Implementation of problem-based learning (PBL) with virtual laboratory to improve students’ critical thinking and achievement

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Abstract. Critical thinking skill is an important tool used by students to solve the common problems either internal problem or problems that are found in school. This research aimed at indicating the influence of problem-based learning model implementation accompanied with the virtual laboratory to students’ critical thinking skills and learning achievement. The method was a true experiment and the sample was taken by using the true experiment technique, where grade ten-two class was selected as the experimental class and grade ten-three class as control class. Each of the classes consisted of 30 students. The experimental class was taught using PBL accompanied by the virtual laboratory. The collected data were analyzed by studying the comparison of improvement from a result of pretest and N-Gain and continued by using the t-test. The findings showed that there were no differences between students’ average scores between the experimental class and control class. N-Gain showed the real differences between the two classes. Overall, N-Gain for critical thinking skill function analysis revealed better results in experimental class than control class. It can be concluded that problem-based learning model implementation accompanied with virtual laboratory effectively increases students’ critical thinking skills and learning achievement.

1. Introduction
Critical thinking skill (or well known as KBK) is an important tool for students in learning physics when they faced every physical problem. Most active students used critical thinking skills in solving the problems; but the real observation showed that many students had difficulties to visualize what they had been learned such as graphics or mathematics. The critical thinking skill so far is rarely implemented in the learning process. The factor that causes a lack of students’ critical thinking skills is that teachers do not have good competence in managing the learning process [1]. Critical thinking is making sense, reflective thinking that is focused on deciding what to trust or to do [2].

From case study and interview with teachers of senior high school in Banda Aceh showed that (1) students were only given cognitive question test that consisted of knowledge, understanding during evaluation; (2) students had zero motivation in learning; (3) students did not have confidence in
solving the questions which were given by teachers in front of class; (4) students did not have
mathematical concepts; and (5) students were rarely doing practical studies at school because the
school only provided one laboratory. In addition, the most difficult material felt by students in 10th
year was Newton's Law material. The information obtained was that only 7 out of 30 students (23%)
who met the minimum completeness criteria, while 23 out of 30 students (77%) were still below.
Therefore, they felt hard to apply the concepts in learning physics.

In solving the problems, the teachers must have the proper learning models. In accordance with the
problems mentioned above, problem-based learning (PBL) is considered to be a good learning model.
The teachers who apply PBL in the teaching and learning process will be more effective to increase
students’ learning achievement [3]. PBL model is a learning process in which students must actively
use the knowledge they have to produce new information. Thus, the solution for none of the practical
studies is a virtual laboratory [4]. A virtual laboratory is the interactive multimedia-based software that
contains a series of laboratory equipment which can simulate the lab work [5]. The use of virtual
laboratories increases students’ achievement in learning physics. Students who learn physics using this
laboratory have higher KBK than students who learn conventionally [6].

2. Methods
The research method was used to answer the research problems in this study using a true experiment
with two classes. The research design is shown in Table 1.

| Sample      | Class   | Pretest | Treatment | Posttest |
|-------------|---------|---------|-----------|----------|
| Random      | Experiment | X1   | P1          | X2       |
| Control     | Control  | Y1     |            | Y2       |

Descriptions: X1 = Pretest before treatment for experimental class; X2 = Posttest after treatment for experimental class; Y1 = Pretest before treatment for control class; Y2 = Posttest after treatment for control class; P1 = Treatment for experimental class

The research was done by involving the 10th year student from science department in senior high
school Banda Aceh which contained 90 students who divided into three classes and were randomly
selected by using a random sampling technique. Indicators measured in this research were pretest and
posttest to critical thinking skill and learning achievement. The instrument used for this research was
28 questions which were supposed as the trials.

3. Results and Discussion
The analysis for pretest and posttest to the critical thinking skill which was presented in chart 1 and
presented the average score of pretest-posttest and N-Gain for experimental class and control class.
The average score of the experimental class was 45.40 for the pretest. Meanwhile, the average score of
the control class was 44.60. Besides, the average N-Gain for the experimental class was 69.54 and
40.44 was average N-gain for control class.

