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Problem Based Learning Method to Improve Mathematical Problem Solving and Self Efficacy of Students in Engineering Course

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***Abstract*—This study aims to determine the improvement of students' mathematical problem-solving abilities and self-efficacy. The population in this study were Mechanical Engineering students in semester 4 of the 2020 academic year at the Muhammadiyah University of Tangerang who took Engineering Mathematics courses on the topic of Differential Equations. Two classes of the population were analyzed as research samples by treating one class as a control group and the other as an experimental class. The experimental group applied the Problem Based Learning method while the control group applied conventional learning. Data collection was carried out by analyzing student worksheets Problem Based Learning on the topic of Differential Equations to evaluate students' mathematical problem-solving abilities and self-efficacy. The statistical methods used were the mean rank and the Mann Whitney U test. The results showed that the mean ranking of students in the experimental class obtained an average score of 31.89 higher than students in the control class with an average score of 13.11. In addition, the results of the Mann Whitney U test with a U value of 35,500 and p less than 0.05 indicate that the Problem Based Learning method affects students' mathematical problem-solving abilities and self-efficacy.**

Keywords—engineering mathematics, problem-based learning, problem solving, self-efficacy

I. INTRODUCTION

During several periods of the new academic year, teachers, lecturers and education practitioners make changes to the mathematics curriculum used in schools and higher education institutions [1]. In particular, students should be able to develop more complex, abstract, and powerful mathematical structures to enable them to solve a broad variety of meaningful real-life problems. Furthermore, students ought to become autonomous and self-motivated [2] in their mathematical activities such as acquiring mathematical concepts, skills and problem solving; meta-cognitively aware of their mathematical thinking; highly motivated in mathematics learning and develop positive attitudes towards mathematical task [3,4].

Based on the IQF (Indonesian Qualification Framework) curriculum listed in Presidential Decree No. 08 of 2012, Engineering Mathematics is a major competency subject that is obligatory for students majoring in Engineering. Problem solving ability and self-efficacy are essential things that students require when taking this course. In other words, students must be able to mathematically solve and interpret problems related to engineering mathematics in either spoken or written form.

According to Han [5], Engineering Mathematics is a less appealing subject to students. This happens because the lecturers do not facilitate students with problem-solving ability and self-efficacy. In the process of learning mathematics, the ability to solve problems is a necessary basic skill for students. In addition, basic problem-solving skill needs to be complemented with skills in understanding problems, making mathematical models, solving problems and interpreting the solutions. Students are considered capable in solving problems if they master self-efficacy ability. Self-efficacy is interpreted as one's judgement on their ability to arrange the actions needed in solving a problem. Self-assessment that a person has is closely related to self-efficacy. Self-efficacy in this study is specifically defined as self-ability in solving mathematical problems. Mathematical self-efficacy is the ability to solve problems especially those related to mathematics. Therefore, the process in learning mathematics can be interpreted if students are able to develop self-efficacy so that the learning process occurs optimally and is able to improve the problem-solving skill.

Constructivism is a learner-centered approach that develops as a solution to overcome students' difficulties in learning. One essential method of the constructivism approach is Problem Based Learning (PBL) [6]. PBL is described as a learning process that starts from real life problems. Levin [7] defines PBL as a learning approach that makes problems the basis for students to learn. PBL focuses on problems that are presented in an authentic and meaningful way. Problem-based learning teaches students to practice and concentrate on group learning

and find problem-solving results [8]. In other words, learning to solve problems begins with posing problems and questions.

In 1996, Barrow first applied PBL in medical education and then gradually applied it to educational studies in other scientific fields. According to Barrows [9], the features of PBL are the following: (1) Learning is learner-centered; (2) Learning takes place in small learner groups; (3) Teachers are facilitators and guides; (4) Problems organize students' focus and apply learning; (5) Problems are means for improving problem solving skills; and (6) New information is acquired by individual learning. The PBL method requires students to be responsible for their own learning. PBL is carried out in small discussion groups while the teacher acts as a facilitator in learning. The facilitator plays a role in guiding students in the learning process and supervising peer discussions. The role of teachers becomes minimal because students are increasingly responsible for their own learning process [10]. Eventually, students are actively involved in problem solving [11].

II. METHODS

This research is a quantitative study using a quasi-experiment research design method. The subjects of this study included 44 students who enrolled Engineering Mathematics course at the Mechanical Engineering Major, Muhammadiyah University of Tangerang, Indonesia. A half of the total subjects were randomly selected to be assigned to the experimental group and the remaining students were treated as the control group. The control group received traditional teaching methods and the experimental group received learning based on the Problem Based Learning (PBL) approach.

The Students' Worksheet (LKM) with the PBL approach consisted of integrated systematic questions and problems, developed by the author and was used for five weeks of lecture. Pre-test and post-test were delivered to find out the effect of PBL and conventional teaching approaches on students' mathematical problem-solving ability and self-efficacy. The pre-test was given before the implementation of problem-based learning method. The purpose of the pre-test is to determine the initial conditions of students in both experimental and control groups. Then, a post-test was managed to both groups after the implementation of problem-based learning and conventional methods.

