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Improving Students' Mathematical Problem-Solving Ability Using M-APOS Approach to Derivative Material

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ABSTRACT

This research is quasi-experimental research that aims to see the improvement of students' mathematical problem-solving abilities on derived material using M-APOS learning. Data analysis using statistical tests on the pretest, post-test, and normalized gain data. Data analysis was carried out with the help of Microsoft Office Excel and SPSS 24 software. The research sample was 66 people who took the differential calculus course. The research instrument is a mathematical problem-solving ability test in the form of a description of four items. This study concludes that there are differences in the increase in mathematical problem-solving abilities of students who receive M-APOS learning with students who receive expository learning. Furthermore, students gave a positive response to M-APOS learning.

INTRODUCTION

Calculus is a compulsory subject for mathematics education study program students. Students in the second semester obtain differential calculus courses. This course discusses the real number system, functions, limits, continuity of functions, infinite and indefinite forms of function limits, function derivatives, and the use of functions. Differential calculus is a very important course because it is one of the prerequisite courses to follow several other courses, namely integral calculus, and advanced calculus.

Research conducted by [1] on students of Sanata Dharma University class of 2017 regarding the effect of differential calculus on advanced calculus learning outcomes revealed a significant effect. Furthermore, the effective contribution of differential calculus learning outcomes reached almost 21%, and the relative contribution of differential calculus courses was greater than the effective contribution of more than 39% in advanced calculus courses. An effective contribution is a form of measure to get the contribution of an independent variable to the dependent variable in the regression analysis. What is meant by relative contribution is a measure used to show the contribution of an independent variable to R^2.

For integral calculus courses studied in the third semester, the material covered includes indefinite integrals, definite integrals, transcendent functions, integration techniques, and integral applications. In discussing the material on transcendent functions, a study of the logarithmic and exponential functions will be carried out, followed by the material on derivatives and inverse integrals of trigonometric functions. In the fourth semester, students receive advanced calculus courses. Many materials are discussed in depth in advanced calculus courses, namely functions of many variables, limits, and continuity of many variables, derivatives of many variable functions, integrals of many variable functions, applications of integral functions of many variables, integral functions of many variables and applications of integral functions of many variables.

Based on the presentation of material from the three courses, namely differential calculus, integral calculus, and advanced calculus, it can be seen that derivative topics are always discussed in these three courses. This shows that derivative topics are very important to be mastered by students. Furthermore, in addition to the three previously mentioned courses, some courses study derivative topics, namely the differential equations course. This means there are as many as four courses that study derived material. So it is very clear that students are required to have the ability to solve problems on derived material.

Dintarini, in [2], describes the results of research conducted on students of the mathematics education program at the University of Muhammadiyah Malang, analyzing students' difficulties in solving problems when studying differential calculus courses using Polya theory. The result is that students have difficulty planning appropriate strategies to solve problems and find it difficult to relate problems to derivative concepts. Students as prospective teachers must have mathematical problem-solving skills in differential calculus because derived material was taught in high school (SMA). However, in contrast to the importance of mathematical problem-solving skills, especially for derived material, the facts on the ground show that students' mathematical problem-solving abilities are still low. Many students still get C and D grades in differential calculus courses in the 2018-2019 school year. The percentage of students who scored C and D reached 27.86%.

The learning approach that is likely to improve students' mathematical problem-solving abilities is the M-APOS approach. The M-APOS approach is a modification of the ACE approach (*activities, class discussions, exercises)* based on the APOS theory. The M-APOS approach encourages students to learn actively and meaningfully through four stages: Action, Process, Object, and Schema. The M-APOS approach includes giving recitation assignments as an activity so that students form their knowledge. Furthermore, the M-APOS approach makes students have discussions with other students, resulting in an understanding of the material being studied. Students who study with the M-APOS approach will experience meaningful learning where students are aware of and know the reasons for using rules, principles, and formulas. Using the M-APOS approach to improve students' mathematical problem-solving skills is in line with the opinion of [3], who suggested that students are encouraged to learn and find solutions to problems through making a list of questions, answering questions, and being able to explain the answers themselves.

