The analysis of students’ learning difficulties on system of linear equation in two variables topic

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Abstract. This study objectives was to determine student’s error profile, student’s misconception, cause of student misconception, and students learning difficulties on system of linear equation in two variables topic. The research was carried out by giving test of concept understanding on that topic. Subject of the study were junior high school students who had studied the topic. The results of the study revealed that there were the students’ error profile, six students' misconception profiles, four causes of students’ misconceptions, and seven causes of learning difficulties. Based on the results of the students test it was found 71% of students had difficulty in determining the solution of system of linear equations in two variables algebraic form. This indicated students had difficulty in using, utilizing, and choosing a particular procedure on this topic. In addition, from the results of teacher’s interview, it was found one of the cause students’ misconception to be the inaccuracy definition of system of linear equation in two variables (SLETV). Students learning difficulties were mostly derived from student learning activities at school.

1. Introduction
One of the objectives of junior high school mathematics learning in Indonesia is that students have the ability to understand the concept of linear equation in two variables (LETV). There were several prerequisite knowledge to be able to study SLETV topics, one of which is LETV [1]. In fact, there were various problems with the knowledge of these prerequisites. First, the problem was found in Indonesia, students were wrong in calculating “1 − 5 x (−2) = (−4) x (−2) = −8” [2]. Second, the problem was in Singapore that the students misinterpret the meaning of parentheses. The students are asking to simplify the equation, there were 12% of students who incorrectly simplify the equation with an answer “(2xy − y) + y = 2xy − y²” [3]. Third, the broader problem finding is the low percentage of 8th grade students who were able to solve TIMSS questions in 1999 and 2007. Figure 1 presents the TIMSS’s 1999 question on the linear equation in one variable (LEOV) topic, students are asking to find the value “x”.

Figure 1 TIMSS’s 1999 Question on LEOV Topic [4].
Based on the TIMMS 1999 report for the questions in Figure 1, the percentage of all participants who were able to solve the problem was 44%, while the percentage of participants from Indonesia was 18% [4]. Figure 2 presents a TIMMS’s 2007 question that asks students to determine the amount of money needed to buy some items. The percentage of Indonesian participants who were able to solve the problem was obtained by 8% [5].

| Joe knows that a pen cost 1 zed more than pencil. His friend bought 2 pens and 3 pencils for 17 zeds. How many zeds will Joe need to buy 1 pen and 2 pencil. |

Figure 2 TIMSS’s 2007 Question that Asking to Make Mathematical Equations [5].

Fourth, the other problem in LEOV topic was found in Indonesia, students add and multiply the variables incorrectly "2x + x = 2x^2" and "2 (2x + 5) = 4x + 5" [6]. The researcher conducts a preliminary study in one of middle school in Bandung, there were student errors on LETV topic. Students claim the equation "xy + y = 4" is an example of LETV and the inaccurate definition of "SLETV" also found in the teacher's lesson plan, namely "Two-variable linear equation systems are two equations linear two variables that have a relationship between the two and have one solution ".

There were several ways to identify student learning difficulties in learning mathematics, especially on the topic of SLETV is through knowledge prerequisite approaches and conceptual error approaches [7]. Knowledge prerequisite approaches are used to detect student learning difficulties through student failure in terms of knowledge prerequisites for certain basic competencies and conceptual error approaches are used to diagnose student failures through conceptual errors [7]. The SLETV topic requires knowledge prerequisites such as arithmetic operations on variables, making PLSV from a given condition, determining LEOV solutions, and making LETV. SLETV requires the right initial definition so that students are able to understand SLETV-related matters well, such as determining SLETV examples, creating SLETV and determining SLETV solutions. The term difficulty refers to the obstacles that cause students’ errors [8]. As a result the term student learning difficulties in this study refers to constraints in the form of conceptual errors (misconceptions) on the topic of SLETV and knowledge of SLETV prerequisite or mistakes made by students when answering questions.

This study had 3 research question. First, “What is the profile of students’ errors when answering questions on the topic of SLETV?”. Second, “What is the profile and cause of students’ misconception on the topic of SLETV?”. The last research question is “What is the profile of students’ learning difficulties on the topic of SLETV?”.

2. Methods
2.1. Methodology
This research uses qualitative method which is a type of research that addresses issues based on the viewpoint of the subject that collects data mostly of words from subject, explains and analyzes words for some research conclusions [9]. So the researcher uses a written test and followed by interviewing individual students based on student work and teacher interviews to find out the description of the material that the teacher teaches students and the teacher's understanding of the SLETV topic. The subject in this study was 118 junior high schools students in Indonesia who had learn SLETV topic.

2.2. Data Collection
The whole data will be compared for each component to find common ground, those common will be divided in to several categories [10].The detail of the way to collecting data. Firstly, the written test on the SLETV topic in two tier multiple choice [11]. Secondly, semi-structured interviews were conducted for 30 students to explore the reasons behind student work and interviews with a mathematics teacher who taught the three classes to find out the teacher's understanding of the SLETV topic or preparation of SLETV material that had been taught to students.

