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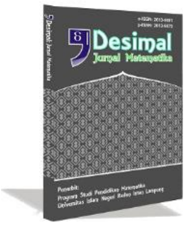

# Mathematical modeling ability based on students' cognitive style in linear program material

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## ABSTRACT

*Modeling abilities and student characteristics are very important in learning mathematics at school. One of the characteristics that must be considered is cognitive style. This study aims to describe the mathematical modeling abilities of students with field independent (FI) and field dependent (FD) cognitive styles in linear programming material. The design of this research is descriptive-qualitative. This study analyzed the mathematical modeling abilities, and then, using a purposive sampling technique, 4 subjects were selected as samples, 2 each for field independent (FI) and field dependent (FD) cognitive style subjects. Data on students' mathematical modeling abilities were obtained through task-based interviews and written tests, while cognitive style data were obtained through the Group Embedded Figure Test (GEFT) written test. The validity of the data was then tested using time triangulation and then analyzed through the stages of data reduction, presentation, and drawing conclusions. So, the results of this study indicate that in modeling problems, students who have a cognitive style of FI tend to be able to fulfill indicators of understanding actual problems, preparing mathematical models from real models, and interpreting mathematical results in real situations. whereas students who have a cognitive style like FD tend to only be able to understand the real problem.*

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## INTRODUCTION

In formal education in Indonesia, mathematics is a definite subject that is taught at the elementary, middle, and high school levels, the high school/vocational high school level, and tertiary institutions. However, it turns out that many students still experience difficulties in learning mathematics (Hadi, Retnawati, Munadi, Apino, & Wulandari, 2018; Siagian, Saragih, & Sinaga, 2019; Ulandari, Amry, & Saragih, 2019). This is because students lack the application of knowledge in the form of material, concepts, and mathematical theories they learn in everyday life, so it makes it seem as if mathematics is an abstract science, and it looks as if knowledge only contains formulas and numbers (Graciella & Suwangsih, 2016).

The student is expected to be able to apply what he has learned at school and apply it in different situations in everyday life to improve mathematical literacy skills. The importance of connecting mathematics with everyday life is one of the keys to dealing with a society that is constantly changing (disruption) (Janah, Suyitno, & Rosyida, 2019; Munifah, Septiyani, Rahayu, Ramadhani, & Tortop, 2020) and changing the paradigm, which states that students' knowledge obtained at school and students' daily experiences have no connection (Febrian, 2016).

Based on this, it is known that learning mathematics is very important for students' abilities to apply concepts, knowledge, and knowledge obtained at school to problems in real life. According to Ang (as cited in Nuryadi, Santoso, & Indaryanti (2018)), The process of changing or representing real-world problems in mathematical form in an effort to find a solution to a problem is called mathematical modeling.

However, in reality, the ability of students in Indonesia to connect mathematics with real life or mathematical modeling is still lacking. It was proven in the 2018 PISA results that the average math score reached 379, with an OECD average score of 487, or ranked 73rd. The low PISA score obtained by Indonesia shows that Indonesian students still have difficulty understanding PISA questions, which include three components: content, context, and process (Kementrian Pendidikan dan Kebudayaan, 2020a). The content of PISA is to assess students' ability to solve real-life problems that are related to phenomena or events, while the context of PISA is something that is closely related to students.

In addition, the results of the research bySumbandari, Misdalina, & Fuadiah (2022) stated that 90.9% were junior high school students and 86.66% were high school students. High school students experience difficulties in doing abstraction (the process of turning a real problem into a mathematical model), resulting in students not being able to do mathematical modeling. In line with the research of Indrawati, Fiqi Annisa, & Wardono (2019), it was stated that out of 28 students, there were 25 who made mistakes when solving 2-variable equation word problems. This happened because they misunderstood the problem and were unable to model the word problem into mathematical symbols. So it is clear that the lack of mathematical modeling skills will make it difficult for students to solve math word problems and even problems that they encounter in everyday life.

Based on teacher observations and interviews conducted at a high school in Seluma Regency, it is known that students at that school have difficulty working on word problems, especially on linear programming material. This can be seen from the linear program word problems given by the mathematics teacher in class; only about 25% were able to answer them completely, and the other 75% were unable to complete them. The following is one of the answers from students who have difficulty determining the mathematical model in linear program word problems.