![Figure 1. Average Score of Pretest, Posttest, and N-Gain for critical thinking skill](image-url)
Figure 1 showed that the score of the posttest and N-Gain for the experimental class is higher than the score for the control class. It can be concluded that the use of the PBL model accompanied by the virtual laboratory is able to improve the average score of students in the experiment class compare to students in the control class. This result is inlaid with the previous research that indicates the use of the PBL model can increase students’ critical thinking skills and creative thinking skills [7]. The data are shown in the following Table 2.

**Table 2. The Differences in Average Score of Pretest for Critical Thinking Skill**

| Score | Class     | Average score | Normality* | Homogeneity** | Significance*** |
|-------|-----------|---------------|------------|---------------|----------------|
| Pretest | Experiment | 45.40 | \(X^2_{\text{count}} < X^2_{\text{table}}\) (5.45) < (5.991) (Normal) | \(F_{\text{count}} < F_{\text{table}}\) (1.04) < (1.84) (Homogen) | \(T_{\text{count}} < T_{\text{table}}\) (0.27) < (1.68) (not significantly different) |
|       | Control   | 44.60 | \(X^2_{\text{count}} < X^2_{\text{table}}\) (5.00) < (5.991) (Normal) | \(F_{\text{count}} < F_{\text{table}}\) (1.78) < (1.84) (Homogen) | \(T_{\text{count}} < T_{\text{table}}\) (9.5) < (1.68) (Significantly different) |
| N-Gain | Experiment | 69.54 | \(X^2_{\text{count}} < X^2_{\text{table}}\) (3.28) < (5.991) (Normal) | \(F_{\text{count}} < F_{\text{table}}\) (1.78) < (1.84) (Homogen) | \(T_{\text{count}} < T_{\text{table}}\) (9.5) < (1.68) (Significantly different) |
|       | Control   | 40.44 | \(X^2_{\text{count}} < X^2_{\text{table}}\) (3.03) < (5.991) (Normal) | \(F_{\text{count}} < F_{\text{table}}\) (1.78) < (1.84) (Homogen) | \(T_{\text{count}} < T_{\text{table}}\) (9.5) < (1.68) (Significantly different) |

Descriptions: *) Chi-square test (normal, where \(X^2_{\text{count}} < X^2_{\text{table}}, \alpha = 0.05\); **) F-test (homogenous, where \(F_{\text{count}} < F_{\text{table}}, \alpha = 0.05\); ***) t-test (significant, where \(t_{\text{count}} < t_{\text{table}}, \alpha = 0.05\))

The different tests of the students’ pretest to students’ critical thinking skills in (Table 2) were analyzed using the -t-test. The result of the analysis showed that the experimental class got the score 45.40 and the control class got the score 44.60. It indicated that the average score obtained was not significantly different. In addition, it showed that the pretest score of the experimental class and the control class was the same. Furthermore, the average N-Gain score obtained in the experimental class was 69.54 and the control class attained 40.44%. The increase of the N-Gain score on students’ critical thinking skills having given treatment showed a significant difference.

The results of the analysis of students’ pretest and posttest scores towards learning outcomes between experimental class and control class were shown in chart 2. It showed that the average score of pretest, posttest, and N-Gain for an experimental class. The average score of pretest for the experimental class was 44.93 and the average score of pretest for control class was 44.20. While the average score of N-Gain for the experimental class was 69.17 and 45.19 was the average score of N-Gain for control class.

![Figure 2. Average Score of Pretest, Posttest, and N-Gain of Learning Achievement](image)
posttest score of students and the data of N-Gain related to the score in experimental and control class were very significantly different. Look at the pretest result and N-Gain data on learning achievement in Table 3 below.

