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International Journal of Ethno-Sciences and Education Research

Vol. 2, No. 4, pp. 137-139, 2022

Measuring the Effectiveness of Differential Calculus Learning Using Open-Ended Based Teaching Materials

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Abstract

This study aims to produce differential calculus teaching materials using a good (valid, practical, and effective) open-ended approach to improve students' critical and creative thinking skills and compare their effectiveness with teaching materials prepared for implementing the curriculum. This research is research and development (Research and Development). The modified Dick & Carey and Borg & Gall models are the development models. The steps in this development are researching and gathering information, developing teaching, selecting and developing teaching materials, initial trials, revisions, main trials, and final product revisions. Initial tests and main trials are carried out in a university. Experts validate product validity. Product practicality is assessed by product users, namely lecturers and students. Product effectiveness was tested using an inferential statistical test by looking at the significant differences in the mean of the pretest and posttest scores regarding students' critical and creative thinking abilities. Next, the effectiveness will be compared between the control and experimental classes. The research results show that the product developed is in an outstanding category according to the experts, practical according to the teacher's assessment, and very practical according to the students. The resulting product is even more effective when compared to teaching materials in terms of critical and creative thinking skills for students.

Keywords: development, teaching materials, open-ended approach, critical thinking skills, abilities

1. Introduction

Differential calculus is one of the subjects studied in the mathematics education study program. In studying differential calculus, it cannot be separated from mathematical representations. Mathematical representations are expressions of mathematical ideas displayed by students as models or substitute forms of a problem situation that are used to find solutions to the problems they face due to the interpretation of their thoughts. A problem can be represented through pictures, tables, graphs, words (verbal), or mathematical symbols. In calculus, students are required to have good mathematical representation skills so that they can solve problems related to mathematical concepts involving calculus. Many problems in calculus are easier to solve if they are represented visually first.

Several studies have revealed weaknesses in students' mathematical representation abilities. The difficulties encountered included students' problems bridging representations and flexibly moving from one model to another (Yerushalmy, 1997). According to Ferrini et al. (1993) said that in learning calculus, students are often satisfied with different results with different representations and do not always realize that these results are inconsistent, even contradicting each other. The writer also encountered this difficulty while teaching differential calculus courses at a university. Most students still experience difficulties using various forms of mathematical representations to explain mathematical ideas and solve mathematical problems. They also still have difficulties in translating between formats of mathematical models. This condition certainly needs to be overcome, considering that students of a tertiary institution are prospective mathematics teachers who should be able to develop representational abilities in their students.

Choosing the right learning approach will support the development of this representation ability. The open-ended approach is one alternative approach to learning mathematics that is expected to improve students' mathematical representation skills. Becker & Shimada, (1997) says that in an open-ended process, the teacher gives a problem situation to students whose solutions or answers to the problem can be obtained in various ways. The lecturer or teacher then uses the differences in approaches or methods used by students to provide experience to students in finding or investigating something new by combining it with the knowledge, skills, and techniques/methods of mathematics that students have studied before. Based on the diversity of solutions and answers; it gives students a lot

of experience in interpreting problems. It may also generate different ideas for solving a problem (Silver, 1997). This, of course, will open up the possibility for students to use various representations to find solutions to the problems they face and can help students solve problems creatively so that through learning with an open-ended approach it is expected to improve students' mathematical representation skills.

2. Materials and Methods

2.1. Materials

We need teaching material oriented toward this approach to carry out lectures using an open-ended process. Therefore this research was preceded by developing teaching materials oriented towards an open-ended approach for differential calculus courses. This teaching material will also consider the abilities to be developed, namely the ability of students' mathematical representations.

2.2. Methods

Furthermore, the teaching materials that have been developed are tested in-class lectures to obtain information about the effectiveness of differential calculus lectures using these teaching materials. Besides the efficacy of studies in terms of improving mathematical representation abilities, it is also seen from student activities while attending differential calculus lectures and students' responses to differential calculus teaching materials based on the open-ended approach that was compiled.

3. Results and Discussion

3.1. Result

A description of the data regarding the results of students' mathematical representation ability tests after attending lectures using differential calculus teaching materials based on the open-ended approach is presented in Table 1.

Table 1: Representation of Students' Mathematical Ability

Ability Size	Average	Standard Deviation
Pra-Test	6.32	3.69
Pos-Test	51.12	7.27
Average Increase	0.39	

Table 1 shows that the initial ability of students' mathematical representation of differential calculus material is meager, with an average pretest score of 6.32 out of a maximum score of 100. After obtaining lectures using differential calculus teaching materials based on the open-ended approach, there is an increase in students' mathematical representation abilities, with a posttest score of 51.12. Calculating the average increase in students' mathematical representation abilities using the normalized gain formula obtained an average increase of 0.39, which is classified as moderate.

The average student activity while attending differential calculus lectures using teaching materials based on an open-ended approach for all activities is 62.25%. Student response to differential calculus teaching materials based on the open-ended process is quite good.

The results of data analysis regarding students' mathematical representation abilities obtained an average increase of 0.39, classified as moderate. These results illustrate that using an open-ended approach to differential calculus lectures can improve students' mathematical representation skills. However, the results have not been maximized because the average score is still meager, which is 51.12 out of a maximum score of 100. This happens because, in the open-ended approach, students can solve problems with various answers and holds so that multiple representations will appear from trouble.

3.2. Discussion

Open problems given to students are not only oriented to get answers or final results but emphasize how students arrive at an answer; students can develop different methods, ways, or ways to solve problems. This provides opportunities for students to carry out greater elaboration so that they can develop their mathematical thinking and help build their creative activities in using various representations in solving problems.

This study's results align with Becker & Shimada, (1997) research, which found that by applying an open-ended approach, students have more opportunities to do something, think, play an active role, do something original, and draw conclusions in their way. This study also concluded that the ability of students who received learning with an open approach was better than in conventional classes.

The results of this study are also in line with Hoffmann & Ritchie, (1997) on learning using the Problem-Based Learning (BBM) approach which concluded that non-routine problems, which also include open-ended problems, can improve students' mathematical representation abilities.

Student activities while attending differential calculus lectures using teaching materials based on an open-ended approach are pretty active; this can be seen from the average functional student activity of 62.25%. This is in line with Nohda's opinion (2000), which says that learning using an open-ended approach can help develop creative activities from students. Through this approach, each student has the freedom to solve problems according to their abilities and interests, students with higher abilities can carry out various mathematical activities, and students with lower abilities can still enjoy mathematical activities according to their abilities.

The data processing results regarding student responses to differential calculus teaching materials based on the open-ended approach are pretty good. Using these teaching materials makes students more motivated and enjoy learning, making it easier to understand the material and making them think more critically. Students also feel pretty satisfied with the content, quality of writing, and pictures of teaching materials. The lowest average score is on belief; some students still think there is too much information in teaching materials, making it difficult for them to remember essential ideas. Some students also stated that the assignments in teaching materials were too many and too complex. Still, learning using these teaching materials made them confident in studying and completing tests.

4. Conclusion

Based on data analysis, it can be concluded that differential calculus lectures using teaching materials based on an open-ended approach are effective. In detail, it can be completed as follows: (1) The average increase in students' mathematical representation abilities using the normalized gain formula is 0.39, which is moderate, (2) the average student activity while attending differential calculus lectures using teaching materials based on an open-ended approach is 61.12%, and (3) the average score of student responses to teaching materials and Student Worksheets (LKM) differential calculus based on the open-ended approach of 3.2 is quite good.

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