Analysis of Student Errors in Solving Ordinary Differential Equations Based on SOLO Taxonomy

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Abstract. This study aims to describe the errors of student in solving ordinary differential equation (ODE) problems based on SOLO taxonomy. In this case there are 5 kinds of errors, namely concept errors, using data, language interpretation, technical, and making conclusions. This descriptive study involved 10 ODE research subjects. The research results obtained are the subjects of research tends to make mistakes in the five SOLO taxonomy errors. The reason is because students are not skilled in using formulas, are not thorough, and the habit of not repeating lessons.

1. Introduction

Ordinary Differential Equations (ODE) is one of the subjects in the Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang. It has an extensive application covering several scientific disciplines, such as engineering, biology, physics, chemistry, medicine, psychology, economics and so on. Real problems in these sciences most mathematical models are expressed in the form of differential equations.\cite{1}

Realizing the importance of the role of ODE, it is desirable that students master ODE courses well in accordance with the demands of the applicable curriculum, but until now students' mastery of ODE material is still relatively low. Students still tend to make mistakes in solving applied questions related to daily life. They have difficulty making mathematical models in the form of ordinary differential equations. Therefore it is necessary to analyze the answers of students in order to minimize the mistakes made.\cite{2}

The mistakes by students need to be analyzed further, in order to get an overview of the weaknesses of students in the test. This error can also be a clue to the extent to which students have mastered ODE.

An alternative to describe and analyze errors made by students in completing the test by determining the quality of student’s answer using the SOLO taxonomy (Structure of the Observed Learning Outcome) or the structure of observable learning outcomes. In the SOLO taxonomy there are five levels in classifying the students' abilities, namely prestructural (P), unistructural (U), multistructural (M), relational (R), and extended abstract (EA).\cite{3}

SOLO taxonomy level can be used to determine the level of a problem, and quality of response/analysis of tasks given to students. In this study, the taxonomy of SOLO was used to compile items and determine the level of the problem and as a basis for studying student errors.

The SOLO taxonomic question criteria, otherwise known as superitem, they are (1) un-instructural questions using a clear and direct information from the problem, (2) multi-structural questions which
are questions using two or more and separate information contained in the question, (3) questions relational is a question by using a problem from two or more information contained in the question, (4) extended abstract question is a question using abstract general principles or hypotheses derived from information in the problem or suggested by information in the problem. [4]

Error analysis is done by using the type of error according to Subanji and Mulyoto. [5] The types of student errors in solving ODE problems are as follows.

1.1. Concept Error (CE)
The indicators include (i) errors determining the theorem or formula in answering a problem and (ii) the use of theorems or formulas by students is not in accordance with the conditions of the prerequisite for the enactment of the formula or does not write the theorem.

1.2. Error Using Data (ED)
The indicators include (i) not using the data that should be used, (ii) errors entering data into variables, (iii) adding data that is not needed to answer a problem.

1.3. Language Interpretation Error (LE)
The indicators include (i) errors in expressing everyday language in mathematical language and (ii) errors in interpreting symbols, graphs, and tables into mathematical language.

1.4. Technical Error (TE)
The indicators include (i) miscalculations, (ii) errors in manipulating algebraic operations.

1.5. Error making conclusions (EC)
The indicators include (i) conducting conclusions without the right supporting reasons, (ii) concluding unauthorized statements with logical reasoning.

2. Methods
This type of research is descriptive research with goal to describe the mistakes of students in solving ODE problems based on SOLO taxonomy. The research was conducted at the Mathematics Department of the FMIPA Universitas Negeri Padang. The research subjects were 10 students selected based on the test scores of the first stage of students in the ODE course. The details of taking the research subjects were three subjects from the high group, four subjects in the middle group, and three subjects in the low group.

The data collection technique in this study was through giving a test. The results of the tests were analyzed to determine the type of errors made, then interviews were conducted to confirm the errors and find out the causes of the mistakes made by the research subjects.

Data analysis techniques are carried out by stages (1) data reduction, (2) data presentation, (3) conclusions or verification. Triangulation is done to check the validity of the data. The instruments of this research are test questions and interview guidelines.[6]

