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Persistent Errors in Solving Linear Programming

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***Abstract*—Students have experienced errors in solving linear programming so that it could affect their performance and learning in this subject. The present study analyzed the errors using an in-depth error analysis on linear programing students' problem solving efforts at different points in this subject to predicting student difficulty on some test items which are most persistent. Results indicate that various types of errors occur in different points and this is an indication of linear programming achievement difficulties. Many of the errors made by students are due to concept and procedural errors in solving linear programming. Recommendations for the necessity of certain errors are discussed.**

Keywords: error analysis, linear programming

I. Introduction

Mathematics is a universal science that underlies technological development, has an important role in the mastery of various scientific disciplines and also in everyday life [1,2]. The object of study in mathematics is facts, concepts, operations, and principles that have abstract character. With mathematical characteristics like this, more careful efforts are needed to see the responses given by students to every problem that exists in mathematics [3].

Algebra is a very important component in mathematics [4-6]. One of the algebra courses in the mathematics education study program is linear programming. The implementation of linear programming in daily life covers a variety of fields, including technology, finance, and others [7]. But until now there are still many students who consider this subject as a difficult subject so their grades in this course are not satisfactory.

The low ability of students in a course can be measured by students' mastery of the material being taught. One way is to provide tests or questions about the material to students. Student errors in completing the problem can be used as a clue to know the extent to which students master the material. Therefore, the existence of these errors needs to be identified, then sought solutions to resolution, thus information about errors in solving mathematical problems can be used to improve students' abilities in lectures [1,8]. Furthermore, specifically identifying student errors is very important to help students who experience difficulties and have low academic ability. By identifying students' errors, the teacher can provide teaching that is centered on the needs of students [9].

Errors are defined as inaccuracies in the process of solving mathematical problems, either algorithmically, procedurally, or can be seen with other techniques [7]. Relevant research conducted by Bell shows that errors in solving mathematical problems, one of which is caused by errors in reading mathematical problems encountered. Students tend to read material directly but are unable to understand what they read [10]. Therefore, a mature understanding of concepts must be possessed by students so that problem solving can be solved correctly and appropriately [11].

Based on the background description, the source of the error that comes from the student must immediately get a solution by analysing the main problem that causes a student to experience an error in solving the problem. Thus, this study aims to analyse student errors in solving linear programming problems. By describing the errors of students in solving linear programming problems, it is expected that lecturers can provide appropriate scaffolding and can improve students' abilities in linear programming.

II. Methods

This type of research was qualitative research. The subjects in this study were students in semester 4 of the academic year 2018/2019 who took linear programming courses as many as 18 students. Data collection techniques in this study were tests and interviews. The validity check in this study used triangulation techniques. Triangulation is a data validity checking technique that utilizes something other than the data for checking or as a comparison of that data [12]. In this research, the type of triangulation used was triangulation with sources, namely by comparing the test observations data with the interview data. Data analysis conducted refers to the qualitative data analysis of the Miles and Huberman model namely, data reduction, data presentation and conclusions [13].

Errors analysis in this study used an in-depth error analysis on linear programming students' problem-solving efforts at different points in this subject to predicting student difficulty on some test items which are most persistent. Error analysis conducted in this study included error analysis in making mathematical models and error analysis in solving linear programming problems using graphical methods. The indicators of each error analysis were as follows.

1) Errors in making mathematical models. Students are considered to make this error, if students:

- not writing analogy variables used in making mathematical models,
- there is an error in analogy variables used in making mathematical models,
- not writing mathematical model,
- not writing non-negative boundaries, or
- the mathematical model created is not following the information about the problem.

2) Error in solving linear programming with the graph method. Students are considered to make this error, if students:

- make an error in drawing a linear programming graphic,
- incomplete in drawing linear programming graphics,
- make an error in shading the solution area,
- make an error in determining the optimal point, or
- make an error in determining the optimal solution result.

III. Results and Discussion

The results of data analysis of all types of errors made by students in solving linear programming were as follows.

TABLE I. STUDENT ERROR TYPE

Type of Errors	Number of Errors	Percentage of Errors
Errors in making mathematical models	11	61,11%
Error in solving linear programming with the graph method	10	55,56%

In the types of errors in making a mathematical model, there were four types of errors and the causes of students making these errors which are presented in Table II.