3. Result and Discussion
3.1. Result
The results of research and discussion are obtained in the form of students’ error profiles, students’ misconception profiles, causes of students’ misconceptions, and profile of student learning difficulties. Students’ mistakes on the topic of LETV are grouped into four categories, namely arithmetic errors, algebraic forms, variables, and mathematization [6]. There were 448 errors found in the students with percentage details as follows algebraic forms 23%, Arithmetic 8%, Variable 63%, and Mathematization 6%. The most errors obtained by students occurred in the variable category as many as 282 errors. This shows that students were not understand the variables. Found 6 student misconceptions on SLETV topic to be presented in Table 1, there are 4 causes of students’ misconception on SLETV topic which will be presented in Table 2, and 7 students’ learning difficulties on SLETV topics and the percentages that will be presented in Table 3.

| No | Misconception                                                                 |
|----|------------------------------------------------------------------------------|
| 1  | Each variable in LETV has a value of at least 1                               |
| 2  | There were multiplications between two variables (example : \(xy + y = 4\))   |
|    | Students think the power of variables \(x\) and \(y\) in the example does not have the power of numbers (example : \(x + y = 4\)) |
| 3  | SLETV are combined of 2 LETV                                                  |
| 4  | The equation that has two variables is a LETV (example : \(xy + y = 4, x^2y + xy = 2\)) |
| 5  | Each variable in LETV has a value of at least 2                               |

Table 1. Students’ Misconception on SLETV Topic.

| No | Causes of Students’ Misconception                                           |
|----|----------------------------------------------------------------------------|
| 1  | The teacher does not explain to students about LETV that there is no multiplication between the variables |
| 2  | The teacher does not explain to students the example of the equations of two other variables that do not include in LETV |
| 3  | The inaccuracy of the definition of SLETV in the teacher’s lesson plan     |
| 4  | Inaccuracy of LETV definitions in textbooks                                 |

Table 2. The Causes of Students’ Misconception on SLETV Topic.

| No | Students’ Learning Difficulties                                      | Percentage |
|----|---------------------------------------------------------------------|------------|
| 1  | Restate the definition of LETV                                      | 66%        |
| 2  | Determine the examples and non-examples of LETV                     | 69%        |
| 3  | Determine the causation of an equation that includes LETV           | 61%        |
| 4  | Determine the example of SLETV                                      | 58.66%     |
|    | Determine the value of the relationship between width and length of the rectangle in LETV form | 45.33%     |
| 5  | Determine an SLETV solution in algebra form                         | 71%        |
| 6  | Determine the relationship of the value of two variables to the word problem in the SLETV form | 49.66%     |

From Table 3, it was found that students experienced 7 difficulties on the topic of SLETV. The highest percentage of difficulties is “students have difficulty determining SLETV solutions in the form of algebra” with a percentage of 71%. This shows that students still have difficulty in using 3 methods to determine the solution of SLETV.

3.2. Discussion
3.2.1. Students’ Answers
Regarding to some errors in arithmetic category (students are asked to determine the sum value of the variables \(p\) and \(q\), where the variable \(p\) is the variable \(x\) and the variable \(q\) is the variable \(y\) which is the solution of SLETV) it is found that students make a reduction for two LETV and an error occurs when
determining the result of “$-2q - (2q) = 0q$” so that it can be said that student was wrong in conducting arithmetic operations on SLETV questions in the form of algebra. Additionally, they show some error in making algebraic form in LETV equations between width and length of the rectangle, where perimeter of rectangle and the width of the rectangle are known.

It is found that student assume that there are multiplications between the two variables in LETV, so that it can be said that student make mistakes when explaining variable characteristics in LETV or incorrectly explaining variable characteristics in LETV. Furthermore, it is obtained that students substitute the value of the rectangular width on the variable representing the length of the rectangle, then continue until the rectangular width is found, so that students can be said to make mistakes when asked to make LETV from a given condition.

3.2.2. Findings from Students’ Interview

From the interviews, students found students’ misconceptions on SLETV topic. The following will be presented in one conversation when the researcher interviews the students. The conversation below presents the characteristics of LETV written by students in accordance with students’ knowledge, found students’ misconception is "the power of numbers of each LETV variable is at least 1".

R = Researcher, S1 = 1st Student

R: What do you think about the characteristics of LETV according to S1? Try writing it down.

S1: Already sir ... (Fig. 7.)

P: OK. I want to ask, does the power of numbers of variables in LETV have a minimum of 1. For example there is a LETV, may I change the power of numbers of it to 1000 or –1?

S1: You can't sir ...

P: why can't?

S1: because if -1 is not an integer sir, whereas 1000 is not allowed.

P: OK. So what is the rule for the power of numbers of LETV? At least one or a maximum of one? or one?

S1: we’ll, yes sir. one.

3.2.3. Findings from Teacher’s Interview

From the results of interviews with teachers, there were found several causes of student misconceptions that is "the teacher did not explain to students that there was no multiplication of variables (example: $xy + y = 4$) in LETV and the teacher did not provide examples of equations that have two variables but not LETV ".

R = Researcher, T = Teacher

R: when you explain the characteristics of LETV. Did you also explain that there should be no multiplication between variables in LETV?

T: hmm, that’s true that can’t be multiplication between the variables

R: I mean the one like before, ma’am ... there is the $xy$ ... or, for example, you also explains that there are similarities between two other variables which are not included in LETV, such as quadratic equations or circles.

T: hmm, it can’t be ... I did not explain that and I do not explain also that there are similarities between two other variables which are not included in LETV.

4. Conclusion

Based on the results obtained that student error profiles that were found 6 profiles of students’ misconceptions on SLETV topics, 4 causes of students’ misconception, and 7 students’ learning difficulties on SLETV topic. In general, the causes of students’ misconceptions and learning difficulties come from teaching and learning activities in schools, this is obtained from teacher interviews.
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