Table 3. The Differences in Average score for Pretest and N-Gain to Learning Achievement

| Score   | Class      | Average score | Normality* | Homogeneity** | Significance*** |
|---------|------------|---------------|------------|---------------|----------------|
| Pretest | Experiment | 44.93         | $X^2_{count} < X^2_{table}$ (0.40) < (5.991) (Normal) | $F_{count} < F_{table}$ (1.64) < (1.84) (Homogen) | $T_{count} < t_{table}$ (0.25) < (1.68) (not significantly different) |
|         | Control    | 44.20         | $X^2_{count} < X^2_{table}$ (2.38) < (5.991) (Normal) | $F_{count} < F_{table}$ (1.64) < (1.84) (Homogen) | $T_{count} < t_{table}$ (1.83) < (1.84) (not significantly different) |
| N-Gain  | Experiment | 69.38         | $X^2_{count} < X^2_{table}$ (1.46) < (5.991) (Normal) | $F_{count} < F_{table}$ (1.83) < (1.84) (Homogen) | $T_{count} < t_{table}$ (5.5) < (1.68) (Significantly different) |
|         | Control    | 45.18         | $X^2_{count} < X^2_{table}$ (1.78) < (5.991) (Normal) | $F_{count} < F_{table}$ (1.83) < (1.84) (Homogen) | $T_{count} < t_{table}$ (1.68) < (1.68) (not significantly different) |

Descriptions: * Chi square test (normal, where $X^2_{count} < X^2_{table}$, $\alpha = 0.05$); ** F-test (homogen, where $F_{count} < F_{table}$, $\alpha = 0.05$); *** = Uji t (significant, where $t_{count} < t_{table}$, $\alpha = 0.05$)

The difference of test related to the pretest score of students’ critical thinking skills in Table 3 was analyzed using the t-test. The results of the analysis of students’ pretest in the experimental class indicated that the average score obtained was not significantly different. Furthermore, the average N-Gain score obtained from both in experimental class and control class showed an improvement. The average N-Gain score on students’ learning achievement having given treatment showed a significant difference. This revealed that after the learning process using the PBL-assisted PhET model the average score of students’ learning outcomes in experimental class increases compared to the class of control which used the conventional model. Students who were taught the PBL model had a higher score of in-depth processing, gradual processing, self-regulation, and external regulation in independent learning compared to students who studied with a lecture-based curriculum [8]. Data obtained from research clearly showed that the PBL model assisted by the virtual laboratory was truly effective in improving critical thinking skills and student learning achievement. This was proved by an increase in the average N-gain for the experimental class.

The analysis of KBK enhancement was done by counting the N-Gain in each function of critical thinking which the next step will be obtained the N-Gain with some criteria; low (0-0.30), medium (0.31-0.69) and high (0.70-1.00) [9]. There were 8 functions of KBK analyzed; they were (1) asking problem (Problem statement), (2) goals, (3) information, (4) concept, (5) assumption, (6) point of view, (7) interpretation and inference, and (8) implication and cause.

The analysis of KBK in each function was done in experimental and control classes. The low, medium and a high percentage of N-Gain for each function will be calculated to compare the result between experiment and control class. The various criteria of N-Gain were found from students in experiment and control classes. The results of the analysis KBK functions in the experiment class were presented in Figure 3.
Figure 3. N-Gain Percentage of Critical Thinking Skill in Experimental and Control Class

Chart 3 showed the average N-Gain score in each indicator of students’ critical thinking skill divided into 3 categories namely low, medium, and high. In the experimental class, the indicators of information, interpretation, and inference had the highest score (0.8, high category). Meanwhile, the indicators of implication and cause got the lowest score (0.4, medium category). This was because students did not fully understand the implication and consequences of Newton’s law when it was applied to math. In control class, indicators design (purpose) which got the highest score of 0.7 (high category). Meanwhile, the concept indicator received the lowest score (0.1, low category) and information indicator got medium category (0.4). This was caused some students had some difficulties in understanding the concept which had been given. Consequently, it affected the information indicator. For some students when the questions were given, they did not fully understand the point of the question. It occurred because the students only memorized the formulas [10]. As a result, when they were given different questions, the students were not able to answer the questions.

Overall, the N-Gain score for each critical thinking function showed better results in the experimental class through the application of the PBL learning model assisted by the virtual laboratory than the control class that applied the conventional learning model.

4. Conclusions
The implementation of the PBL model accompanied by a virtual laboratory effectively increases the critical thinking skill and learning achievement of students. It is proved with the improvement of average score N-Gain of critical thinking skill which is 69.54 and learning achievement is 69.17.

5. References
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