Analysis of mathematics student understanding: calculus concepts

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Abstract. The purpose of this study is to find out: (1) how well mathematics students in semester 2 of the academic year 2018/2019 UNU Purwokerto understand the concept of calculus, (2) the things that cause students’ difficulties in understanding the concept of calculus. The method used in this research is qualitative with descriptive methods. Furthermore, the technique of determining the source of data is using purposive sampling. The number of students selected as research subjects consisted of 12 students in the semester 2 mathematics study program year 2018/2019; in which 3 students were in the medium category and 9 students were in a low category. Meanwhile, there are 4 subjects chosen for the interview: 2 subjects of the moderate category and 2 subjects of the low category. There are two data taken in this study, they are the results of the conceptual understanding test and the results of the interview. Later on, the results of the tests and interviews will be validated by using triangulation methods. Based on the results and discussion of this study, the following conclusions are obtained: first, mathematics students’ understanding of the concept of calculus consists of a high category of 0%, a medium category of 25%, and a low category of 75%. Therefore, it can be concluded that the understanding of the concept of mathematics calculus for semester 2 students in 2018/2019 academic year is still low. The analysis of the understanding of the calculus concept of students of mathematics study program shows a higher understanding of integral material and lower on using the integral material. The second conclusion is the things that cause students’ difficulties in understanding the concept of calculus are students still learned by memorizing and they lack the motivation to repeat the material. Moreover, they rarely practice the questions and they learned only a little of basic concepts of mathematics in high school.

1. Introduction

Mathematics is a science that is obtained with reason. This does not mean that other knowledge is obtained not through reasoning, but in mathematics emphasizes activity in two ratios (reasoning). Thus, everyone in learning mathematics requires understanding or reasoning in depth. This can support students to be able to take the entrance test in college [1].

On the tertiary level, one of the few study programs that is interesting to students is the Mathematics Study Program. Including the NahdlatulUlama University in Purwokerto; there is a Mathematics Study Program that already has 3 batches of students from different school backgrounds. There are many students who come from high school majoring in Natural Sciences, Social Sciences and even from vocational schools. With diverse schools of origin taking into account the portion of hours of mathematics in high school or equivalent, surely students from the Science majors have more
understanding about Mathematics than other majors. In addition, students will also have a different level of difficulty in learning mathematics, especially calculus. Based on the results of the study, it shows that students' mathematical learning difficulty lies in factual knowledge 12.2%, conceptual knowledge 19.7%, procedural knowledge 20.7%, and metacognitive knowledge 47.4% [2].

In the curriculum of the Mathematics Study Program, there are basic subjects that are also studied during high school; one of them is Calculus. Calculus consists of three subparts: calculus 1, calculus 2, and advanced calculus. Material learned during high school or equivalents such as derivatives, integrals, and even limits is also a pre-requisite material for studying Calculus courses. The ability of students on these materials may become a factor that significantly influences student learning outcomes in Calculus courses. Previous researchers have shown that students’ mastery of pre-requisite material influences student or student learning outcomes [3, 4]. Besides, student's initial knowledge about certain material is the strongest predictor of student learning outcomes in certain subjects [5].

Based on the results of researchers’ experience, who both teach calculus in the course of the course Calculus 2, it is known that the weaknesses of most students are that they can only do calculations mechanically. They tend to be passive; they only listen and copy. These kinds of learning activities result in the process of memorizing concepts or procedures. Thus, the level of understanding of the concept is low and students will find difficulties in using the concept if given more complex problems [6]. This means that although calculus courses have been studied in high school, students’ understanding remains low. The same thing also happened to the results of interviews conducted by researchers with several mathematics education students. They said that calculus is one of the subjects that is very difficult to understand because, at high school, students are only given formula and time to work on the problem without any detailed explanation of the concept. The initial ability raises the need for the ability to identify elements that are known and needed in solving problems according to the concept [7].

Based on the explanation above, it can be seen that there are still many students who do not understand the concept of calculus. Therefore, researchers are interested in researching students with the following problem formulation: 1) how is the understanding of the concept of calculus 2 in students of the Mathematics Study Program at UNU Purwokerto? 2) What are the things that cause students’ difficulties in understanding the concept of calculus 2?