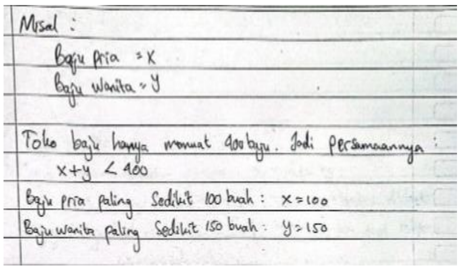



**Figure 1.** Example of Student Answers in Solving Story Problems on Linear Programming Material

Based on Figure 1 and the results of interviews with teachers at the school, it is known that the difficulties experienced by students include difficulties in understanding and connecting any information given in the questions in a real form, turning the information into an appropriate mathematical model, and returning conclusions from the mathematical model that have been obtained to real problems in the problem.

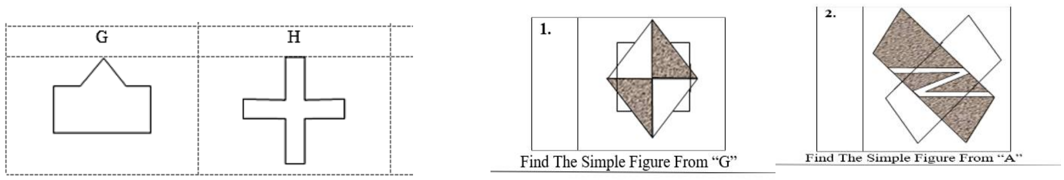
In the process of developing mathematical modeling abilities, teachers will encounter different characteristics. One of the student characteristics that needs to be considered specifically in learning mathematics is cognitive style. When solving word problems, students will be able to choose solutions, receive real information, and model problems that differ from one student to another; this can be due to differences in cognitive styles (Nasriadi, 2016; Verawati, Hikmawati, & Prayogi, 2020).

According to Muhtarom, cognitive style can be defined as the way a person receives, remembers, and thinks or as specific ways of receiving, storing, forming, and utilizing information (Rohmah, Septian, & Inayah, 2020). According to Witkin, someone with the Field Dependent (FD) cognitive style can think globally, receive and follow available information, and tend to prioritize external motivation, while someone with the Field Independent (FI) cognitive style is good at analyzing objects from the surrounding environment, classifying objects, and prioritizing internal motivation (Verawati et al., 2020; Wulan & Anggraini, 2019).

According to Utami, Zainudin, & Anggraini (2020), Field Dependent (FD) and Field Independent (FI) styles are types of cognitive styles that reflect a person's analytical way of interacting with their environment. Individuals with FD cognitive styles tend to accept a pattern as a whole. They find it difficult to focus on one aspect of a situation or to analyze patterns in its different parts. In contrast, the FI cognitive style accepts the separate parts of the overall pattern and is able to analyze the pattern into its components.

There are several previous studies, such as an analysis of mathematical reasoning abilities for spatial material in terms of cognitive style by Rohmah et al. (2020), an analysis of students' mathematical modeling abilities using a scaffolding strategy with a solution plan on trigonometry (Nuryadi et al., 2018), an Analysis of Mathematical Problem Solving Ability in TIMSS-Type Problems Based on Cognitive Style, and Mathematical Modeling Ability in Solving Contextual Mathematical Problems (Khusna & Ulfah, 2021).

The cognitive style of FD and FI students can be measured using the GEFT (Group Embedded Figure Test), which is a series of standardized paper and pencil tests. This test consists of 3 sessions, namely session 1 consisting of pictures that are quite simple and the score is not counted because it functions as student practice, and sessions 2 and 3 each consist of 9 questions, each of which gets a score of 1, and the wrong question gets a score of 0. So that the maximum total GEFT score that can be obtained by students is 18 and a minimum of 0. The following is an example of a question on the GEFT.




(a) (b)

**Figure 2.** (a) Simple Drawings and (b) Complex Drawings to Find Simple Images

Then, according to Maab, modeling competence includes the skills and ability to apply the modeling process in an appropriate and directed manner. In addition, Maab formulates modeling competencies into several indicators, which are then used in this study, namely (1) understanding real-world problems, (2) preparing mathematical models from real models, (3) solving mathematical problems in mathematical models, and (4) interpreting mathematical results in real-world situations (Nuryadi et al., 2018).

