematical models of the given problem, drawing the mathematical models, and writing the objective function. A2 student explained in detail/systematically in making basic decisions from determining mathematical models, drawing mathematical models, and determining objective functions. The drawback is that student did not provide a shaded area from predetermined mathematical models, only illustrated using the arrow direction of the specified line equation and there was an error in determining one of the mathematical models of "*A tour group consisting of 240 people will rent a hotel room for one night*" students write $2x + 3y \geq 240$ which should be $2x + 3y \leq 240$. The mistakes made are the same as A1 students.

Based on the results of the A1 student interview on the solution of the answer given as follows:

P : Please explain the model used in the discourse "A tour group consisting of 240 people will rent a hotel room for one night".
A2 : the inequality is $2x + 3y \geq 240$.
P : Why did you put a sign greater than or equal to? Does that mean the number of people is more than 240 people?
A2 : Because it consists of 240 people.
P : Means that the meaning consists of 240 people showing greater than or equal to or less than or equal to?
A2 : Could be less than or equal to (confused and silent).
P : Then how do you determine the objective function of a given problem?
A2 : I review the reading of " The amount of room rent for 2 people and 3 people per night is Rp 200.000,00 and Rp 250.000,00 respectively " so that it can be written that the objective function is as $f(x) = Rp\ 200.000,00x + Rp\ 250.000,00y$ *based on the variable example specified earlier.*

Next, the following is the student's answer to The Basis for the Decision indicator from the question given to negative self-concepts with the student code being A4.

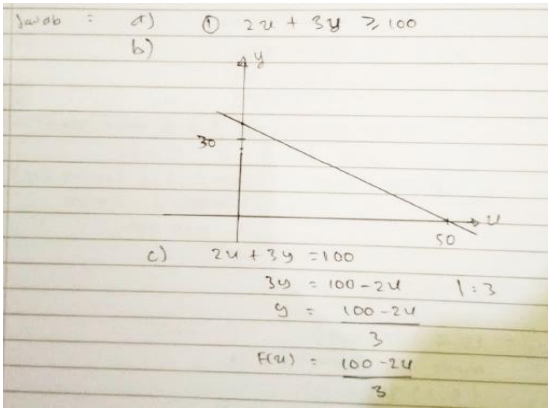

Figure 6. A4 Student's Answer to Indicator 2

Based on the results of the answer, it was found that students with code A4 could not solve problems systematically and precisely. Thus, students with code A4 could not determine the basis for making decisions based on the problem-

solving problems given.

Based on the results of the interview with A4 students on the solution of the answer given as follows:

P : How do you explain the answer to question number 2?
A4 : How? I find it difficult to explain (smile).

The results of the analysis of the answers of 3 students with code A1, code A2, and code A4 concluded that students were still less thorough and had difficulty in determining the basis for decision making from questions in the form of problem-solving, students were less thorough in interpreting sentences and did not describe the shaded area completely. which is used as the set of solution regions of the given models, did not write down the coordinates of the point of intersection of the axes (0,0). Thus, the results of the analysis show that as students have not been able to determine the basis for making decisions to create a mathematical model, determine the shaded area of the given mathematical model and determine the objective function of the problem given to the problem. According to Surya (2013) Fujika, et al (2015) that one of the characteristics of critical thinkers is to be able to utilize information to formulate problem solutions or make decisions, and if necessary seek additional relevant information, that critical people are people who quickly identify relevant information and separate it from irrelevant information.

Analysis of students' answers to the Inference indicator

The following is the student's answer to the Inference indicator from the question given to the positive self-concept with the student code being A1.

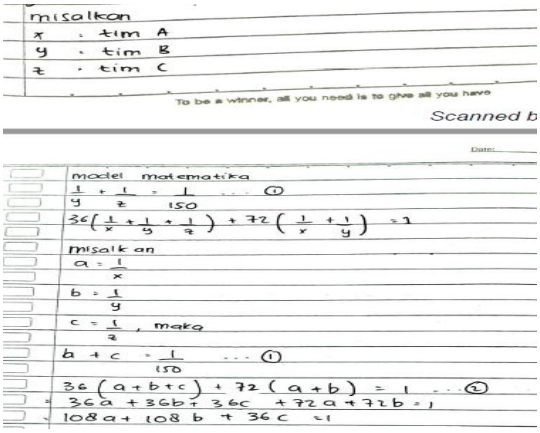

Figure 7. A1 Student's Answer to Indicator 3

Based on the answer, it was found that A1 student could not solve the given problem, A1 student only wrote down the example variables from the questions given and changed them into a mathematical model that is $\frac{1}{y}+\frac{1}{z}=\frac{1}{150}$. Thus, A1 students cannot conclude the given problem.

