Students’ difficulties on solving mathematical problem based on ESD objectives

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Abstract. The objective of this study was to analyze students’ difficulty on solving mathematical problem based on Education for Sustainable Development (ESD) objectives. One of ESD objectives is Clean Water and Sanitation used as context of mathematical problem given beside economic and social context. The method used in this study was descriptive qualitative research. The subject of this study were 34 high school students. They were tested mathematical problem deal with derivatives based on ESD objectives. Polya's problem-solving steps were used to analyze students’ difficulties on solving mathematical problems that focus on derivatives. The results showed that students have difficulty in devising a problem-solving plan which related to ESD context when they seek maximum value using the concept of the first derivative algebraic functions and they have error in determining the derivative functions. The conclusion is that students are able to solve mathematical problems but they have difficulties when meet the problem related with mathematical problems in the ESD context. This can serve as a basis for further research on the development of high school mathematics teaching materials based on ESD objectives to improve mathematical problem solving ability.

1. Introduction
Mathematical problem solving ability is one of the capabilities students must have. Polya in [1] stated that solving problems is a process of finding appropriate actions and strategies to achieve clearly understood but not immediately achievable goals. So, the type of non-routine mathematical problems that the solution is not immediately achieved can be categorized as a mathematical problem-solving. Mathematical problems based on the objectives of educational for sustainable development or ESD can be a non-routine problem due to non-routine issues. The ESD context is chosen because its application provides many benefits to both academic and non academic achievements based on Warju in [2].

In Indonesia, the ESD context is rarely used in mathematics learning, more widely used in science and social studies. This can be seen from research conducted by Prabawani [3] on eco-friendly education within the framework of ESD that was not specifically applied in mathematics learning. Thus, it would be something new if mathematical learning could be integrated with ESD objectives. This is in line with the UNESCO opinion in [4] that ESD should be integrated into the curriculum and textbooks or teaching materials in formal education, which consisted of early childhood education, primary and secondary education, vocational and training education, and higher education. Thus, mathematical learning needs to integrate ESD objectives. The way that can be done is by presenting the problems of mathematics in the context of ESD so that students are accustomed to deal with real life problems as an application of
mathematics that they learned and students do not feel that mathematics is just an abstract science in the form of numerical calculations.

One of the objectives of ESD is Clean Water and Sanitation was used as a context of mathematical problems in addition to economic and social context. This is in line with McKeon [5] that sustainable development generally includes three components: environment, society, and economy. If dealt with a mathematical word problem that is associated with the real-life context as mentioned above, students generally experience difficulties. This can happen because a mathematical word problem with the ESD context of derivative material requires the implementation of a series of arithmetic operations to obtain the right end result based on Ling et al [6] so that most students have difficulty in the process of solving the problem.

Juandi stated that there were several sources of problems in mathematics learning in the ESD context, namely development of methodology, didactic design, instructional media, assessment to measure ESD competence, and problems exploring the effects of treatment on achievement of ESD competencies [7]. Some of the problems described by Juandi become the motivation to know the difficulties of students in solving the mathematical problems based on the objectives of ESD through a study because not much research on ESD, especially in the field of mathematics education [7]. The results obtained are expected to be the basis for developing a methodology, didactic design, learning media, and assessment to measure ESD competence. For this purpose, this study was conducted with the aim of identifying students' difficulties in solving mathematical problems based on the objectives of Education for Sustainable Development (ESD).

2. Methods
This type of research was descriptive qualitative research. This research was conducted in one of high school in Bandung. Subjects in this study were students of grade XII SMA as many as 34 students with age range about 16-18 years.

