Problem-based learning model on students' critical-thinking skills: A meta-analysis study

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Abstract. The Problem-based Learning model is increasingly popular in physics learning since it encourages students to think openly, actively, and reflectively. Thus, it affects students' critical-thinking skills. Through the meta-analysis, this study discussed how Problem-based Learning improved students' critical-thinking skills. In this study, the researchers employed the experimental design with a meta-analysis technique. The research had been conducted by collecting articles from Google Scholar, Scopus, and ERIC (Education Resources Information Center). A total of 122 articles had been obtained which then 15 articles were selected and analyzed through 5 stages, namely (1) Orientation, (2) Conceptualization, (3) Investigation, (4) Discussion, and (5) Conclusion. The results of this study indicated that the Problem-based Learning model was able to improve students' critical-thinking processes from the elementary level to the tertiary level. However, research on the Problem-based Learning model toward students' critical-thinking skills has not been done much in the field of physics-based on levels and dependent variables.

Keywords: Critical-thinking, Meta-analysis, Problem-based Learning

1. Introduction

Education in the 21st-century has experienced significant development [1,2]. The speed of this development cannot be separated from the results of research, both basic and applied research [3]. Education is an effort to increase the potential and quality of each individual [4,5]. In other words, the development of education is very important, especially in the current era of globalization. It requires students' skills in critical thinking to be developed in learning. These skills are applied during the learning process as well as in everyday life [6]. The characteristics of a critical thinker are solving a problem with a specific goal, analyzing, announcing, grouping ideas according to facts, and concluding a reference for solving problems using correct arguments [7,8]. Critical thinking is considered as a process that starts with a problem, ends with a solution, and self-interpretation [9–11]. If students are accustomed to thinking using critical-thinking patterns to solve a problem in everyday life, they will get used to forming their thought patterns.

One learning model that can improve students' critical-thinking skills is the Problem-based Learning model [12]. The problem-based learning model begins with a problem where students are given time to think together to find information and develop problem-solving strategies [13]. The problem-based learning model can be an efficient learning strategy, has a positive effect on teaching, and provides problem-solving skills [14].
The Problem-based Learning model towards students' critical-thinking skills has been widely researched and discussed, among others in the field of mathematics [15,16], counselling [17], arts [18], literature [19], biology [20], chemistry [21], and religion [22]. However, research that only focuses on physics learning is still lacking. There are only fifteen articles that discuss the Problem-based Learning model in physics learning. This indicates that research on Problem-based Learning model is rarely studied in physics learning, especially in improving students' thinking skills. Therefore, there was an opportunity to study the Problem-based Learning model in physics learning, especially in improving students' thinking skills and other dependent variables.

2. Method
This study employed the meta-analysis research with quantitative-descriptive methods. The electronic search found a total of one hundred and twenty-two articles in the Google Scholar, Scopus and ERIC databases searched using the keyword “Problem-based Learning model and students' critical-thinking skills” because the researcher focused this research on analyzing the effect Problem-based Learning model (PBL) on students' critical-thinking skills. Finally, the fifteen selected articles were analyzed through 5 stages, namely orientation, conceptualization, investigation, discussion, and conclusion. The stages and steps of this research are shown in Figures 1 and 2.

![Figure 1. Stages of Analysis](image)

![Figure 2. Steps of Research](image)
The third step of this study was to calculate the effect size. The calculation had been performed using the following formula:

\[
\text{Effect Size} = \frac{\text{Post Test Score} - \text{Pre Test Score}}{\text{Standard Deviation}}
\]

**Table 1. The Effect Size Interpretation Criteria**

| Size          | Interpretation     |
|---------------|--------------------|
| 0-0.20        | Weak Effect        |
| 0.21-0.50     | Modest Effect      |
| 0.51-1.00     | Moderate Effect    |
| > 1.00        | Strong Effect      |

3. Result dan Discussion
Fifteen articles related to the Problem-based Learning model on students’ critical-thinking skills had been obtained. The article data was processed by analyzing and determining the results of the research. Then, the data was presented qualitatively and quantitatively. The data of the searched articles can be seen in table 2.

**Table 2. Search Result**

| Code | Name                          | Independent Variable                  | Dependent Variable        | Design                    |
|------|-------------------------------|---------------------------------------|---------------------------|---------------------------|
| A1   | Zuryanti, et.al.              | problem-based learning model          | Critical-thinking         | Posttest only             |
|      |                               |                                       |                           | One group                 |
| A2   | Muslim, M.I Hakim, and R. Meidawati | problem-based learning model        | Critical-thinking         | Pretest-Posttest         |
|      |                               |                                       |                           | One Group                 |
| A3   | Widodo Budhi and Siti Suwarni | problem-based learning model          | Critical-thinking         | Posttest only             |
|      |                               |                                       |                           | Two Groups                |
| A4   | Sijanem et.al.                | Problem-Based Learning Model          | Critical-Thinking         | Pretest-Posttest         |
|      |                               |                                       |                           | One Group                 |
| A5   | M. Serungke, Muhibbudin, and Suhrawardi | Problem-Based Learning Model | Critical-Thinking and Achievement | Pretest- Posttest        |
|      |                               |                                       |                           | Two Groups                |
| A6   | U. Setyorini, S.E Sukiswo, and B. Subali | Problem-Based Learning Model | Critical-Thinking         | Pretest- Posttest         |
|      |                               |                                       |                           | One Group                 |
| A7   | Pricilla Anindyta, and Suwarjo | Problem-Based Learning Model          | Critical-Thinking         | Pretest- Posttest         |
|      |                               |                                       |                           | Two Groups                |
| A8   | Ahmad Farisi, Abdul Hamid, and Melvina | Problem-Based Learning Model | Critical-Thinking         | Posttest only             |
|      |                               |                                       |                           | Two Groups                |
| A9   | P. Dwijananti and D. Yulianti | Problem-Based Learning Model          | Critical-Thinking         | Pretest- Posttest         |
|      |                               |                                       |                           | One Group                 |
| A10  | L. Yulianti, R Fauziah, and A. Hidayat | Problem-Based Learning Model | Critical-Thinking         | Pretest- Posttest         |
|      |                               |                                       |                           | One Group                 |
| A11  | I Made Astra, Raharjo Nur     | Problem-Based Learning Model          | Critical-Thinking         | Pretest- Posttest         |
|      |                               |                                       |                           | Two Groups                |
After the treatments had been conducted, then the pretest and posttest was administered. The pretest was carried out before the application of the Problem-based Learning model method and the posttest was carried out after the application of the Problem-based Learning model method. Based on the results of the pretest and posttest, the researchers found that there was an increase in the critical-thinking skills at each level of educational research as described in table 3.