Based on the description and previous research, no one has analyzed students' mathematical modeling abilities in linear programming material in terms of cognitive style. So the researcher aims to describe the mathematical modeling abilities material for linear programming for students with field independent (FI) and field dependent (FD) cognitive styles.

## METHOD

Based on the problems found by researchers, the research sample is 4 students in class XI IPA 2 high school (24 students), 2020/2021 academic year, located in Seluma Regency, Bengkulu province. Determination of the sample using the purposive sampling technique. Purposive sampling is a technique for taking samples from data sources with certain considerations. The first consideration is that students have been selected in the categories of slightly FD, slightly FI, strongly FD, and Strongly FI. Second, all students who have the same cognitive style category will be selected for the best or highest level of mathematical modeling ability. Finally, the selection of subjects is based on the recommendations of the mathematics teacher in the class.

The design of this study is a qualitative analysis, which can be seen in Figure 3 below.

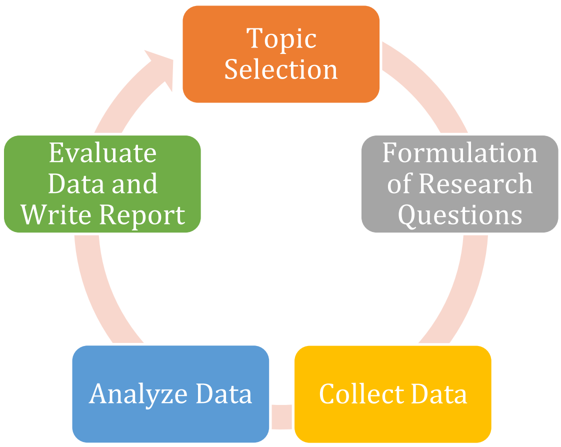



**Figure 3.** Qualitative Research Stages

At the topic selection stage, problems are obtained based on analysis and observation at school. In the next stage, the researcher formulates research questions in a concise, achievable, and relevant manner. Then the researchers collected data using test instruments, and interview instruments. After the data is obtained, it is analyzed and then presented in the form of a description.

The primary data in this study were obtained in the form of the actions, utterances, and results of students' work during the research process, namely in the form of data on students' cognitive styles and data on students' mathematical modeling abilities. Meanwhile, the secondary data sources in this study were educators, where secondary data were in the form of documents, student scores from mathematics educators, and the school.

In this study, three data collection techniques were used, namely observation techniques, test techniques, and interview techniques, as well as the data validation technique, namely time triangulation.

Researchers conducted a credibility test to test the validity of the data. In this study, the data credibility test was carried out by time triangulation. This research analysis is divided into three streams of activities that occur simultaneously, including data reduction, data presentation, and verification. The procedures carried out in this study were the preparation stage, the data collection stage, the data validation stage, the data analysis stage, and the report preparation stage.

According to Jeff Q. Bostic, the reliability of the GEFT instrument is 0.82. You can see the interpretation of the GEFT score for this study in Table 1 (Zannah & Andriani, 2017).

**Table 1.** Interpretation of GEFT Scores According to Student Gender

| Category | Male Students Score | Female Student Score |
|---|---|---|
| *Strongly* FD | 0-9 | 0-8 |
| *Slightly* y FD | 10-12 | 9-11 |
| *Slightly* FI | 13-15 | 12-14 |
| *Strongly* FI | 16-18 | 15-18 |

## RESULTS AND DISCUSSION

### Result 1: Description of Students' Cognitive Style Results through the GEFT Test

The GEFT test is given to all students in class XI, IPA 2. Before being given to students, the grammar on the GEFT test was prepared according to the level of understanding of high school students and was declared valid by two validators. Based on the results of the cognitive style data that has been collected, 13 students with the FI cognitive style and 11 students with the FD cognitive style were identified. The results of the data are grouped and placed in Figure 4.