The M-APOS approach is a modified approach from the APOS approach. APOS stands for Action Process Object Schema. The main idea of APOS is to seek the mental formation of students through action, then thought or processed and concluded into an object, then the object must be described again. Schemas are formed from the existence of actions, processes, and objects [4]. The APOS approach uses the ADL (Activities Discussion Exercises) cycle. The ADL cycle consists of three stages: activities carried out in a computer laboratory. The discussion stage occurs in class while students work outside the classroom for practice questions. While the M-APOS approach or APOS modification is the result of research conducted by Nurlaelah in 2009 in the algebraic structure course using the APOS approach. The research at that time encountered several problems at the activity stage in the computer laboratory.

The problem is that the software and hardware are unavailable on time, resulting in a delayed learning process. Students still find it difficult to compile computer programs using the ISETL language ((*Interactive SET Language*). Students who fail in making programs are ultimately unable to construct their knowledge, cannot make conclusions and make students lazy to learn. Students are given assignments compiled in student worksheets (LKM) to overcome these problems. Student worksheets help students to arrange programs with answers to questions regarding the preparation of ISETL. The use of student worksheets is a modification of the APOS approach. The assignment of worksheets to improve student's abilities is in accordance with the research results by [5], which revealed that learning is not direct and can improve high-level mathematical abilities. The provision of student worksheets includes success in the indirect learning approach.

Based on research conducted suggests carrying out learning by utilizing the M-APOS approach to study the derivative material of algebraic functions. [6] defines problem-solving if students are aware of a problem in the situation, know that the problem needs to be solved, feel like doing and solving it, but cannot immediately solve it. Problem-solving is part of thinking. As part of thinking, problem-solving practice will increase the ability to think at a higher level. So that it can be said that problem-solving ability in mathematics is very important for a student to have and is also one of the factors that determine student learning outcomes in mathematics.[7] explained that mathematical problem-solving ability is very important in learning mathematics because it is the ultimate goal in teaching mathematics; even problem-solving ability is the heart of mathematics.

According to [8], problem-solving skills are very important so that students can solve the problems they face and help them think analytically in everyday life decisions. Problem-solving has three interpretations: problem-solving as a) goals, b) process, and c) approach. Problem-solving as a goal relates to how to solve the problem until it is successful. Problem-solving as a process is an activity that prioritizes the importance of procedures, steps, strategies, or ways for students to solve problems to find answers. Problem-solving as an approach, namely learning, begins with a problem, and then students are allowed to find and construct mathematical concepts. The three interpretations of problem-solving cannot be separated but are interrelated.

Of course, every student has a different way/strategy of solving mathematical problems. This is due to internal factors, namely readiness and intellectual property, affecting how to respond to the problem. For example, students may not get the answer to the problem because the ways to solve it are also varied, such as experimenting, predicting, and so on. [9] suggests six stages in problem-solving (1) problem identification includes understanding the problem and identifying the problems encountered. (2) problem representation, namely formulating and understanding the problem correctly. (3) solution planning. (4) implement/implement planning. (5) assess planning. (6) assess the results of the solution.

[9] compiled four steps or stages that must be taken in problem-solving: understanding the problem, planning how to solve it, implementing the plan, and interpreting the results. At the stage of understanding the problem, there are activities to identify the mathematical concepts involved, identify the relationship between these concepts, and then state the relationship between the concepts in question in the form of a mathematical model of the problem in question. The mathematical model can be in the form of mathematical expressions or pictures, diagrams, or other mathematical models. Several ways to help students overcome difficulties in solving problems include: a) Asking questions to direct students to work; b) presenting a cue (*clue* or *hint*) to solve the problem instead of providing a settlement procedure; c) helping students explore their knowledge and formulate their questions according to the needs of the problem; d) help students overcome their difficulties.

[3] states that there are five steps to solving problems: formulating the problem clearly,

restating the problem in a form that can be resolved, developing (temporary) hypotheses and strategies for solving them, performing troubleshooting procedures, and evaluating the solution. There are several ways that teachers can use to help students solve problems according to Nasution [10], including:

1. the most ineffective way is if we show students how to solve the problem.
2. A better way is to give verbal instructions to help students solve the problem.
3. The best way is to solve the problem step by step using specific rules, without formulating the rules verbally. Using examples, pictures, and so on, the student is assisted and guided to find the solution to the problem.