The instrument used in this research was a test instrument consisting of five items of mathematical problem-solving with a time allocation of 90 minutes. The topic in problem solving given was derivative, especially on applying derivative to solve real problem. Derivative problems tested in this study were based on indicators of problem solving abilities in one of the objectives of ESD i.e. Clean Water and Sanitation that was ensuring the availability and management of water and sustainable sanitation for all. In addition, the mathematical problems provided were real problems in the ESD context in the economic and social spheres. The five items test instrument consisted of one item in the social context, two items in the economic context, and two items in the context of the environment. Types of mathematical problems given in the form of closed mathematical problems and outside of mathematics. That was the problem only had one correct answer and a real problem in daily life.

Furthermore, the test instruments that have been compiled were then validated by experts in the field of mathematics. Validation was done by considering the suitability of problem solving indicator with item, readability, suitability of language with good and correct Indonesian rules, depth of problem description according to student's level of development, and relevance of matter with competence that must be mastered. After validated by experts, the test instrument was used to test the students' mathematical problem solving abilities by seeking at students' difficulties in solving the mathematical problems. One week before implementation of the test, the researcher let the subject know that they will be tested, dealt with derivatives in ESD context. In the process of conducting the test, students were prohibited from using calculating tools such as calculators or mobile phones. At the time of execution of research, researcher acted as test supervisor and assisted by one observer to observe the course of the test progress.

After the research data in the form of student result data obtained, the data were then analyzed. To analyze the data, the first thing to do was to compare each student's answer result with score rubric. The score of each correct item was 10. So, if the student could answer and solve the problem correctly for all questions then the total score obtained was 50. In addition to scoring, analyses of student answers based on Polya [8] was also conducted. They are: 1) understanding the problem, 2) devising a plan, 3)
carrying out the plan and 4) Re-checking [8]. Each step of the Polya problem-solving process was given a score adjusted to the difficulty level of the problem. Each Polya problem solving step was used to analyze students' difficulties. The analysis was done to find out the difficulties of students in the process of solving mathematical problems based on ESD objectives in the form of qualitative analysis.

3. Result and discussion
The researchers conducted an analysis of each student's respond that were compared with the score rubric. The results of the student's respond were also analyzed based on the steps of problem solving according to Polya in [8] namely: 1) understanding the problem, 2) devising a plan, 3) carrying out the plan, 4) Re-checking. The results of the student's respond analysis that were compared with the scores rubric were shown in table 1.

| Item Number | The number of students respond appropriately | The number of students respond inappropriately | Information |
|-------------|---------------------------------------------|----------------------------------------------|-------------|
| 1           | 0                                           | 34                                           | Students experienced problems finding the derivative values of an algebraic function with a negative rank. Students experienced difficulty finding profit function that was function of selling price minus function of production cost. Students experienced difficulty connecting the concept of maximum and minimum values with the first derivative of the function. Students did not understand the concept of the speed function associated with the derivative. Students were able to solve the problem, but there are errors when calculation and error in determining the requested unit. |
| 2           | 5                                           | 29                                           |             |
| 3           | 17                                          | 17                                           |             |
| 4           | 11                                          | 23                                           |             |
| 5           | 20                                          | 14                                           |             |

Item number one presented a function in the form of fractions that could be transformed into a function with a negative rank, causing the student to be deceived and having an error while deriving the function. In the item number 1, no student answers correctly because students experienced difficulty in deriving function with negative rank. In this case, students are categorized as having difficulties when implementing the plan as the third step of problem-solving process based on Polya in [8] because of miscalculation in deriving the function.

The following is a sample of mathematical problem-solving based on the objectives of ESD, item number 2 that could be seen in Figure 1.
Since 2016, Indonesia achieved self-sufficiency in rice by not importing rice. This was due to an increase in national rice production. In an effort to achieve national food security, the government maximizes the agricultural sector so that rice imports can be avoided and otherwise can export rice abroad.

A company engaged in agriculture produces goods with production costs expressed in the function \( f(x) = 5000 + 2000x + 10x^2 \) rupiah. The selling price for one item is 7000 rupiah. Based on the illustration:

a. How many items are produced for maximum profit?

b. What is the maximum profit the company can make?