TABLE II. TYPES OF ERRORS IN MAKING MATHEMATICAL MODELS

Type of Errors	Cause of Errors
Not writing analogy variables used in making mathematical models	Lack of understanding of the problems, so it cannot determine which information should be assumed
there is an error in analogy variables used in making mathematical models	Lack of accuracy in reading information about problems and for analogy variables that have been made
not writing non-negative boundaries	inaccurate
the mathematical model created is not following the information about the problem	Lack of understanding of the problems, fooled by the information provided on the questions

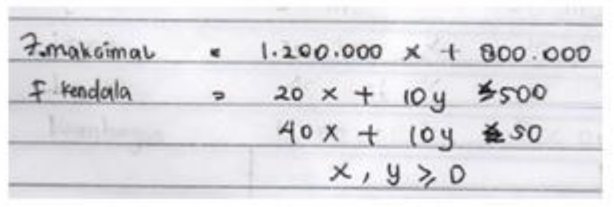

Fig. 1. Example of students errors in making mathematical models.

Figure 1 is one of the results of the work of students who made errors in making mathematical models. The results of student work in Figure 1 show that students have been able to make mathematical models, but the mathematical models arranged are not following the information conveyed in the questions. In the problem mentioned that every month the most sold TV in types 27 inc as many as 40 units and 20 inc as many as 10 units. This means when arranging constraints adapted to the most number of units sold each month. If we suppose that x is the number of 27 inc TVs sold and y is the number of 20 inc TVs sold, the appropriate constraint function for the statement is $x \leq 40$ and $y \leq 10$. The constraint function written by students is $40x + 10y \leq 50$. Besides errors in writing the constraint function, students also make errors in writing the objective function of the mathematical model, where the variables used in the objective function are not written down. This shows that there is an error of mathematical models compiled by students with the information conveyed about the problems. The results of interviews between researchers (R) and students (S_1) are as follows.

R : What you do after making an analogy of variables?

S_1 : Write the objective function, because what is requested is how much production to reach the maximum profit of the company, meaning that what is required is a maximum Z. This means that the maximum Z is $1.200.000x + 800.000y$

R : Where is y in the objective function?

S_1 : Oh yeah, I forgot to write the y variable. I'm not careful, ma'am.

R : Then after compiling the objective function, what do you do next?

S_1 : Determine the function of the obstacle. Here for hour constraints is $20x + 10y \leq 500$. Next to constraints the number of units sold is $40x + 10y \leq 50$.

R : Why is the constraint function for the number of units sold is $40x + 10y \leq 50$?

S_1 : Because TV in 27 inc types is sold 40 units and 20 inc is sold 10 units each month. If added together every month, 40 + 10 = 50

The results of the interviews showed that students made errors in making mathematical models due to the lack of accuracy of students in writing the objective function so that there were missed variables and student errors in determining the constraint function due to lack of understanding of the information contained in the problem. Lack of understanding of the information about problems results in errors transforming the problem into a mathematical model.

Errors in writing variables in the objective function and errors in operating the variables in the constraint function indicate that students lack an understanding of the concept of linear programming. Errors that are often made in solving algebraic problems are mistakes in understanding the concept of algebraic material itself [14]. Furthermore, the cause of students' mistakes in solving the problem of the word Social Arithmetic is that the subject cannot interpret the intended keywords and cannot understand the vocabulary/key variables in the Social Arithmetic material, the subject cannot determine what is known in detail, not identifying exactly what is known to cause misinterpretation, not reading the question carefully so that there is information missing, lacking in various exercises so that it cannot immediately solve different problems, not understanding the whole problem properly so that it is not consistent in identifying what is known, and not being able to explain the information in the problem precisely [15]. Rohmah and Sutiarso's research results also state that the error factor in solving the mathematical problem is students are not able to absorb the information properly, students do not understand the so-called problem transformation, students do not fully understand the material [2].

Effective instructional techniques for overcoming errors in making mathematical models is to use representations as using tables as a tool in making mathematical models [14]. Appropriate scaffolding of errors made by students in the stages of understanding and transformation is to provide an explanation of the purpose of the problem (explaining), giving questions or review of the purpose of the problem (Reviewing), giving examples of problems similar to the problems faced students (restructuring), and provide direction to make mathematical models (developing conceptual thinking) [4,16].