Based on the results of the A1 student interview on the solution of the answers given as follows:

P : Can you solve the given problem?
A1 : I have a little difficulty in determining the problem-solving process, so yesterday in answering, there was a lack in determining the mathematical model so that I did not get the conclusion that was asked for from the problem.

Next, the following is the student's answer to the Inference indicator from the question given to the positive self-concept with the student code being A2.

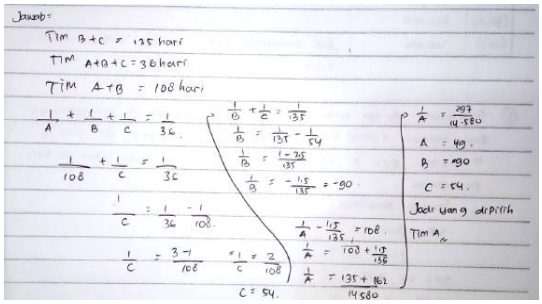

Figure 8. A2 Student's Answer to Indicator 3

Based on the answer, it was found that A2 students could correctly determine the mathematical model including $\frac{1}{A}+\frac{1}{B}+\frac{1}{C}=\frac{1}{36}$; $\frac{1}{A}=\frac{1}{108}$ and $\frac{1}{B}+\frac{1}{C}=\frac{1}{135}$ only didn't explain the meaning of the variables written, student solved it systematically and got the results correctly and at the end make simple conclusions.

Based on the results of the interview with A2 students on the solution of the answers given as follows:

P : Did you write down the meaning of the variable on the answer sheet?
A2 : No because I forgot and rushed to answer it.
P : How did you conclude?
A2 : Because of the result/conclusion from the solution, the time needed by each team was obtained and the conclusion was drawn according to what was asked in the question.

Next, the following is the student's answer to the inference indicator from the question given to the negative self-concept with the student code being A4.

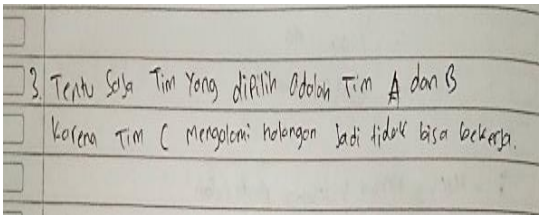

Figure 9. A4 Student's Answer to Indicator 3

Based on the results of the answer, it was found that students with code A4 did not write answers in a systematic and structured manner, students only wrote answers but did not use the solution procedure.

Based on the results of the interview with A4 students on the solution of the answer given as follows:

P : How do you conclude the answer to question number 3?
A4 : I don't understand the problem.
P : How can you answer this question?
A4 : I answered carelessly, the important thing is that there was an answer/not empty.

The results of the analysis of the answers of 3 students with code A1, code A2, and code A4 concluded that students were still less thorough and wrong in completing answers for students coded A1 and A4 while code A2 was only incomplete in determining Inference. According to Susanto in Fujika, et al (2015) one of the stages to teach or train students to be able to think critically is the skills of concluding, readers are required to be able to describe and understand various aspects gradually to arrive at a new formula, namely a conclusion.

Analysis of students' answers to the Advances Clarification indicator

The following is the student's answer to the Advances Clarification indicator of the question given to positive self-concept with the student code being A1.

