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Improving Mechanical Engineering Student's Achievement in Calculus through Problem-Based Learning

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Abstract This research aims to evaluate the effectiveness of problem-based learning (PBL) approach to improve mechanical engineering student's learning achievement. As for the research sample, it consisted of 56 engineering students selected by cluster random sampling which were grouped into the experimental class and the control class. The instrument used is in the form of a description test used to measure student's learning achievement. T-test and N-Gain test were used to analyze research data, while student mastery learning was presented in quantitative descriptive. The results of this research concluded that PBL is effectively applied in the learning process for mechanical engineering students because the learning achievements of students who get PBL learning are better than the learning achievements of students who get conventional learning, the majority of students complete their mastery learning and there is an increase in student's achievement of high categories.

Keywords Problem-based learning, conventional learning, learning achievement

1. Introduction

Mathematical problems Calculus is one of the main courses in the curriculum in Indonesia, both for mathematics and engineering. The fact shows that many engineering students are no exception to mechanical engineering students who do not like calculus because it is difficult and less useful in the field of engineering [1] [2]. Engineering students often have difficulty understanding concepts because of their lack of ability to do deductive reasoning. This happens because students still face conventional approaches in the learning process [3] [4]. Conventional approaches are closely related to the use of lecture methods, where teachers are more active in providing guidance while students only accept material passively. Textbooks are used as the only source of information for classroom teaching, which emphasizes the computing side rather than understanding concepts [3] [5] [6].

Although the conventional approach can be done but this approach is criticized for producing students who are passive and do not take into account the various needs and abilities of students [7]. Many students are unable to associate the concept of calculus with its application in real life. Thus, lecturers need to emphasize the importance of a student to realize that interactions between students, students and lecturers, and students with learning resources are necessary in calculus learning in engineering [8]. Therefore, it needs a learning approach that provides more interaction and learning opportunities for students so they can produce graduates who are relevant to the needs of the industry. Problem-based learning (PBL) is an approach that uses in overcoming real life problems as a context for students to learn, as well as to acquire essential knowledge and concepts from lecture material [9-11]. PBL emphasizes that the learning process moves from the transfer of information to the construction process of knowledge socially and individually. This is in line with the constructivism understanding that every student can understand teaching material through everything according to his own construction.

Furthermore Barret [9] and Arends & Kilcher [12] explain the steps in implementing PBL include: 1) giving problems (questions) by lecturers, 2) students conducting discussions in small groups through clarifying cases of problems given, defining problems, exchanging ideas, setting things needed to solve problems, and determine what must be done to solve the problem. 3) Students conduct studies related to the problem by finding sources in the library, database, internet, and observation. 4) Students return to the group to exchange ideas, peer learning, and work together in solving problems, 5) students present solutions found, and 6) Students assisted by lecturers evaluate all learning activities. PBL is able to improve students learning skills, this approach also helps students explore real problems that will be encountered after graduation [10] [11] [13]. Through PBL, each student interacts and helps each other the learning process so that they can overcome the different levels of student's learning abilities. Students who do not understand the course material will get help from students who understand the course material and at the same time students who understand lecture material can better consolidate their mastery of knowledge and skills. Based on the description above, the objectives of this research are: 1) Are there differences in learning achievement of mechanical engineering students with PBL and conventional learning?, 2) How is the mastery learning of students with PBL and conventional learning ?, and 3) How is the improvement in learning achievement of mechanical engineering students with PBL and conventional learning?

2. Methods

2.1. Research Sample

This research was conducted in September 2018 s.d. January 2019, middle semester 2018/2019 academic year. To ensure the objectivity of researchers and avoid bias in research, the sample in this research was selected using cluster random sampling technique so that it can provide equal opportunities to a group of students gathered in the class to become a research sample. The research sample consisted of 56 mechanical engineering students at the Universitas PGRI Semarang, Central Java Province, Indonesia. The sample is divided into two classes, namely the experimental class (PBL learning) and the control class (conventional learning), with each class consisting of 28 students. Before doing the research, test the normality with the Lilliefors method, the homogeneity test with the Bartlett test, and the t-test is done first. The results showed that samples from conventional learning classes and PBL classes came from populations that were normally distributed, the variance between the two groups was homogeneous, and the two samples had the same initial ability.

2.2. Instrument and Procedures

At this stage the researcher determines methods, teaching materials, learning strategies and learning media. The learning method used in each lesson plan made is a cooperative learning method. Teaching materials used by researchers are printed books, and the learning strategies chosen are active learning. Before being used, the device was validated by two validators and concluded that the device was suitable for use, with an expert rating of 84.4% (good), and 86.6% (very good) to be used.

The test questions are arranged in reference to the syllabus used in the mechanical engineering research program at the Universitas PGRI Semarang. The test questions were first validated by two experts, then tested to find out the reliability, the level of difficulty and the differentiation of items. Test questions are used to measure the ability of student's learning achievement in the experimental class and the control class. The results of the test analysis of the test instruments are presented in Table 1, which clearly shows that there are three items used as a matter of pre-test and post-test in this research.

2.3. Data Analysis

2.3.1. Test t-test

The t-test is used to find out whether there is a difference of mean of student's achievement between PBL class and conventional class. The data tested is the post-test result, in the following way:

$H_0 : \mu_1 \leq \mu_2$ (The mean of student's achievement of PBL class is less than the average of conventional class).

$H_a : \mu_1 > \mu_2$ (The mean of student's achievement of PBL class is better than the average of conventional class).