From several expert opinions on problem-solving, it can be concluded that mathematical problem-solving ability is an effort made by students/students by studying, finding solutions to mathematical problems faced by using various ways based on previously studied to achieve the desired goals. Achieved in learning mathematics. [9] stated that the four steps of Polya can be used as a reference in measuring mathematical problem-solving abilities. In this study, to measure students' mathematical problem-solving abilities, they were given a problem-solving test in the form of questions about the material being taught. Indicators that show mathematical problem-solving ability in this study are as follows:

1) understanding the problem, namely identifying the adequacy of data for problem-solving; 2) planning or designing a problem-solving strategy, namely making a mathematical model of a situation or everyday problem and solving it; 3) carrying out calculations, namely choosing and implementing strategies to solve problems inside or outside mathematics; 4) re-examine the correctness of the results or solutions, namely explaining or interpreting the results according to the original problem and checking the correctness of the results or answers. Based on the explanation above, this study aims to determine how to increase students' mathematical problem-solving abilities on derived material.

METHODS

This research is a quasi-experimental design with a pretest-posttest control group design. In this quasi-experimental study, the subjects were not grouped randomly, but the researcher accepted the subject's condition as modest [3]. In this study, two classes were used: the experimental and control classes. The initial stage of this research is to determine the research sample. Then two classes were taken randomly, one for the experimental and one for the control classes. This treatment is given to see its effect on the measured aspect, namely the students' mathematical problem-solving ability. The research design used in this study is as follows:

O X O

O O

The experimental group was given treatment (x), namely the M-APOS approach, and the control group was given expository learning. In addition, each research class was given a pretest and post-test (O). The population of this study was all students of the 2019/2020 class. The selection of Mathematics education undergraduate students as research subjects is based on consideration of students' cognitive development level in the formal operation stage. Therefore, it is deemed appropriate to use the M-APOS Approach. In addition, first-semester students are still in the stage of adolescence, and at this time, students are in the process of self-discovery/identity and self-confidence formation. Therefore, some materials are predicted to be suitable for learning with the M-

APOS Approach to develop students' mathematical problem-solving abilities.

The sample in this study is a total sample or population sample. The variables of this study consisted of three variables, namely: (1) the independent variables included the M-APOS learning approach; (2) dependent variables, including students' mathematical problem-solving abilities; The instrument used to measure students' mathematical problem-solving abilities in this study was an essay test consisting of 4 questions. The data collection technique in this research is a test technique. The intended test is a mathematical problem solving carried out after learning. This test is given to improve the mathematical problem-solving students of the Mathematics Education Study Program after being given learning using the M-APOS approach.

There are two types of data in this study, namely quantitative data and qualitative data. Quantitative data was obtained through analysis of student answers on students' mathematical problem solving, then grouped based on the learning approach used, namely the M-APOS learning approach and the expository. Qualitative data was obtained through observations of the activities of lecturers and students in implementing learning and data from interviews with students. This data was analyzed descriptively to support the completeness of quantitative data in answering research questions.

The quantitative data processing is carried out through several stages: The first stage: is performing descriptive analysis of the data and calculating the values of Pretest, Posttest, Gain, and Normalized Gain. With this stage, it can be seen how big the achievement is, the increase in students' mathematical problem-solving abilities in classes that use the M-APOS learning approach and classes that use expository learning approaches. The second stage: at this stage, statistical prerequisite tests are carried out, which are used as the basis for hypothesis testing, namely the normality test for the distribution of the sample subject data and the homogeneity test of variance for parts or the whole group. The third stage: determining the increase in students' mathematical problem-solving abilities between the experimental class and the control class, determining whether or not there is an interaction or not between the independent variable and the control variable on the dependent variable to test the difference using the average difference test using the SPSS program assistance 24.0 for Windows.

In addition to quantitative analysis, the researcher will conduct a qualitative analysis of the answers to each question, observation data, and student response data. It aims to study further students' mathematical problem-solving abilities and to determine whether the implementation of learning is in accordance with the learning provisions set out in the two learning models.

RESULTS AND DISCUSSION

Problem-solving ability data that will be processed and analyzed in this study include pretest and post-test scores. In addition, it has been stated that this study wanted to know how mathematics learning with M-APOS improved students' mathematical problem-solving abilities. This can be known by comparing the results of the achievement of the M-APOS class and the expository class before and after being given different treatments.

The student's initial mathematical problem-solving ability before being given treatment is reflected in the pretest score. In contrast, the student's final mathematical problem-solving ability after being given treatment is reflected in the post-test score. The improved quality is reflected in the normalized gain value (n-gain) obtained from calculating the pretest, post-test, and ideal maximum scores. Below is a table that describes the pretest, post-test, and n-gain scores from the M-APOS and

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expository classes.