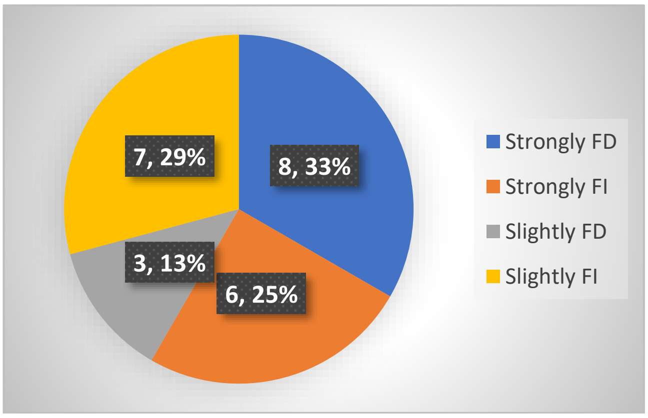



**Figure 4.** Cognitive Style Results Class IX IPA 2

Based on the data in Figure 4, there are 8 Strongly FD students, 3 Slightly FD students, 7 Slightly FI students, and 6 Strongly FI students. Then four subjects were selected, following the 'purposive sampling' technique or with certain considerations. The results of selecting the four subjects are shown in Table 2.

**Table 2.** The Results of the Research Subject's GEFT Test

| Cognitive Style | Cognitive Style Category | Score GEFT | Subject |
|---|---|---|---|
| *Field Dependent* (FD) | *Strongly FD* | 6 | $SFD_1$ |
| | *Slightly FD* | 2 | $SFD_2$ |
| *Independent Fields* (FI) | *Strongly FI* | 17 | $SFI_1$ |
| | *Slightly FI* | 12 | $SFI_2$ |

### Result 2: Description of the Results of Students' Mathematical Modeling Ability

All students in class XI IPA2 whose cognitive style category was known were then tested for their mathematical modeling ability. This modeling ability test has previously been declared valid by two expert validators, namely mathematics lecturers and experienced teachers. Mathematical modeling ability test instruments I and II were made different but parallel in the type and level of difficulty of the questions. The following is the form of the questions on the first test of mathematical modeling abilities, as shown in Figure 5.

Pak Andi is a craftsman who makes three types of handicrafts, namely bubu and bunang. Pak Andi expects a profit of Rp. 15,000.00 per fruit for selling bubu and Rp. 10,000.00 per fruit for selling bunang. To make bubu, it takes 1200 seconds to whittle and 40 minutes to weave, while to make bunang, it takes 0.25 hours to whittle and 1/6 of an hour to weave. If Pak Andi only has 24.5 hours per week to sharpen and 2310 minutes per week to weave, how many bubu and bunang will Pak Andi have to make in order to get the maximum profit **each day**?

(a) (b)

**Figure 5.** (a) Bubu Crafts; (b) Bunang Crafts

The results of the student's description answers on tests I and II were then compared, and valid data was taken. In this study, the data of 24 students in class XI, IPA 2, were declared valid based on time triangulation. The results of the students' answers on tests I and II were then given a score. The minimum score is 0, and the maximum score for each test is 100. Each student is seen with the highest score for each test I and test II, and the student's highest score on the modeling ability test at school is grouped into five categories according to Nuryadi et al. (2018); the categories can be seen in Table 3.

**Table 3.** Frequency Distribution of Mathematical Modeling Ability

| Score | Category | Frequency | Percentage |
|---|---|---|---|
| 80 – 100 | Very good | 5 | 20.83% |
| 60 – 79.9 | Good | 6 | 25.00% |
| 40 – 59.9 | Enough | 8 | 33.33% |
| 20 - 39.9 | Not enough | 2 | 08.33% |
| 0 – 19.9 | Very less | 3 | 12.50% |
| **Average** $=\bar{x} = \frac{\sum fi.xi}{\sum fi}$ | **Enough** | **56.67** | |

Based on Table 3, statistically, the mathematical modeling abilities of class XI at IPA 2 Senior High School obtained the sufficient category for the average score of all students of 56.67.

**Result 3: Description of the Results of the Analysis of Students' Mathematical Modeling Ability in Terms of Cognitive Style**

Data on the mathematical modeling abilities of the 4 subjects, namely $SFI_1$, $SFI_2$, $SFD_1$, and $SFD_2$, were analyzed, and then trends were observed. Following are the results of the analysis of the 4 subjects in solving linear programming questions on written tests and task-based interviews as seen from the 4 indicators of mathematical modeling ability:

1. Mathematical Modeling Ability Subject Cognitive Style *Independent Fields*

Based on the time triangulation, the data on the mathematical modeling abilities of the two FI subjects was declared valid. The following is the tendency of students with the FI cognitive style towards the four indicators of mathematical modeling ability:

(1) Understand the Real Problem

Both subjects were able to correctly and accurately write down the problems asked in the linear programming questions. The subject also looks easy to understand; it can be seen that the $SFI_1$ subject only requires 2-3 repetitions in reading the questions. When interviewed, the two subjects were able to explain the questions using their own language. The two subjects were also able to provide an overview of the steps and results of the answers to be obtained. This can be seen in the answers from the $SFI_1$ interview subject: "Essentially, we have to find the maximum point on the graphic image. So we can get the maximum number of sales per day, Mr. Andi sis, through these steps (refer to the answer sheet)".