2. Method
This research is a descriptive study that aims to describe the understanding of the concept of calculus and the things that cause students’ difficulties in understanding that concept. The subjects of this study were the second-semester students of the Mathematics Study Program at the Faculty of Science and Technology of the Nahdlatul Ulama University Purwokerto. This research was conducted in March-May 2019. The data in this study were obtained from the results of diagnostic tests and interviews. The diagnostic test itself was made in the form of description tests that had been adapted to the indicators to determine the extent of understanding the concept of calculus. Then, the interview was conducted on student representatives who had low, medium, and high concept understanding of the calculus concept, each of which consisted of 2 representatives in each understanding category. This interview aimed to complete and strengthen the written test results data and revealed the things that were not in the written test.

The subjects in this study were taken by purposive sampling technique. The research subjects were all second-semester students of the Mathematics Study Program at the Faculty of Science and Technology of the Nahdlatul Ulama University Purwokerto, amounting to 22 students from class A and B, and then there were also 12 randomly selected students from Class A and B. The data validation used the triangulation method. Meanwhile, data analysis techniques were using data reduction, data presentation, and concluding [8]. The results of the students’ answers to the conceptual understanding test instrument were analyzed by calculating the student's final score on a scale of 3 [9]. Furthermore, determining the criteria of students based on assessment standards was arranged on a scale of 3 with the following intervals on Table 1.
Table 1. Standard Rating Scale

| Score     | Category |
|-----------|----------|
| ≥ 2,333   | high     |
| 1,667 – 2,333 | intermediate |
| ≤ 1,667   | low      |

The instruments made by researchers were questions related to understanding calculus concepts and interview guidelines. The indicators of understanding the concepts of calculus were divided into 8 question indicators where the question indicators were taken from the materials in the calculus 2 course. Each indicator had a value scale consisting of 5 on Table 2, namely:

Table 2. Scales of Concept Understanding Value

| Value | Description                                      |
|-------|--------------------------------------------------|
| 0     | no answer                                        |
| 1     | can answer but the concept is wrong              |
| 2     | can answer according to the concept but the results are wrong |
| 3     | can answer but not according to the concept but the results are correct |
| 4     | can answer according to the concept and the results are correct |

3. Result and Discussion

In an effort to obtain data, this research was carried out through several stages namely the stage of research preparation, the stage of research implementation, the stage of data validation, and data analysis. The first stage was research preparation; in which before conducting research, researchers conducted a literature review related to the research and supporting instruments that would assist them in obtaining data. The instruments made by researchers were questions related to understanding calculus concepts and interview guidelines.

Table 3. Percentage of Results of Calculus Understanding Levels

| Category | Frequency | Percent (%)|
|----------|-----------|-------------|
| High     | 0         | 0 %         |
| Intermediate | 3     | 25 %        |
| Low      | 9         | 75 %        |

Based on the results of the understanding of calculus concept tests, there were 12 students who were subjected to the study, in which 3 of them were in the moderate category and 9 students were in the low category. From each of the category, researchers chose 2 students to continue the interview stage. In this study, researchers conducted a validation approach to obtain valid data on the selection of research subjects and understanding of the concept by triangulating the method by comparing the data obtained through the concept understanding and documentation test with the results of the interview. The results of the analysis of the results of the diagnosis test answers in the form of concept understanding questions can be seen from the following table 3.

Figure 1. Percentage of Categories of Understanding Calculus Concepts
From table 3 and figure 1, the results show that students who are in the high category are 0%, the intermediate category is 25%, and the low category is 75%. This shows that there are still many students who do not understand the concept of calculus.

Table 4. Analysis of Material Data

| No | Category | Theory | Integral | Integral Technique | Transcendent Function | Integral Use |
|----|----------|--------|----------|-------------------|-----------------------|-------------|
| 1  | High     | 0      | 0        | 0                 | 0                     | 0           |
| 2  | Intermediate | 17    | 15       | 15                 | 12                    | 0           |
| 3  | Low      | 32     | 27       | 24                 | 20                    | 0           |
| Jumlah | 49    | 42     | 39       | 32                 | 32                    | 0           |

Figure 2. Material Data Analysis

Based on table 4 and figure 2, it is known that the student category is low. The highest concept understanding is on integral material while the lowest concept understanding is on integral use material. Whereas in the moderate category students, the highest and lowest concept understanding are the same in integral material and integral use material. Thus, it can be concluded that the students of the Mathematics Study Program at the University of Nahdlatul Ulama Purwokerto have a high understanding of integral material.