2.3.2. Students learning mastery

Mastery learning is a minimum level of mastery over the substance of calculus teaching material. Students are said to master learning if they get a minimum value of 70, and mastery learning is classically met if at least 85% of all students complete the learning material. Value of 70 is the minimum criteria of mastery learning (KKM) established by mechanical engineering program in Universitas PGRI Semarang. The percentage of classical learning completeness is calculated using the formula: P = (Number of students who have completed (> 70): Number of students who took the test) x 100%

Table 1. Analysis of Essay Test Instrument

Question	Reliability		Difficulty Level		Differentiation of Item		Remark
	r	Criteria	Score		r	Criteria	
1	0.662	Reliable	0.93	Easy	0.65	Good	Used
2			0.70	Medium	0.44	Good	Used
3			0.25	Difficult	0.41	Good	Used
4			0.42	Medium	0.18	Poor	Unused
5			0.29	Difficult	0.36	Enough	Unused

2.3.3. Test improvement of students' achievement

To calculate the improvement of mechanical engineering student's achievement in calculus before and after learning, it is calculated by the normalized gain formula [14], namely:

N-Gain (g) = (posttest score – pretest score) : (maximum ideal score – pretest score)

The result of N-Gain calculation then interpreted on Table 2.

Table 2. Interpretasi N-Gain (g)

Amount of N-Gain (g)	Interpretation
$g \geq 0.7$	High
$0.3 \leq g < 0.7$	Medium
$g < 0.3$	Low

3. Results

3.1. Test of prerequisites

Table 3 provides data that $L_{obs} < L_{table}$, with p = 5% and n = 28, thus it was concluded that the samples from conventional learning classes and PBL classes came from populations that were normally distributed.

Table 3. Normality Test Result

Learning strategy	n	L_{obs}	L_{table}	Hypothesis	Remark
PBL	28	0.122	0.167	H_0	accept
Conventional	28	0.148	0.167	H_0	accept

Presented in Table 4 that $F_{obs} = 0.691$, $F_{table} = 1.904$, p = 5%, and H_0 accepted.. thus it was concluded that the variance of the two groups was homogeneous.

Table 4. Homogenity Test Result

Learning strategy	n	s^2	F_{obs}	F_{tab}	Hypothesis	Remark
PBL	28	56.52	5.83	1.70	H_0	Reject
Conventional	28	81.80				

3.2. Test of research data

Based on the results of the statistical test prerequisite test, then the test was carried out to determine the differences in learning achievement of mechanical engineering students from the application of each learning approach. Presented in Table 5 that s_p 8.316, $t_{obs} = 5.83$, with the score of v = 28 + 28 – 2 = 54 and p = 0.05, obtained $t_{(0.05,54)} = 1.70$. Therefore H_0 is rejected. It be concluded that the learning achievements of mechanical engineering students who get PBL learning are better than the learning achievements of mechanical engineering students who get conventional learning.

Table 6 shows the pre-test and post-test score of the two research classes, where the pre-test scores were taken before PBL learning, while the post-test scores were taken after PBL learning. Related to the achievement of student learning completeness, in the PBL class the percentage of learning completeness was 85.714%. Whereas in the conventional class, completeness was only 53.571%, which means that almost half of the students had not yet completed the KKM.

The N-Gain test is used to see the improvement in learning achievement of mechanical engineering students from the application of each learning approach. The data used are the pre-test and post-test value data. Obviously it is presented in Table 7 that the increase in learning outcomes of mechanical engineering students who get PBL learning is 0.70. While the increase in learning outcomes of mechanical engineering students who get conventional learning is 0.40. This shows that PBL is better for improving learning achievement than conventional learning.

Table 5. The results from the t-test of the post-test scores

Learning strategy	N	Mean	t_{obs}	t_{table}	Hypothesis	Remark
PBL	28	85.07	5.83	1.70	H_0	Reject
Conventional	28	72.10				

Table 6. Mean of Pre-Test, Post-Test, and Mastery Learning Percentage

Learning Strategy	Mean		Mastery learning Percentage
	Pre-test	Post-test	
PBL	41.914	80.893	85.714%
Conventional	44.714	67.071	53.571%

Table 7. Improved Students' Achievement

Learning strategy	N-Gain	Interpretation
PBL	0.70	High
Conventional	0.40	Medium

4. Discussion

The results of this research showed that the learning achievement of students who received PBL was better than the learning achievements of students who received conventional learning. This shows that the PBL approach has been able to foster interaction between students, students with lecturers, students with learning resources in calculus learning, and students are able to associate the concept of calculus with its application in real life. Through giving problems, students are challenged and motivated to solve them so that students are increasingly active in learning [8] [15-17]. This result is supported by the majority of mechanical engineering students (85.714%) who have learned PBL to have achieved KKM as determined by the school, which is 70; this is different from the completeness of students with conventional learning which is only 53.571%. Furthermore, this fact is also reinforced by the increase in student achievement of students who get PBL of 0.7 in the high category and only an increase of 0.4 with the moderate category in conventional learning. Thus, the application of PBL to calculus material has taken into account the needs and abilities of students in learning [7].

PBL learning process as described by Barret [9] and Arends & Kilcher [12] has been able to improve student learning skills, this approach also helps students explore real problems that will be encountered after graduation. This is in line with the opinion that PBL uses real-world problems as a context for students to learn, and to acquire essential knowledge and concepts from lecture material [9-11] [13]. During the learning process, students actively construct knowledge socially and individually as well as constructivism. Whereas in conventional learning it can be seen that students passively receive the knowledge explained by the lecturer, which emphasizes more on computing than understanding the concept [3] [5] [6].

5. Conclusions

This research shows that the PBL approach is effective for improving student's learning achievement compared to conventional learning. Lecturers need to often apply PBL in lectures so that students will increasingly be accustomed to linking teaching material to daily life, and improving their learning achievement. Lecturers need to pay attention to student collaboration to develop ideas for solving problems. Furthermore, the application of PBL needs to be developed in other subjects and other technical fields.

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