Table 1. Descriptive Statistics Scores of Mathematical Problem Solving Ability

Statistical Data	M-APOS			Expository		
	Pretest	Postest	N-Gain	Pretest	Postest	N-Gain
$\bar{x}$	52.79	83.35	0.65	55.38	79.94	0.55
SD	7.018501143	6.2274191	0,11703989	8.217801	4.812199	0.078572
N	34	34	34	32	32	32
Maxsimum Score = 100						

Table 1 shows that the average score of the early mathematical problem-solving ability of students in M-APOS class and expository class is 52.79 and 55,38. It can be seen that the difference in the average score of the initial mathematical problem-solving ability of the two classes is only 2.59. Furthermore, after the learning activities were carried out, it was seen that the average score of mathematical problem-solving abilities in both the M-APOS class and the expository class had increased. The M-APOS class increased by 30.56 and the expository class by 24.56.

The increase in the score of mathematical problem-solving skills between the pretest and post-test shows that the mathematics learning given to each class can develop students' mathematical problem-solving abilities. However, if observed, the difference in the average post-test score between the two classes reached a value of 6.00. This value is twice as significant as the average difference in the pretest scores. This means that at the end of the lesson, the M-APOS class students' mathematical problem-solving abilities are much more developed than the expository class students.

In the previous Table 1, it also appears that there are no students in both the M APOS class and the expository class who get an n-gain score of 0. This means that all students generally experience an increase in scores after carrying out learning activities, both with M-APOS and expository learning. Table 2 shows the classification of n-gain criteria in the M-APOS and the expository classes.

Table 2. Classification of Students Based on N-Gain Mathematical Problem Solving Ability

Class	Category Improvement	N	$\bar{x}$	Percentage (%)
M-APOS	High	10	0.78	29.41
	Medium	25	0.60	70.59
Expository	High	1	0.71	3.13
	Medium	31	0.54	96.87

The classification is taken from the n-gain criteria according to Hake (1999). The table above shows that in the *M-APOS* and expository classes, the most significant percentage of n-gain is in the medium category. In the high category, only one student in the expository class achieved an n-gain score of 0.71. The difference in the percentage of n-gain high criteria between the M-APOS class and the expository class reached 26.28%. Students with n-gain in the moderate category are more in the expository class. This shows that M-APOS is better at improving problem-solving skills than expository learning. Furthermore, statistical tests will be carried out on the pretest, post-test and n-gain data for the M-APOS class and the expository class to obtain answers to the problem formulation.

The mean difference test on the pretest aims to see whether the students' initial problem-solving abilities in the M-APOS and expository classes are not significantly different. The post-test mean difference test aims to see whether the final problem-solving ability of the M-APOS is significantly better than the expository class. While the difference in mean n-gain aims to answer the hypothesis

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of increasing problem-solving abilities of students who get M-APOS significantly better than students who receive expository learning. The data is first tested for normality and homogeneity to determine whether the statistical test used is parametric or non-parametric.

The calculated normality test was the *Shapiro-Wilk test* because the data was more than 30. Table 3 shows the results of the normality test scores for pretest, post-test, and n-gain for the M-APOS and expository classes. Table 3 shows that the results of the normality test for the pretest, post-test, and n-gain scores for the M-APOS and expository classes have a Sig value of more than $\alpha = 0.05$. This resulted in H_0 being accepted, meaning the pretest, post-test and n-gain scores for the M-APOS and expository classes were normally distributed. From these results, the homogeneity test was continued.

Table 3. Normality Test Results Scores Pretest, Posttest, and N-Gain Problem Solving Ability

Class		**Shapiro-Wilk Test**			
		Statistics	**Df**	**Sig.**	**H_0**
Pretest	M-APOS	0.097	34	0.742	Accepted
	Expository	0.174	32	0.368	Accepted
Postest	M-APOS	0.091	34	0.580	Accepted
	Expository	0.075	32	0.608	Accepted
N-Gain	M-APOS	0.093	34	0.782	Accepted
	Expository	0.144	32	0.361	Accepted

To test the homogeneity of variance of the pretest score test Levene with the help of the SPSS 24 program at a significance level of $\alpha = 0.05$. The summary of the homogeneity test calculation is presented in Table 4 below.