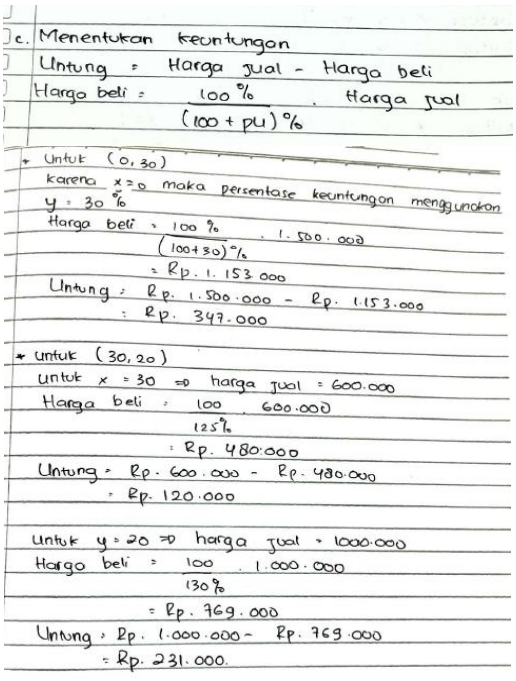

Figure 10. A1 Student's Answer to Indicator 4

The results of the analysis show that students with code A1 were finished in making mathematical models, determining the point of intersection of the coordi-

nate axes and the set of solution regions to the given problem. In addition, the student provided further explanations in making objective functions in determining profits and providing conclusions in determining the maximum profit from the answers obtained but the answers given were wrong.

Based on the results of the A1 student interview on the solution of the answers given as follows:

P : How to explain the answer to question number 4?
A1 : Based on the problem given, first make an example variable, determine the modeling, solve the problem, and make conclusions.
P : How do you provide further explanation regarding determining profit?
A1 : Regarding profit, I use the profit formula, namely the selling price minus the purchase price.
P : How do you interpret the meaning of the following statement "The selling price of type I cake is Rp. 20.000 per pan with a 25% profit and the selling price of type II cake is Rp. 50.000 per pan with 30% profit"?
A1 : The selling price of type I cake is Rp 20.000,00 per pan with 25% profit, meaning that the profit earned for type I cake is Rp 5.000,00 and the capital for type I cake is Rp. 15.000,00, while the selling price of type II cake is Rp 50.000,00 per pan with 30% profit, means that the profit earned for type II cake is Rp 15.000,00 and the capital for type II cake is Rp 35.000,00.
P : When you were working on the question, why did you not write it down like the answers you have described now? (While showing the student's answers).
A1 : (just smile).

The following is the student's answer to the Advances Clarification indicator of the question given to positive self-concept with the student code being A2.

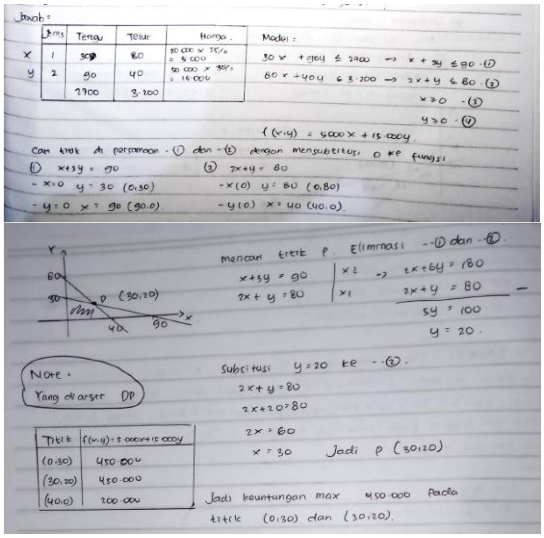

Figure 11. A2 Student's Answer to Indicator 4

The results of the analysis showed that A2 students write down answers systematically, completely, and correctly. Furthermore, A2 students provided further explanation of the answers related to determining the objective function in determining the maximum profit obtained. Meanwhile, the A4 student did not write the answer on the answer sheet.

The results of the analysis of the answers of 3 students with code A1, code A2, and code A4 concluded that student was still not thorough and wrong in completing answers for A1 student, while A2 student was able to solve problems systematically, precisely, and completely in giving further explanation of the given problem. While A4 students have not been able to provide further explanations because A4 students did not provide the answer on the answer sheet. According to Desmita in Astari dan Sumarni, (2020) effective critical thinking requires individuals to monitor when they are trying to understand an idea, to be aware of when they need new information, and to figure out how they can easily collect and learn that information.