Pretest and post-test entailed different essay questions of five which were made based on the preview, had a scoring rubric and their solutions. The indicators as well as the level of difficulty applied for both pre-test and post-test are identical.

The measurements of mathematical problem-solving ability and self-efficacy were taken from the results of worksheets and learning evaluation as well as presentation and investigation. The final result of this research showed that students were able to solve the problem, came up with a solution and then presented it.

During the PBL process, students formed groups of three. Each group member collaborated using the LKM with the PBL approach. LKM consisted of the first order differential equation topic including subchapter of differential equation with direct integration, differential equations with separation of variable, homogeneous differential equations, exact differential equations, linear differential equations and Bernoulli differential equations.

Each subchapter began with a problem outline and ended with the target learning outcomes to be achieved. The teacher presented a problem framework which then the students try to comprehend. Students were directed to search information in textbooks prepared by the teacher to answer questions. Before proceeding to the second problem, students required to solve questions from the first problem framework. At this stage the teacher acted as a facilitator who provided direction and controlled group discussions based on the questions at the LKM. In addition, they were asked to answer assessment questions in groups at the designated time. The next stage required each group representative to present the solution from the results of the group discussion. Then, the teacher gave feedback to the results of the students' presentations in order to obtain conclusions in this session.

In this study, the non-test instrument used was a student self-efficacy questionnaire. This questionnaire consisted of 20 self-efficacy statements measured using Likert scale model. The data collection techniques for self-efficacy were carried out by distributing questionnaires, with four alternative answer options which consisted of favorable and unfavorable items starting from SS (Strongly Agree), S (Agree), TS (Disagree), and STS (Strongly Disagree). Table I below presents the scoring format for the mathematical self-efficacy scale:

TABLE I. QUESTIONNAIRE SCORING RUBRIC

Statement	Strongly Agree (SS)	Agree (S)	Disagree (TS)	Strongly Disagree (STS)
Positive Statement	4	3	2	1
Negative Statement	1	2	3	4

The results of the self-efficacy scale scoring questionnaire data are described using the following formula:

$$p = (\text{raw score}) / (\text{ideal score}) \times 100\% \quad (1)$$

with the raw score and the ideal score are obtained from the total answer scores.

III. RESULTS AND DISCUSSION

The purpose of this study is to answer question "Are there statistically differences in problem-solving ability and self-efficacy of group achievement level during learning with the Problem Based Learning (PBL) and conventional approaches?"

The comparison of the average problem-solving ability between the PBL group and the conventional group is shown descriptively in Table II. It can be seen from the post-test result that the PBL group performed better than the conventional

problem-solving group after applying the PBL approach to the experimental class.

TABLE II. THE RESULTS OF THE MANN-WHITNEY U TEST ON THE ASSESSMENT OF THE CONTROL AND EXPERIMENTAL CLASSES

Test	Group	Mean	SD	n
Pretest	experimental	9.59	3.404	22
	control	15.23	4.680	22
Post-test	experimental	62.73	2.979	22
	control	50.91	7.646	22

Based on the results of the Mann-Whitney U Test analysis presented in Table III, the average problem-solving ability of the experimental group was 31.89, higher than the problem-solving ability of the control class which was only 13.89. This gap is statistically significant and can be seen at U = -4.950 and $p < 0.05$.

TABLE III. THE RESULTS OF THE MANN-WHITNEY U TEST ON THE ASSESSMENT OF THE CONTROL AND EXPERIMENTAL CLASSES

Group	Number	Mean Rank	Sum of Ranks	U	P
experimental	22	31.89	701.50	-4.950	0.000
control	22	13.11	288.50		

IV. CONCLUSION

According to the description regarding the conduct of the observational research described above, several conclusions are obtained. First, the problem-solving ability and self-efficacy of Mechanical Engineering students at Muhammadiyah University of Tangerang has improved after the application of the PBL model in the experimental class. Second, the increase in problem-solving ability and self-efficacy occurs due to the students' active engagement in the PBL class.

Third, the daily mathematics problems presented during the class make abstract mathematical concepts easier to understand so that not only problem-solving ability but also self-efficacy increase. Fourth, the teacher is no longer the centre of learning process but the consistency of the teacher as a learning facilitator greatly determines the success of the PBL implementation.

The main point of the effectiveness of PBL is the students' ability to work together to solve problems. Therefore, students can manage the PBL learning to facilitate collaborative mathematics learning. This is possible as the characteristic of PBL is similar with collaborative group discussions. PBL also begins the learning with presenting problems to activate initial knowledge through group discussions, has teachers to facilitate learning, and provides resources to help them solve problems. This study is comparable to previously reported findings that focused on re-measurement analysis of students' interest and achievement statistics who underwent the PBL learning model.

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