Figure 1. Mathematical problem-solving samples based on ESD objectives.

On the problem in figure 1, many students experienced difficulty in solving problems because they had not been able to determine the function of profit. The following is presented the results of students' respond that had been able to solve the problem properly and which were not. Results of students' respond who answered properly are presented in Figure 2 below.

![Figure 2](image1.png)

Figure 2. Results of students' respond who were able to solve the problem properly.

Figure 2 shows that the student rewrite what is known in the problem, according to the first Polya problem solving step so that the student is assumed to have understood the problem well. Students were then able to write a profit function or \( u(x) = 7000x - (5000 + 2000x + 10x^2) \). The student was able to understand that the profit function can be sought by subtracting the selling price function with the production cost function. In this case students have been able to develop a problem-solving plan by creating a new function that is profit function for later searched derivatives in order to obtain maximum profit value. Students are able to execute the problem-solving plan well when they were able to determine its derivative value and the calculation of maximum profit. However, the student had not written the complete unit that is used in rupiah. This needs to be emphasized so that students do not assume trivial in unit determination so that students will better understand what is actually asked in the problem. Results of students' respond who answered improperly are presented in Figure 3 below.

![Figure 3](image2.png)

Figure 3. Results of students' respond who were not able to solve the problem properly.

Figure 3 shows that the student did not write down what is known in the problem so that the student was assumed to lack understanding of the problem. It was also seen that students directly deriving the function of production costs when what was wanted was profit function. In this case, students were less careful in developing problem-solving plans, so that students have difficulty in the process of solving...
further problems. In other words, when the student had an error during the process of developing a problem-solving plan, the next problem-solving process would experience an error.

This showed that changing the mathematical problems in the daily life context based on the objectives of ESD into the form of mathematical model is a difficulty experienced by most students. This is supported by Jupri in [9] that the main difficulty of students in solving mathematical problems was when to formulate a mathematical model.

In the item number three and four, students had difficulty understanding the concept of first derivative applications in daily life context that was to find the maximum and minimum value and seek speed. Based on Singh in [10], this student's difficulties resulted from a mistake in understanding the problem when students were able to read the question well but students failed to understand what was needed to solve the problem.

In the item number five, most students had been able to solve problems in the ESD context well but there were little mistake in writing the requested unit. This students' difficulties as a result of encoding errors when the student had been able to solve the problem correctly but they failed to write the correct form and accepted answer because of the mistake of writing the unit based on Singh in [10].

By knowing the difficulties and mistakes of students in solving the mathematical problem based on ESD objectives, there will be many benefits obtained i.e. teachers can provide Learning Therapy so that students are able to improve their ability in solving mathematical problems based on Suyitno and Suyitno in [11] and can be used as a base in developing the appropriate teaching materials to improve the mathematical problem solving ability.

4. Conclusion

From the research that has been implemented, it can be concluded that students have been able to solve mathematical problems in the topic of derivative when they are asked to find the first derivative of an algebraic function. However, when dealt with mathematical problems in the ESD context, students experience difficulties. The student's difficulty is when it comes to change the real problems in the ESD context into a mathematical model. Most students experience errors in connecting the concept of minimum and maximum values with the first derivative of algebraic functions. In addition, there are also students who have been able to connect the concept but have errors in determining the value of derivatives and errors in determining the requested unit. Thus, students' difficulties in solving mathematical problems that need to be emphasized here are the first, students having difficulty determining the derived algebraic functions. Second, students have difficulty making problem-solving plans when dealt with mathematical problems in the ESD context. Third, students have difficulty in finding the maximum and minimum values using the concept application of the first derivative function. Lastly, the student are less careful in determining the unit requested in the question. Furthermore, students need help to understand the concepts of derivative applications in real life and techniques for deriving a function. This can serve as a basis for further research on the development of high school mathematics teaching materials based on ESD objectives to improve mathematical problem solving ability.

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