This is because, according to Alifah & Aripin, (2018), the FI cognitive style is more able to accept separate elements from the overall pattern and is able to analyze the pattern into its components. FI subjects are able to see the information provided by the problem as a whole, analyze the main problems that occur, and determine what components are needed to solve the problem (Pambudi, Widada, Nirwana, & Herawaty, 2020). So that students with the FI cognitive style tend to be able to meet the indicators of understanding the real problem.

(2) Setting up a Mathematical Model from a Real Model

According to Witkin and Goodenough, individuals with the FI cognitive style have the ability to abstract parts from contextual settings, and these people tend to have a more analytical approach to solving problems (Tisngati, 2015; Wulan & Anggraini, 2019). Both Strongly FI subjects were able to correctly write a mathematical model based on the information provided in the questions. The two subjects also presented information in tabular form so that it was easy to determine the mathematical model in the form of a system of equations needed, as shown in Figure 6.

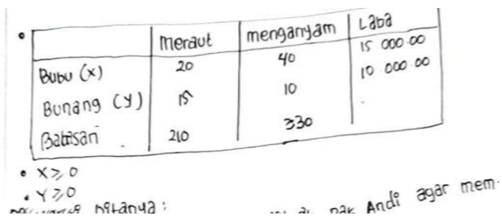



**Figure 6.** Tabular Form Used by $SFI_1$ to Make It Easier to Determine a Mathematical Model

Both Strongly FI subjects were able to provide logical and accurate arguments when asked about the model they wrote. The results of the answers of the two subjects, for example, were that the two subjects were able to explain the reasons for using the symbols ≤ and ≥ in the system of equations they wrote, as shown in Figure 7.

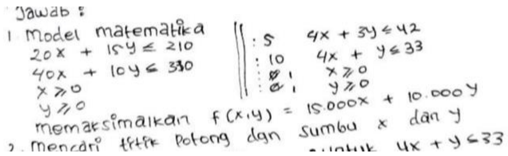



**Figure 7.** The Mathematical Model Form of the $SFI_1$ Answer!

$SFI_2$ subject did not write down the terms $x > 0$ and $y > 0$ on the first test, when conducting an interview based on the $SFI_2$ subject, he immediately realized his mistake and gave an explanation that he had forgotten to write them down. Meanwhile, $SFI_1$ subjects were able to correctly write down the terms $x > 0$ and $y > 0$. So that FI students tend to be able to fulfill the indicators of preparing a mathematical model from a real model on linear programming questions.

(3) Solving Mathematical Problems in Mathematical Models

$SFI_1$ subjects are able to solve problems in the mathematical model correctly and accurately. while the $SFI_2$ subject experienced an error when determining the extreme point, so that the maximum point obtained was wrong. During the interview, it was discovered that the $SFI_2$ subject had misconceptions. Which resulted in $SFI_2$ subjects continuing to make the same mistakes in test II. The $SFI_2$ subject error is shown in Figure 8. $SFI_1$ subjects are able to solve problems in the mathematical model correctly and accurately. while the $SFI_2$ subject experienced an error when determining the extreme point, so that the maximum point obtained was wrong. During the interview, it was discovered that the $SFI_2$ subject had misconceptions. Which resulted in $SFI_2$ subjects continuing to make the same mistakes in test II. The $SFI_2$ subject error is shown in the following Figure 8.