Table 3. The Percentage of Improvement of Students’ Critical-Thinking Ability

| No | Code  | Level                | Pretest Score | Posttest Score | Critical-Thinking Improvement |
|----|-------|----------------------|---------------|----------------|-----------------------------|
| 1  | A1    | Elementary School    | 67.71         | 94.28          | 26.57                       |
| 2  | A2    | Junior High School   | 42.6          | 78.9           | 36.3                        |
| 3  | A3    | Elementary School    | -             | 22.73          | 22.73                       |
| 4  | A4    | Senior High School   | 27.86         | 80.9           | 53.04                       |
| 5  | A5    | University           | 45.40         | 79             | 33.6                        |
| 6  | A6    | Junior High School   | 47.35         | 66.1           | 18.75                       |
| 7  | A7    | Elementary School    | 73.015        | 76.725         | 3.71                        |
| 8  | A8    | Junior High School   | -             | 32.57          | 32.57                       |
| 9  | A9    | University           | 63.10         | 79.80          | 16.7                        |
| 10 | A10   | Senior High School   | 28.86         | 80.9           | 52.04                       |
| 11 | A11   | Senior High School   | 41            | 91             | 50                          |
| 12 | A12   | Senior High School   | -             | 0.62           | 0.62                        |
| 13 | A13   | Senior High School   | -             | 72.91          | 72.91                       |
Table 3 shows that the Problem-based Learning model can improve students' critical-thinking skills from the elementary school level to the university level. The critical-thinking skills of students increased significantly. The average percentages of students’ critical-thinking improvements from the lowest to the highest were 0.62% and 72.91% with an average of 35.10%. The average value of students' critical-thinking before the application of Problem-based Learning model was 31.56% which then increased to 66.671%. The critical-thinking skills increased significantly by 35.10%. The percentage of the results of students' critical-thinking improvement varied. the researchers found that the difference in the percentage was caused by two factors, namely external and internal factors. Internal factors are factors that come from within (interest, talent, health) while the external factors are factors that come from outside (family, school, and environmental factors).

Besides knowing the percentage of students' critical-thinking improvement before and after the application of the Problem-based Learning model, the researcher also calculated the effect size. The effect size was used to determine the influence of the Problem-based Learning model on students' critical-thinking skills. The result is presented in Table 4.

Table 4. Effect Size Analysis

| No | Code | Effect Size Analysis Results | Category |
|----|------|-----------------------------|----------|
| 1  | A1   | 0.265                       | Modest Effect |
| 2  | A2   | 0.363                       | Modest Effect |
| 3  | A3   | 0.227                       | Modest Effect |
| 4  | A4   | 0.530                       | Moderate Effect |
| 5  | A5   | 0.336                       | Modest Effect |
| 6  | A6   | 0.1875                      | Weak Effect |
| 7  | A7   | 0.037                       | Weak Effect |
| 8  | A8   | 0.325                       | Modest Effect |
| 9  | A9   | 0.167                       | Weak Effect |
| 10 | A10  | 0.520                       | Moderate Effect |
| 11 | A11  | 0.500                       | Modest Effect |
| 12 | A12  | 0.062                       | Weak Effect |
| 13 | A13  | 0.729                       | Moderate Effect |
| 14 | A14  | 1.2                         | Strong Effect |
| 15 | A15  | 0.368                       | Modest Effect |

Table 4 shows the analysis results obtained from the effect size formula. The Problem-based Learning model showed a high influence on students' critical-thinking skills because the students did not only focus on learning the concepts, but also learning other methods to solve problems.

Furthermore, based on the reviewed articles, there were open opportunities for Problem-based Learning model research in the field of physics to be analyzed through meta-analysis. There was only one Scopus indexed article that discussed the effect of the problem-based learning model on students’
critical-thinking skills. Moreover, in the field of mathematics, there has been no meta-analysis study of the effect of the problem-based learning model on students’ critical-thinking skills in physics. Also, research related to the Problem-based Learning model has high opportunities for other variables. Through the meta-analysis study, this article discussed how the Problem-based Learning model can improve students’ critical-thinking skills. This article also presents data on the percentage of increase before and after the application of the Problem-based Learning model at each level of educational research.

4. Conclusion
Based on the research results, the researcher concluded that the Problem-based Learning model was effective in improving students' critical-thinking skills. However, research on the Problem-based Learning model has been rarely carried out in physics learning since there were only 15 articles that discussed the Problem-based learning model in physics learning. This indicated that research on Problem-based Learning model was lacking, especially on students’ thinking skills variable. However, in other subjects, the Problem-based Learning model has been discussed quite a lot, even in each dependent variable. Therefore, there is an opportunity to study the Problem-based Learning model in physics learning at each level of education and the dependent variable.

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