Table 4. Test of Homogeneity of Variance

Class		**Levene Test**			
		df1	**df2**	**Sig.**	**H_0**
Pretest	M-APOS	1	64	0.138	Accepted
	Expository				
Postest	M-APOS	1	64	0.137	Accepted
	Expository				
N-Gain	M-APOS	1	64	0.042	Rejected
	Expository				

Because the pretest scores of both classes are normally distributed and have the same population variance. So to test the significance of the difference in the initial mathematical problem-solving ability scores, a statistical test was carried out, namely the t-test. The summary of the results of the average difference in the pretest scores for mathematical problem-solving abilities is presented in Table 5 below.

Table 5. Results of the Difference in Mean Pretest Scores on Mathematical Problem-Solving

		t-test for Equality of Means				
		T	**Df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**
Pretest	Equal variances assumed	-1,375	64	0,174	-2,58088	1,87752

From Table 5 above, it is known that the value of Sig. (2-tailed) of 0.174 more than $\alpha = 0.05$. 05This shows that H_0 is accepted, meaning that the average mathematical problem-solving ability of

M-APOS students at the beginning of learning and the average mathematical problem-solving ability of expository class students is not significantly different. To test the significance of the difference in the final mathematical problem-solving ability score and its improvement in the M-APOS and expository classes, parametric statistical tests were carried out. The parametric test is the t and t' test with = 5%. Table 6 shows the results of the difference in the average post-test scores.

Table 6. Test Results Differences in Mean Posttest Scores Problem Solving Ability

		t-test for Equality of Means				
		T	**Df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**
Postest	Equal variances assumed	2.482	64	0.016	3.41544	1.37602

From Table 6, it can be seen that the value of Sig. (2-tailed) obtained from the post-test score is 0.016. Half of the value of Sig. $\frac{1}{2}$ (0.001) = 0.008 less than α = 0,05 so H_0 rejected. Hal ini This means that the APOS class M's mathematical problem-solving ability is significantly better than the expository class students' mathematical problem-solving abilities. To see the increase in mathematical problem-solving abilities, students who received M-APOS were significantly better than students who received expository learning using the t' test. Table 7 shows the test results for the average difference in the n-gain score.

Table 7. Test Results of Differences in Average N-Gain Scores in Mathematical Problem Solving Ability

		t-test for Equality of Means				
		T	**Df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**
N-Gain	Equal variances not assumed	4.142	58.055	0.000	0.10118	0.02442

From Table 7, it can be seen that the value of Sig. (2-tailed) obtained from testing, the n-gain is 0.000. Half of the value of Sig. $\frac{1}{2}$ (0.000) = 0.000 less than α = 0.05 sehingga H_0 rejected. This means that the average increase in mathematical problem-solving abilities of students in the M-APOS class after learning is significantly better than that of expository class students. This is also because the M-APOS learning approach makes students more active in the learning process. Students can understand problems, plan problem-solving strategies, carry out calculations, and re-examine the correctness of problem-solving solutions by working on Student Worksheets (LKM) and can express their opinions so that learning outcomes are more meaningful, and students can improve problem-solving skills based on what is they learned.

The results of this study are in accordance with the results of research conducted [11], where M-APOS learning makes it easier for students to master difficult material because M-APOS encourages students to improve their understanding abilities. [10] concluded that MA APOS can improve the mathematical understanding ability of class VIII students in a public junior high school in Bandung. Continuing, the research of [12] explained that M-APOS could also improve the ability to understand concepts and reasoning in class VIII SMP Ma'arif Batu City. By applying M-APOS learning, it can improve the ability to understand concepts of SMKN students [13].

CONCLUSIONS AND SUGGESTIONS

This research concludes that the students' initial problem-solving abilities in the M-APOS and expository classes are not significantly different. Furthermore, there is a significant difference in the final mathematical problem-solving ability of students taught with the M-APOS learning approach and the expository learning approach, and there is a significant difference in increasing mathematical problem-solving abilities for the N-Gain scores between students taught with the M-learning approach. APOS and expository learning approaches.

Based on the results of the research that has been carried out, several things are taken into consideration in learning; namely, this research improves mathematical problem-solving abilities. Besides that, it is also recommended that it be done at other schools or universities to develop other abilities. Moreover, for further research purposes, the M-APOS and expository learning approaches can be used for other materials in mathematics learning.

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