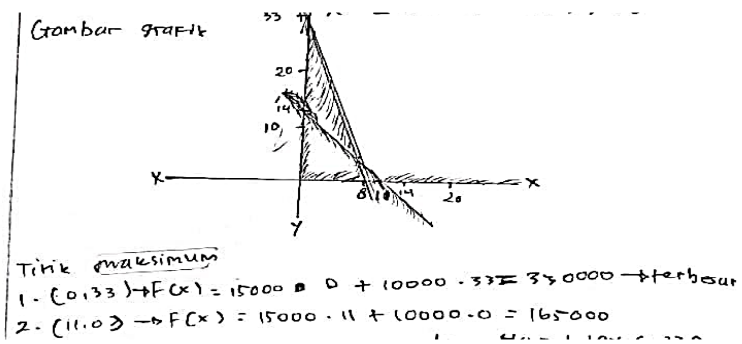



**Figure 8.** The $SFI_2$ Subject Answers that Incorrectly Estimate the Graph

$SFI_2$ subjects were very confident in the answers they wrote. However, when the researcher asked, "Is the area you shaded (not the settlement area) a settlement area for $4x + y \leq 33$ of this curve as well?" The $SFI_2$ subject was silent and still answered "yes" hesitantly. So that students with the FI cognitive style tend not to be able to meet the indicators of solving math problems in the mathematical model.

(4) Interpreting Mathematical Results in Real Situations

It can be seen from the written answers that the two subjects were able to return the solution in the form of a mathematical model to the given linear program contextual problem. When conducting task-based interviews, students were also able to explain in their own language the results of the conclusions they reached. Even though the answers to the $SFI_2$ subjects were not quite right due to misconceptions in determining the settlement area, the $SFI_2$ subjects were able to properly interpret the conclusions they obtained in solving the mathematical model into real situations according to the questions (Ramdhani, Usodo, & Subanti, 2017) that had been given, as shown in Figure 9.

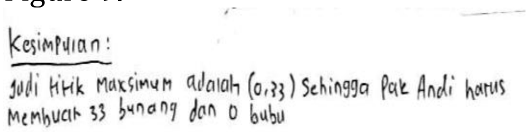



**Figure 9.** $SFI_2$ Subjects Return Conclusions to Real Problems

So, students with the FI cognitive style tend to be able to interpret mathematical results in real situations.

Based on the statement above, students with the FI cognitive style are able to fulfill three indicators of mathematical modeling ability: understanding real problems, preparing mathematical models from real models, and interpreting mathematical results in real situations. However, they have not been able to fulfill one indicator of mathematical modeling ability, namely solving mathematical problems in a mathematical model. This is in line with research (Kementrian Pendidikan dan Kebudayaan, 2020b), which shows that for FI subjects to be able to understand verbal statements of problems and convert them into mathematical sentences, be more analytical in receiving information, and solve problems in real-life contexts, and research by Lusiana (2017), where FI students tend to make mistakes in organizing data and mistakes in drawing conclusions, and the results of Murtafiah & Amin (2018), that subjects with field independent cognitive styles were more analytical, so they were able to understand the verbal statement of the problem and change it to a math sentence; he also stated that the subject solved the problem correctly. However, this is not in line with the research of Amalia (2017), where, besides making mistakes in the process of solving problems, people also tend to make mistakes when understanding the problem.

2. Mathematical Modeling Ability Subject Cognitive Style *Dependent Fields*

Based on the time triangulation data, the mathematical modeling abilities of the two FD subjects were declared valid. Analysis of the tendency of students with FD cognitive style towards four indicators of mathematical modeling ability is as follows:

(1) Understand the Real Problem

In the process of solving the problem, the two subjects had difficulty understanding the problem, but in the end, both subjects were able to write down the problems asked in the linear program questions correctly and precisely, as seen in the answers of subject $SFD_1$ as shown in Figure 10.

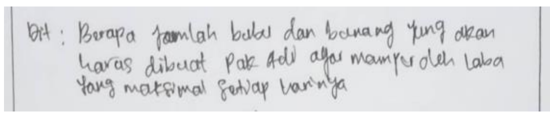



**Figure 10.** Problems $SFD_1$ Subjects Found

$SFD_1$ subjects only need 3 times to understand the questions, but $SFD_2$ requires more than 4 times in order to understand the problem and the information provided by the question. In accordance with the opinion of (Sepriyani, Asyhar, & Asrial, 2018), individuals who are dependent on the field tend to be less analytical when looking at a problem and have difficulty breaking down information into isolated parts.

They During the interviews, although they stuttered, both subjects were able to explain the questions using their own language. Both subjects can determine this. This can be seen in the answers from the $SFD_1$ subject interview: "Who was asked how many traps and bunang should be made every day so that maximum income, so we have to model the sharpening and weaving time into a mathematical model and then finish it". so that students with the FD cognitive style tend to be able to meet the indicators of understanding the real problem.