Analysis of students' answers to the Supposition and Integration indicator

In Supposition and Integration, all students did not provide answers on the answer sheet.

CONCLUSIONS

The results showed that students with positive self-concept were able to solve problems with up to 4 indicators including indicators (1) Elementary Clarification; (2) The Basis for the Decision; (3) Inference; and (4) Advances Clarification. While students with negative self-concept were not able to solve the questions given, the answers given were not systematic. The results of the analysis showed that the ability of students to solve linear programming problems still needs to be improved where almost all the questions are given, students with negative self-concept could not answer the questions. The mistakes made include (1) Writing concepts that were not appropriate, incorrect, and not systematic, (2) Incomplete figures on student answer sheets, (3) writing reasons for arguments that were still unclear, while the results of the interview show students were able to convey answers orally in solving linear programming problems.

The low level of students' critical thinking ability in solving linear programming problems has not familiarized students with problems with cognitive levels C4-C6 so that students were less accustomed to developing their critical thinking ability. Considering the importance of critical thinking ability, teachers need to innovate in learning. One of the learning innovations that can be used to improve students' critical thinking ability by applying problem-based learning (PBL) is expected to improve student's critical thinking ability with negative self-concept to be more confident in solving given problems, in addition to students with positive self-concept can be increased to a higher indicator in dealing with a given problem. Several studies have stated that PBM can improve students' critical thinking ability (Tiwari et al., 2006; Dwijananti & Yulianti, 2010; Nargundkar et al., 2014;Sulaiman & Azizah, 2020).

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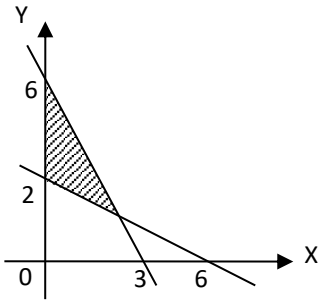
Appendix 1

Critical Thinking Ability Test Specification and Items

No	Critical Thinking Ability Indicators	Question Items
1	Elementary Clarification	Look at Figure 1 below!  Figure 1 Explain how to determine the system of inequalities for the shaded area in Figure 1 above!
2	The Basis for the Decision	A tour group of 240 people will rent a hotel room for one night. The rooms available at the hotel are rooms for 2 people and for 3 people. The group will rent at least 100 hotel rooms. The amount of room rent for 2 people and 3 people per night is Rp 200.000,00 and Rp 250.000,00, respectively. Explain how to: a. Determine the mathematical model of the problem b. Draw a mathematical model of the problem c. Determine the objective function of the problem
3	Inference	The painting company tender has 3 teams, namely TEAM A, TEAM B, and TEAM C. Experience TEAM B and TEAM C have worked together on painting within 4,5 months (assumed 1 month = 30 days). On one occasion, they worked together for 36 days. After that, due to an obstacle, TEAM C could not continue the work, so TEAM A and TEAM B needed an additional 72 days to complete the painting. Each TEAM can paint with a daily fee of Rp. 5.000.0000,-. If the costs incurred are minimum, then the TEAM chosen is...
4	Advances Clarification	Mrs. Tika every day produces two types of cakes every for sale. Each type I requires 30 grams of flour and 80 eggs, while the type II cake requires 90 grams of flour and 40 eggs. The ingredients available for both types of cakes are 2,700 grams of flour and 3,200 eggs. The selling price of type I cake is Rp. 20.000 per pan with 25% profit and the selling price of type II cake is Rp. 50.000 per pan with 30% profit. If all types of cakes are sold out, then explain how to determine the maximum profit from the sale of both types of cakes!
5	Supposition and Integration	Badu is a businessman who accommodates various brands of rice, including *rojolele*, *dua mawar*, and *pandan wangi*. The stock of rice in the Banu warehouse is obtained from farmers in Pringsewu district. In addition, Badu also opened a shop in the terminal market to sell retail. After checking the stock in his shop, it turned out that Badu lacked 60 tons of rice, so Badu had to transport 60 tons of rice from the warehouse to his shop. For transportation, Badu rented two

types of vehicles. Type A vehicles can carry 3 tons and Type B vehicles can carry 2 tons. The rent for each carriage using type A and B vehicles is Rp.250.000 and Rp.200.000, respectively. With this rental method, Badu needs at least 24 times of transportation to rent both types of vehicles

a. Explain how Mr. Badu makes a mathematical model for the problem above!
b. Explain how many type A and type B vehicles should be rented to keep the rental costs to a minimum!