In the type of error in solving linear programming with the graph method, there are four types of errors and the causes of students making these mistakes which are presented in Table III.

TABLE III. TYPES OF ERRORS IN GRAPH METHOD

Type of Errors	Cause of Errors
make an error in drawing a linear programming graphic	Inaccurate in determining the intersection of the line equations on the constraint function, wrong in making the boundary line constraint function
incomplete in drawing linear programming graphics	Forgot to write the X-axis and Y-axis
make an error in shading the solution area	Difficulty in determining the shaded area following the existing constraint functions
make an error in determining the optimal solution result	Calculation error when entering into the objective function

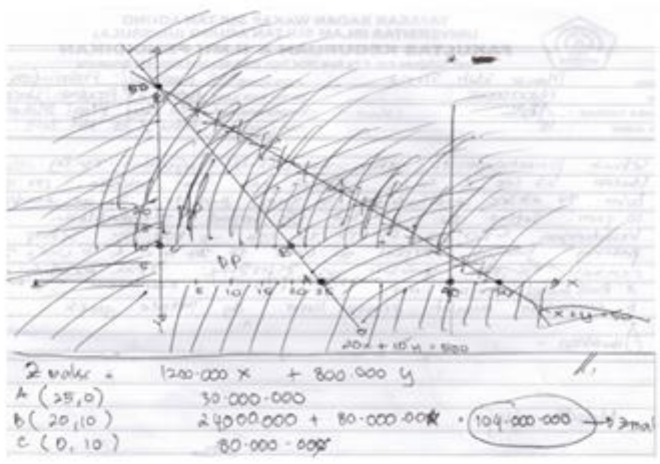

Fig. 2. Example of students errors in graph method.

Figure 2 shows one of the results of student work that made a completion error using the graph method. Students have been able to draw graphs of completion precisely, but students make mistakes in performing calculation operations when calculating the objective function. Given the objective function of the linear programming is $1.200.000x + 800.000y$. When searching for a point the maximum destination function is at point B (20, 10) students make a calculation error that is $800.000 \times 10 = 80.000.000$. This results in the maximum Z result obtained by the student incorrectly. The results of interviews between researchers (R) and students (S_2) are as follows.

R : how do you determine the maximum value of the objective function?

S_2 : by entering the boundary points in the result area in the objective function

R : What is the max Z value that you get?

S_2 : The maximum Z value is at point B(20, 10) so we put it in the objective function to be $(1.200.000 \times 20) + (800.000 \times 10)$ = 24.000.000 + 80.000.000 = 104.000.000

R : Is the answer correct?

S_2 : ... (look back at the answers). Oh yeah ma'am, I'm not careful. Should be $800.000 \times 10 = 8.000.000$ not 80.000.000.

The results of the interviews showed that students made mistakes in performing mathematical calculation operations in determining the maximum objective function due to a lack of student accuracy. This indicates a procedural error in solving the problem.

Procedural error is a mistake that is pretty much done by students because students are not careful in doing the calculation process of problem-solving [2,11]. Effective instructional techniques for increasing student ability in solving linear programming with the graph method is students should be better doing more exercise and re-check the answer sheet before they submit it [15]. Rahayanungsih and Qohar further said that proper scaffolding in overcoming procedural errors is asking students to review the results of their work (reviewing) [16].

IV. CONCLUSION

The types of errors made by students in making mathematical models include: Not writing analogy variables used in making mathematical models, there is an error in analogy variables used in making mathematical models, not writing non-negative boundaries, and the mathematical model created is not following the information about the problem. The cause of errors in making mathematical models is due to the lack of students' understanding of the problems given and errors in making models of problem transformation into mathematical models. Therefore, the lecturer needs to provide the right scaffolding so students can understand the given problem well. This can be done by asking students to make a table to summarize what information is conveyed in the problem, provide an explanation of the purpose of the given problem, give questions, give similar examples, and provide direction to make mathematical models.

The types of errors made by students in solving the graphical methods include: make an error in drawing a linear programming graphic, incomplete drawing of linear programming graphics, make an error in shading of the solution area, and make an error in determining the optimal solution results. The cause of errors in solving the graph method is due to procedural errors in making graphics and inaccurate students in doing mathematical calculations. Therefore, the lecturer needs to give lots of practice questions and remind students to always check their work before it is collected.

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