(2) Setting up a Mathematical Model from Real Model,

$SFD_1$ subjects well enough to write a mathematical model from the information provided by the questions; this can be seen in the answers to $SFD_1$ questions in Figure 11.

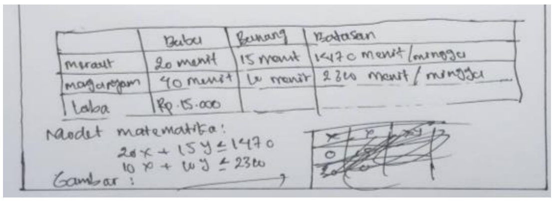



**Figure 11.** $SFD_1$ Subject Mathematics Model

From the answers above, the $SFD_1$ subject has not been able to write down information that is not written in the questions, namely the conditions $x > 0$ and $y > 0$. This is because students with the FD cognitive style have difficulty seeing information separately, meaning that they see the biggest problem in the overall situation (Sepriyani et al., 2018). Meanwhile, $SFD_2$ subject were unable to write a mathematical model correctly and correctly. $SFD_2$ subjects wrote down information on the questions in a descriptive form and did not use tables. During the task-based interview, $SFD_1$ subjects were also unable to provide clear arguments regarding the written mathematical model. This can be seen when the researcher asked the $SFD_1$ subject, "Why do you use the ≤ symbol in the mathematical model?" Subject $SFD_1$ answered "Because usually symbols are used like that". It's the same with $SFD_2$ subjects, who even use the = symbol in their mathematical model. So that FD students tend to be able to meet the indicators of preparing a mathematical model from a real model on linear programming questions.

(3) Solving Mathematical Problems in Mathematical Models

Both FD Subjects are not able to solve problems in mathematical models correctly and precisely. This can be seen from the written answers of students who did not continue their work after determining the mathematical model. During the task-based interview, the researcher asked, "After obtaining the model, what steps should you take?" $SFD_1$ subject said, "We should draw a graph and determine the maximum value, but I don't understand how to draw that graph", while $SFD_2$ subject answered "I don't know". From the interview, it was found that the $SFD_1$ subject quite understood the flow of completing the mathematical model, while the $SFD_2$ subject did not know what steps to take next to complete the mathematical model.

In line with the results of research by Wulan & Anggraini (2019), which stated that students who have the FD cognitive style cannot change problems into mathematical sentences (mathematical symbols), students with the FD cognitive style tend not to be able to meet the indicators of solving math problems in the mathematical model.

(4) Interpret Mathematical Results in Real Situations.

The two FD subjects were unable to relate the solution to the real situation of the problem. This happened because the two FD subjects were unable to continue their work until the maximum point was obtained. So, students with the FD cognitive style tend to be able to interpret mathematical results in real situations.

Based on the statement above, students with the FD cognitive style are able to fulfill one indicator of mathematical modeling ability, namely understanding the real problem. However, it has not been able to meet the three indicators of mathematical modeling ability, namely preparing a mathematical model from a real model and interpreting mathematical results in real situations. This is in line with the research of Lusiana (2017), where FD students tend to make procedural errors, organize data, manipulate systematically, and draw conclusions, and is not in line with the research of Amalia (2017), which states that FD students also make mistakes in understanding problems. Other supporting research is from Murtafiah & Amin (2018), which states that FD subjects are less able to change verbal sentences into mathematical sentences and complete the steps correctly.

## CONCLUSIONS AND SUGGESTIONS

Based on the results of the scores from the mathematical modeling ability test, students in class XI IPA 2 fall into a fairly good category. In modeling problems, students who have a Field Independent (FI) cognitive style are able to understand real problems, prepare mathematical models from real models, and translate mathematical results into real situations. Students who have a Field Dependent (FD) cognitive style are able to understand real problems.

The researcher's suggestion to teachers who teach is to use an appropriate model to improve students' mathematical modeling abilities and carry out learning evaluations to reduce misconceptions experienced by students. As for suggestions for students to do more exercises in the form of word problems or literacy and increase knowledge from various sources. The final suggestion for other researchers is that other researchers can find out the relationship between mathematical modeling abilities by using expert indicators, materials, or other student characteristics.

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