The Effectiveness of Problem-Based Learning Materials In Improving Students' Mathematical Critical Thinking Skills : A Study In Calculus Course

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Abstract—Critical thinking is an important skill to acquire, particularly for students at higher education. This study aims to investigate the effects of problem-based learning materials used in the topic of width of surface area and round volume on students' mathematical critical thinking skill. This quasi-experimental study uses one-group pretest-posttest design. Involving all students in semester two of the Mathematics study program, faculty of education, at a local university in Riau province of Indonesia as population, the study selects 52 students as samples. The instruments used in the study are test sheets on mathematical critical thinking skills, using one sample t-test statistical measurement. Findings of the study show that based on different academic competence levels (high, medium, and low) it is found that the use of problem-based learning materials in width of surface area and round volume can improve students' mathematical critical thinking skills. However, the improvement is not really significant that teachers need to find more innovative ways to increase this thinking skill. This study tries out a specifically-designed learning material to help students learn width of surface area and round volume topic. Since the designed learning materials are problem- based, findings show that they are able to improve students' mathematical critical thinking skills. Considering the scarcity of problem-based learning materials or text-books in calculus which focus on the development of students' mathematical critical thinking skills, this learning material can be developed into a comprehensive calculus text-books with this new focus.

Keywords— mathematical critical thinking skill, academic competence level, problem-based learning materials

I. Introduction

Critical thinking is a skill which students, especially of higher education, should own and develop. In this information era, the skill provides them with the ability to survive the challenge of present global world. This is line with what [9] believe that "with critical thinking, students became more curious and the habit of critical thinking will improve the mathematical ability of students". Meanwhile, these researchers also state that "the critical thinking skills can create and train someone to do (doing the math problems in mathematics learning" [10]

That critical thinking skill is important is also emphasized by other scholars. They provide some criteria that should followed when planning to develop critical thinking skills. Karlimah (2010) in cited [8] mentions six recommendations to be considered and used by mathematics education department in teaching mathematics courses. One of the recommendations states that each course in Mathematics course should include activities which support the development of students' analytical thinking, critical analysis, problem solving, and communication skills.

In a similar vein, [1] also argues that critical thinking skill is the ability of people to explain what they are thinking. To learn critical thinking skill means learning how to ask question, when to ask, what the question is, how the logic behind the question is and when to use it, as well as the method to use. in general, people are considered to have owned critical thinking skills if they can test their experience, evaluate their knowledge, ideas and consider arguments before justifying them.

Based on some definitions mentioned above, it can be concluded that critical thinking is a skill that students of higher education should own, develop and make it as their habit in performing all activities in their daily life, particularly in learning mathematics courses. With this skill, students are expected to be able to survive the global challenge which is fully loaded by myriad information, and therefore, needs critical judgment.

In relation to the development of students' critical thinking in Indonesian context, a study on the mathematical critical thinking skill of higher education students in solving mathematical problems based on their academic achievement level by [9] reveals some findings. First, most students are not really familiar, some even consider it taboo, with mathematical critical thinking skill and its practices. This evidence shows how they are not used to, if never at all, being exposed on questions which challenge their mathematical critical thinking skills. Second, classroom teaching practices do not introduce and direct students to develop their mathematical critical thinking skills. Third, the teaching and learning materials that the lecturers provide for them also do not include aspects (theory and practice) that can develop and nurture students' mathematical critical thinking skills. These unsatisfactory

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conditions need swift handling, otherwise, it is hard to improve students' mathematical critical thinking skills.

On the basis of this research finding, the present study develops a learning material which can assist students to construct and develop their mathematical critical thinking skills. With this purpose in mind, the development of learning material is based on problem solving, which is called Problem-Based Learning (PBL). Jacobson (1997) as cited in [4] argue that Problem-Based Learning has three main purposes; (1) developing students' ability to regularly provide a systematical and critical think on a question or problem, (2) developing self-directed learning, (3) obtaining content mastery.

The above description about the relationship between mathematical critical thinking and problem solving skills has clearly shown that problem-based learning is believed to be able to develop students' mathematical critical thinking skills. In this study, the learning material which is developed on the basis of problem is the width of surface area and round volume which is expected to be able to build and develop the mathematical critical thinking skills of the students.

II. Research Method

This study uses a quasi-experimental method with one-group pretest-posttest design. The population of the study is all students in semester 2 (two) of a Mathematics education program, faculty of education, at a private university in Riau province of Indonesia. The instrument used to collect data in this study is a test sheet on mathematical critical thinking skill. The results of test were then statistically analyzed using one sample t-test. The data analysis has the following steps.

a) Students were grouped/classified on the basis of their pre-test scores which were obtained by;

- Calculating mean of pre-test scores,
- Calculating the standard deviation of the pre-test scores,
- Grouping students based on certain pre-determined academic criteria

Students' groups based on academic criteria (pretest score) can be seen in Table 1 below.