Table 5. Analysis of Problem Indicator Data

| No | Category | Indicator | Score |
|----|----------|----------|-------|
| 1  | High     | 0 0 0 0 0 0 0 | 0 0 |
| 2  | Intermediate | 7 10 9 6 8 7 6 6 | 59 |
| 3  | Low      | 15 17 16 11 13 11 10 10 | 103 |

Based on table 5 and figure 3, it is known that in the integral material, the highest problem indicator achieved by the medium and low categories is indicator 2, which is calculating integrals with the basic theorem of calculus. Meanwhile, the lowest problem indicator achieved is indicator 1, which is calculating integral of course. In the integration technique material, the highest problem indicator achieved by the medium and low categories is indicator 3, which is calculating partial integrals. Then, the low problem indicator achieved is indicator 4, which is calculating integral with rational substitution.
Figure 3. Analysis of Problem Indicator Data

In the transcendent function material, the highest problem indicator achieved by the medium and low categories is indicator 5, which is calculating the logarithmic function integral, while the lowest problem indicator is achieved by indicator 6, which is calculating the inverse and derivative of a function. In the use of integral material between the two indicator questions that are all the same, there is no higher or medium and low categories. Based on the results of the analysis, it was found that the highest students' understanding of concepts on the indicator 2: integral material and the lowest on indicators 7 and 8: the use of integral material.

In this study, researchers conducted interviews with 4 research subjects taken from 2 subjects from the medium category and 2 subjects from the low category. This happened because there was no high category in the categorization. Based on the results of data collection through interviews, there were several things that caused students difficulty in understanding the concept of calculus: students’ learning strategies are still through memorizing, they lack the motivation to repeat the material, and they rarely practice the questions, and basic concepts of mathematics in high school was not taught well.

Based on the results of this study, there are two conclusions: first, mathematics students’ concept understanding on calculus consists of a high category of 0%, a moderate category of 25%, and a low category of 75%. Thus, it can be concluded that the understanding of the concept of calculus 2 of semester 2 mathematics students in 2018/2019 academic year is still low. Furthermore, related to The analysis on the understanding of the calculus concept of students of mathematics study program shows higher understanding on integral material and lower on using the integral material. Second, the things that cause students difficulties in understanding the concept of calculus are that students still learn through memorizing, they lack the motivation to repeat the material and they rarely practice the questions, and basic concepts of mathematics in high school were not taught properly.

In addition, based on the results of existing research, it is stated that the factors causing difficulties in understanding calculus material are the ability to understand low problems, understanding in drawing functions in dimensions two and three is still low, and have not yet understood trigonometric integrals [10]. Also in the results of other studies stated that: difficulties in understanding the material volume of a rotating object, namely: (1) difficulty understanding concepts such as incorrectly applying the method used, incorrectly determining the upper and lower boundaries of course integral; (2) difficulty in accuracy of calculations; and (3) difficulty in representing images [11].

4. Conclusion

Based on the results and discussion of this study, a number of conclusions are obtained as follows: First, the understanding of the concept of mathematics student calculus consists of a high category of 0%, a moderate category of 25%, and a low category of 75%. Therefore, it can be concluded that the understanding of the concept of mathematics calculus for semester 2 students in the 2018/2019 academic year is still low. The analysis on the understanding of the calculus concept of students of mathematics study program shows higher understanding on integral material and lower on using the integral material. Second, the things that cause students difficulties in understanding the concept of calculus are students’ learning strategy which is still through memorizing, lacking the motivation to
repeat the material, rarely practicing the questions, and basic concepts of mathematics in high school were not taught well.

After conducting research and analysing the results, the researchers can provide suggestions, they are: (1) students are expected to repeat the material that has been learned. Doing repetition frequently in the learning process can develop students' memory, (2) students are expected to change their learning patterns or learning methods from memorizing to understanding patterns, (3) lecturers are expected to be able to motivate students in learning so that the motivation appears in the learning process, and (4) the lecturers are expected to be able to determine the right model and learning method so that the students can understand the material better.

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