Appendix 2

Self-Concept Questionnaire

Instructions for Filling Out Questionnaire

The following statements are to help you describe yourself. Answer the statements as if you were describing yourself as you are right now. Please answer with your first response. Don't skip any number. Carefully read each statement and then choose one of the 4 available answers by writing a cross (X) in the column provided. The meaning of the 4 answer choices:

- Answer S : Agree
- Answer CS : Tend to agree
- Answer CTS : Tend to disagree
- Answer TS : Disagree

No	Statements	S	CS	CTS	TS
1	I have a healthy body				
2	I like to look presentable all day long				
3	I am an attractive person				
4	I am a person who is often sick				
5	I don't keep my body clean				
6	I am an unattractive person				
7	I am satisfied with my body size				
8	I am not too tall and not too short				
9	There is a desire in my heart to change certain parts of my body				
10	I don't feel as healthy as I should be				
11	I want to fix some parts of my body				
12	I feel that my physical appearance is not what I expected				
13	I take good care of my body				
14	I can do my tasks				
15	I try to keep my appearance as good as possible				
16	I am lazy to exercise				
17	I often feel awkward				
18	I don't care about the neatness of my appearance				
19	I am a person who can understand other people				
20	I am a believer in religion				
21	I am an honest person				
22	I am a person who is not able to carry out religious rules				
23	I am not a good person				
24	I do not comply with the applicable rules/norms				
25	I am satisfied with my behavior				
26	I obey religious teachings as I wish				
27	I am satisfied with my relationship with God				
28	I wish I was more trustworthy				
29	I should worship more often				

No	Statements	S	CS	CTS	TS
30	I shouldn't lie often				
31	I am religious in my daily life				
32	I almost do what is right every time				
33	I try to change if I realize what I am doing is wrong				
34	Sometimes I use dishonest ways to get ahead				
35	I do everything I can to get what I want				
36	I find it difficult to do things according to the norm				
37	I am a cheerful person				
38	I am quite able to control myself				
39	I easily adapt to situations				
40	I am a hater				
41	I am a meaningless person				
42	I am a person who loses my mind easily				
43	I am satisfied with the way I am				
44	I am a fun person				
45	I am proud of my abilities				
46	I am not the person I really want to be				
47	I ignore myself				
48	I wish I didn't give up as easily as it is now				
49	I can take care of and cope with myself in any situation				
50	I solve problems quite easily				
51	I can accept my mistakes without feeling hurt or angry				
52	I change my mind easily				
53	I do things without thinking				
54	I try to run away from my problems				
55	I have a family who helps me in dealing with any difficulties				
56	I am a person who means a lot to my family				
57	I am a happy family member				
58	I am not trusted by my friends				
59	I am not loved by my family				
60	I feel that my family does not trust me in certain areas				
61	I am satisfied with my relationship with my family				
62	I treat my family properly				
63	I can understand family properly				
64	I am too sensitive to the things my family says				
65	I should have more faith in my family				
66	I should love my family more				
67	I try to be honest with my family				
68	I help with housework				
69	I really care about my family				
70	I often fight with my family				
71	I don't want to lose when I'm dealing with my family				
72	I don't do what my family wants				
73	I am a gregarious person				

No	Statements	S	CS	CTS	TS
74	I am popular among female friends				
75	I am popular among male friends				
76	I feel uncomfortable when I am with other people who are not my family				
77	I don't care what other people do around me				
78	I have a hard time making friends				
79	I am as friendly as I want to be				
80	I am satisfied with the way I treat others in my daily life				
81	I try to please others but not too much				
82	I should be more polite to other people				
83	I am not a good member of society				
84	I should get along better with other people				
85	I try to understand the views and opinions of others				
86	I try to see the good side in everyone I meet				
87	I easily adapt to other people				
88	I have difficulty conversing with other people				
89	I don't easily forgive other people's mistakes				
90	I find it difficult to be friendly to other people				