TABLE I SCORE-BASED CATEGORY/GROUP

Group	Score Interval
High	$x \geq \bar{x} + stdev$
Medium	$\bar{x} - stdev \leq x < \bar{x} + stdev$
Low	$x < \bar{x} - stdev$

Adapted from [2]

Notes:
x = Student's score
$\bar{x}$ = Mean
$stdev$ = Standard Deviation

b) Calculating mean score of pretest, post-test, and N-gain
To identify the improvement of students' mathematical critical thinking, the formula gain – normalized (N_Gain) used is:

$$N\_Gain = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score}$$

Reference [5]

Furthermore, reference [5], argues that the value N_Gain is interpreted in the following groups or categories below:

$N\_Gain > 0{,}7$: High
$0{,}3 \leq N\_Gain \leq 0{,}7$: Medium
$N\_Gain < 0{,}3$: Low

c) Calculating mean score of pretest, post-test, and N-gain

III. Findings And Discussion

Before implementing the problem-based learning materials on the topic of width of surface area and round volume, the researchers administered a pre-test to sample students using the prepared test instrument of mathematical critical thinking skills. The pretest was administered to identify the current level of students' mathematical critical thinking skill on the width of surface area and round volume before the implementation of problem-based material which is developed by the researchers.

Then, the post-test was administered to participating students who have been treated with problem-based learning materials. Having administered the posttest, the researchers analyzed the data through the following steps:

1) Students' grouping/classification based on the academic competence level based on obtained pretest scores, as shown below.

TABLE II STUDENTS' GROUP/CLASSIFICATION BASED ON ACADEMIC COMPETENCE LEVEL

Pretest Mean	40.56	
Pretest $stdev$	16.96	
Classification Level		Total
High	$x \geq (40.56 + 16.96) = 57.52$	9 students
Medium	$23.6 = (40.56 - 16.96) \leq x < 57.52$	36 students
Low	$x < 23.6$	7 students

2) Calculating the mean of pretest, post-test, and N-gain scores.

TABLE III THE RECAPITULATION OF MEAN OF PRETEST, POSTTEST AND N-GAIN SCORES BASED ON OVERALL STUDENT'S CRITERIA AND ACADEMIC COMPETENCE LEVEL

Level academic competence	Mean			Classification
	Pretest	Posttest	*N-Gain*	
High	67.78	69.44	0.16	Low
Medium	37.75	47.64	0.16	Low
Low	20.00	32.14	0.15	Low

Moreover, the data also show that based on academic competence level, students with high and medium mathematical competence have a similar N-Gain score, which is, 0.16, whereas those from low mathematical competence obtain the N_Gain score of 0.15. This finding also suggests that

on the basis of students' mathematical competence levels, problem-based learning materials on the width of surface are and round volume can give a more significant improvement of mathematical critical thinking skills to students from high and medium academic competence levels than those from low academic competence level.

3) Administering the statistic test of *One Sample T-Test.*

TABLE IV THE RECAPITULATION OF PRETEST, POSTTEST, AND N-GAIN USING ONE SAMPLE T-TEST BASED ON OVERALL AND ACADEMIC COMPETENCE LEVEL

Academic competence level	Test Value	T	*Sig. (2-tailed)*	Notes
High	0.16	-0.19	0.985	H_0 accepted
Medium	0.16	-0.64	0.949	H_0 accepted
Low	0.15	0.021	0.984	H_0 accepted
Overall	0.16	-0.097	0.923	H_0 accepted

Testing criteria: If the value of *Asymp. Sig (2-tailed*) > α= 0,025, then Ho is accepted, otherwise rejected

Testing hypothesis

H_0 : Mean *N-gain* overall students $\geq$ *Test Value*

H_1 : Mean *N-gain* overall students $<$ *Test Value*

Based on Table 4 above, the statistical analysis of one sample t-test shows that hypothesis H_0 is accepted for all levels of academic competence. This means that students at all levels of academic competence have similar or higher mean of mathematical critical thinking improvement than the given test value of 0.16. Likewise, students of medium academic competence level also have a similar or higher mean of mathematical critical thinking than the given test value of 0.16. A comparable way is also followed by students of low academic competence level who have similar or higher mean of mathematical critical thinking improvement than the given test value of 0.15. Overall results also show that the mean of students' mathematical critical thinking improvement is similar or higher than the given test value of 0.16.

On the basis on this analysis, it is concluded that the implementation of problem-based learning materials on the topic of surface area width and round volume can develop and improve students' mathematical critical thinking skills, be it is seen from overall or different levels of academic competence (high, medium, low). However, the improvement made is still low or not very significant.

IV. CONCLUSION

Based on the above finding and discussion, the study concludes that the use of problem-based learning materials on width of surface area and round volume can develop and improve the students' overall mathematical critical thinking skills or specifically based on different academic competence levels (high, medium, low). However, the improvement made is still low, not really significant. The designing process of problem-based learning materials should be made more effective so that it can move into a higher level. To maintain a sustained development of critical thinking skill, students should be continuously exposed to problem-based materials which can steadily improve their mathematical critical thinking skills.

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