3. Results and Discussion
After ODE learning is complete, a test is given. The results are shown in Table 1 and Table 2. In Table 1 we see that the subject made a mistake almost every number of questions. However, research subjects tend to make mistakes in questions number 3 and 4, namely a matter of multi-structural and relational levels. In question number 3 the subject tends to make a concept error while in question number 4 the subject tends to make a conclusion. Then, there are still subjects who don't provide answers to extended abstract level questions, such as subjects M2, M3, L1, L2, and L3.
### Table 1: Types of Research Subject Errors on The Test-1

| Group | Code | Subjects | Unistructural | Unistructural | Multi-structural | Relational | Extended Abstract |
|-------|------|---------|---------------|---------------|------------------|------------|------------------|
| Hight | H1   |         | √             | √             | √                |            |                  |
|       | H2   |         | √             | √             |                   | √          |                  |
|       | H3   |         |               |               | √                |            |                  |
| Middle| M1   |         |               |               | √                |            |                  |
|       | M2   |         |               |               |                   |            |                  |
|       | M3   |         |               |               |                   |            |                  |
|       | M4   |         |               |               |                   |            |                  |
| Low   | L1   |         | √             |               |                   |            |                  |
|       | L2   |         | √             |               |                   |            |                  |
|       | L3   |         |               |               |                   |            |                  |

### Table 2: Types of Research Subject Errors on The Test-2

| Group | Code | Subjects | Unistructural | Unistructural | Multi-structural | Relational | Extended Abstract |
|-------|------|---------|---------------|---------------|------------------|------------|------------------|
| Hight | H1   |         |               |               | √                |            |                  |
|       | H2   |         | √             |               |                  |            |                  |
|       | H3   |         |               |               |                   |            |                  |
| Middle| M1   |         |               |               | √                |            |                  |
|       | M2   |         |               |               |                   |            |                  |
|       | M3   |         |               |               |                   |            |                  |
|       | M4   |         |               |               |                   |            |                  |
| Low   | L1   |         | √             |               |                   |            |                  |
|       | L2   |         |               |               |                   |            |                  |
|       | L3   |         |               |               |                   |            |                  |

**Information:** CE (Concept Error), ED (Error Using Data), LE (Language Interpretation Error), TE (Technical Error), and EC (Error Making Conclusions)
Based on Table 2, we can see that the research subjects made mistakes, where the errors almost occurred in each of the problem numbers. However, the research subject's error has been reduced compared to the 1st test. In addition, research subjects still tend to make mistakes on questions number 3 and 4, namely the question of multi-structural and relational levels. In question number 3 the subject of research still tends to make a concept error while in question number 4 the subject of research makes a technical error. In the second test there are still subjects who did not provide answers, namely at the relational level and the extended abstract level.

The detailed results of the analysis of errors made by students are as follows.

3.1. High Group Research Subjects (H1)
H1 research subjects were able to reach the extended abstract level, where H1 was able to understand the questions correctly, was able to plan and solve the problem well, and H1 was able to connect other data and processes so that they got new generalizations. The following types of errors and causes of H1 errors.

H1 made a mistake on questions number 3, 4, and 5. Errors made include (a) Concept errors, namely: 1) incorrect use of the formula, 2) incorrect in determining the steps to solving the problem; (b) Technical error, namely calculation error; (c) The mistake of making a conclusion is to conclude an invalid statement with logical reasoning. The causes of errors tend to not be able to set the processing time of the questions properly and not carefully in answering the questions.

3.2. High Group Research Subjects (H2)
H2 research subjects were able to reach the extended abstract level, in this case H2 was able to understand the questions correctly, could plan and solve the problem well, and H2 was able to connect the data and other processes so that they got new generalizations. The following are the types of errors and causes of H2 errors.

H2 made a mistake on questions number 2 and 3. Errors made included (a) Concept errors that were wrong in using the formula; (b) Technical error, which is a calculation error. The cause of the error is not being careful and rarely repeating the lesson.

3.3. High Group Research Subjects (H3)
The H3 research subjects were able to reach the extended abstract level, where H3 was able to understand the questions correctly, could plan and solve the problem well, and H3 was able to connect other data and processes so that they obtained new generalizations. The following types of errors and causes of H3 errors.

H3 made mistakes on all questions in the first test while on the second test, H3 made a mistake about questions number 3 and 4. Errors made included (a) Concept error that is wrong in using the formula; (b) Errors using data that is not using data that should be used to solve problems; (c) Erroneous interpretations of language, namely incorrect writing of information in the question; (d) The mistake of making a conclusion is to conclude an invalid statement with logical reasoning. The causes of mistakes made tend not to be careful in answering questions.

These results indicate that high-level research subjects can reach the extended abstract level. This is in line with the research [7], tells that subjects capable of high mathematics were able to reach the extended abstract level.

3.4. Medium Group Research Subjects (M1)
M1 is able to solve the problem to the un-structural level, where M1 is able to understand the problem by using some information but has not been able to plan and solve the problem well. The following types of errors and causes of S1 errors.

M1 made a mistake on all questions in the first test while in the second test, M1 made a mistake about number 2 and 3. Then there was no answer given M1 on questions number 4 and 5 because he could not understand the purpose of the problem. Mistakes made include (a) Concept errors, namely: 1) incorrect use of formulas, and 2) incorrect in determining steps for solving problems; (b) Technical error which is wrong in the calculation process; (c) The mistake of making a conclusion is to conclude an
invalid statement with logical reasoning. The cause of the error is that it tends to not be careful about answering the questions.

3.5. **Medium Group Research Subjects (M2)**
M2 research subjects were able to solve the problem to an un-structural level, where M2 was able to understand the problem by using some information but had not been able to plan and solve the problem well. The following types of errors and causes of M2 errors.

M2 made a mistake about number 3 and there was no answer to question number 5. In the second test, M2 made a mistake on all the questions. Errors made include (a) Concept errors that are wrong in using the formula; (b) Errors using data that is not using data that should be used in problem solving; (c) Technical error which is wrong in the calculation process; (d) The mistake of making a conclusion is to conclude an invalid statement with logical reasoning. The causes of mistakes made tend to be inaccurate, unable to manage the processing time of the questions properly, and do not have the skills to associate information in solving problems.

3.6. **Medium Group Research Subjects (M3)**
M3 research subjects were able to solve the problem to an un-structural level, where M3 was able to understand the problem by using some information but had not been able to plan and solve the problem well. The following are the types of errors and causes of M3 errors.

M3 made a mistake on questions number 2, 3, and 4. In the second test M3 did not provide answers to questions number 4. Likewise in question number 5. Errors made include (a) Concept errors that are wrong in using the formula; (b) Technical error which is wrong in the calculation process; (c) Errors make conclusions, namely concluding unauthorized statements with logical reasoning. The causes of mistakes made tend to be inaccurate, do not understand the concept.

3.7. **Medium Group Research Subjects (M4)**
The M4 research subject was able to solve the problem to an un-structural level, where M4 was able to understand the problem by using some information but had not been able to plan and solve the problem well. The following types of errors and causes of M4 errors.

On the first test, M4 made a mistake on all questions. Whereas in the second test M4 made a mistake about number 3 and 5. Then there was no answer in question number 4. Errors made included (a) Concept errors they are 1) incorrect use of formulas, and 2) incorrect in determining completion steps question; (b) Errors using data that is not using data that should be used; (c) The mistake of making a conclusion is to conclude an invalid statement with logical reasoning. The causes of mistakes made tend not to be thorough, do not understand the concept.

These results indicate that subjects capable of middle mathematics are only able to reach un-structural levels. This is not in line to [7] who said that subjects capable of middle mathematics were able to reach multi-structural levels.

3.8. **Low Group Research Subjects (L1)**
The L1 research subject was able to solve the questions up to the Uni-structural level, where L1 was able to understand the problem by using some information but was unable to plan and solve the problem well. The following types of errors and causes of L1 errors.

In the 1st test L1 was only able to answer questions number 1. In the second test, L1 made a mistake in question number 1. There were no answers given to questions number 3, 4, and 5. Errors made included conclusions namely conclude unauthorized statements with logical reasoning. The cause of the error L1 did not accurately answer the question.

3.9. **Low Group Research Subjects (L2)**
The L2 research subject was able to solve the problem to an un-structural level, where L2 was able to understand the problem by using some information but had not been able to plan and solve the problem well. The following types of errors and causes of L2 errors.

L2 made a mistake on questions number 3 and 4. There is no answer given in question number 5. Errors made include (a) Concept errors include 1) errors using formulas, and 2) incorrect in determining
steps for solving problems; (b) Technical errors include errors in the calculation process; (c) Errors in using data include not using data that must be used. The cause of mistakes made is not understanding the concept, and not understanding the intent of the problem correctly.

3.10. Low Group Research Subjects (L3)

The L3 research subject could not be identified as a mistake, because he could not understand the questions given, so L3 tended not to give answers during the first test or the second test. However, L3 can write down the unknown and ask on all questions. So it can be said that L3 has reached the un-structural level because it has fulfilled the un-structural level indicator that is using an information available in the question to answer the question in this case by mentioning things that are known and asked about the problem. [8] This was also reinforced during interviews, researchers guided L3 in answering un-structural questions and it turned out that L3 was able to answer them. However, L3 cannot write the answer during the test. This is because L3 is not used to working on math problems and does not repeat lessons.

4. Conclusion

In conclusion, subjects with high mathematical abilities are able to reach an expanded abstract level. Those with middle and low ability are able to reach un-structural levels. Errors made by research subjects are (a) conceptual errors in the form of errors using formulas, errors in understanding the purpose of questions, and mistakes in determining the right steps in solving problems, (b) errors in using data that is not using data that must be used in solving problems, (c) language interpretation errors in the form of errors in writing information about questions, (d) technical errors in the form of errors in the calculation process, (e) mistakes in making conclusions, ie making conclusions without proper supporting reasons, and also not checking the answers.

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