

# The Effectiveness of Problem Based Learning in Biology

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# The Effectiveness of Problem Based Learning in Biology with Fishbone Diagram on Critical Thinking Skill of Senior High School Students

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**Abstract.** This research aims at investigating the effectiveness of Problem Based Learning with Fishbone Diagram on the students' critical thinking skill in the Biology learning. This research adopted a quasi-experimental design notably pretest-posttest nonequivalent control group design. Population of this research 73 students of grade X of the State Senior High School 1 of Pundong. The population was taken by using target population, and 49 students were determined as the sample by using random sampling technique. This research adopted critical thinking tests that were administered before and after the learning process took place. The instrument to measure critical thinking skill was a test consisting of 11 items. The instrument was initially validated the expert lecturer (expert judgment) to obtain its content validity and construct validity. Subsequently, empirical validity and instrument reliability were done by using Alpha Cronbach. The data of critical thinking skill were analyzed by using independent sample t-test at the significance level of ( $\alpha$ ) = 0.05. The result showed the significance value of  $0.00 < 0.05$ . This study suggests that PBL with FD was effective in developing the students' critical thinking skill.

## 1. Introduction

The world has experienced fast and unpredictable changes in the 21<sup>st</sup> century that involved voluminous aspects of life such as technology, communication, information, economy, transportation, etc. Schools need to anticipate these changes by developing the 21<sup>st</sup> century skills [21]. There are some competencies that must be developed in living in the 21<sup>st</sup> century. They are critical thinking skill, problem solving, creativity and innovation, communication and collaboration, social skill and cross culture, and mastery of information [17].

The change of curriculum must be done to anticipate the needs of the 21<sup>st</sup> century. In Indonesia, the alteration and revision of curriculum have been performed by the government. The recent curriculum – as a result of the alteration and revision of the previous curriculum – is called the Curriculum of 2013. This curriculum has been designed to develop the 21<sup>st</sup> century skills, either viewed from the standard of content, process, or evaluation. In the process standard, for example, the curriculum of 2013 adopts scientific approach in which a teacher functions as the facilitator or motivator, no longer as a solitary learning source. However, most of the learning processes remain teacher-centered. The learning process should not be a transfer of knowledge in which the knowledge is simply transferred from teachers to students, yet it should be a stimulus to students to develop their thinking skill. Students are expected to be a critical thinker and problem solver [19]. The teacher-centered learning makes students passive during the learning process, therefore they are unable to critical thinking skill excellently.

Critical thinking skill of Indonesian students is still low according to with a survey conducted by PISA (Program for International Student Assessment) and TIMSS (Trends in International

Mathematics and Science Study) in 2015. The survey revealed Indonesia still placed the bottom rank compared to other countries. Of all the tests, Indonesian students were only able to solve the second difficulty level (understanding), whereas higher order thinking skill (HOTS) were categorized into the fourth up to sixth difficulty level [21]. The learning process should be directed to develop the students' critical thinking skill. Critical thinking skill is not only essential in the learning process to achieve a high score, but also it is used to help students solve problems in daily life and career [4], [9].

The students' critical thinking skill can be trained by applying a learning model namely Problem Based Learning (PBL). PBL in Biology is a learning model in which students learn by solving realistic, general, crucial, complex, and open-ended problems about Biology. Based on the literature study, Biology problems in PBL include ecosystems, environmental changes, organ systems in humans, fungi, bacteria, metabolism (photosynthesis), Spermatophyta, biotechnology, invertebrates, and classification of living creatures. In this study, the Biology problems are only limited to the problem of environmental change. The aforesaid problems are the real-life problems that must be resolved by applying some concepts and principles [23], [1]. The real problems adopted in PBL stimulate students to vigorously construct new knowledge that relates strongly to their prior knowledge; therefore, learning is a constructive and contextual process [7]. According to Surya et al. [25], PBL develops the students' critical thinking skill since students are directed to find a problem in the Biology learning, identify any possible solutions, decide the best solution, and discuss and evaluate the applied solution. Thus, students are truly trained to develop their critical thinking skill. This is in line with Orozco & Yangco [16] arguing that PBL improves the students' critical thinking skill and creativity in the Biology learning.

Before solving a problem, one must identify and understand the causes of the problem, thus problem solving can be more straightforward. One of the tools of Root Cause Analysis (RCA) to help a group or individual identify the causes of a certain problem is Fishbone Diagram (FD) [6]. Fishbone Diagram – known as the Cause and Effect or Ishikawa Diagram – was firstly introduced by Kaoru Ishikawa, a Japanese scientist. Fishbone Diagram is an analysis tool to see and find the causes of a problem contributing to it systematically [27]. In reference to [13], Fishbone Diagram is a diagram that is used to investigate the real causes or potentials of a problem. Meanwhile, [10] said that Fishbone Diagram is created to identify and classify the causes of a problem. According to [15], the implementation of FD in PBL fostered students in analyzing; finding and identifying factors affecting a problem more deeply; determining the solution more straightforwardly due to a meaningful and systematic process; building their own knowledge; and expressing and accepting other people's opinion.

Most of the researchers suggest adopting FD as an assistant tool to solve problems. According to Wong [28], FD was utilized to show the connection between a clinical problem and its potential causes. FD enhanced memory skills and helped someone take the relevant medical cases as well as literature. FD can be used in PBL model either in a group or individual learning. Based on a study by Ilie & Ciocoiu [10], it was revealed that FD was a tool to determine the risks of a case with any relevant causes. FD was also straightforward in its practice. A literature study also indicated that PBL enhanced the students' achievements, whereas FD assisted in resolving problems [11].

Several studies have confirmed the effectiveness of PBL with FD in learning. Meylani et al. [15] showed that PBL with FD developed the students' science process skill in the Biology learning of grade X students, notably in the topic of environmental contamination. This research used a true experimental design. Another study done by Prasasti [20] indicated that PBL with FD was effective in enhancing the student's analyzing skill in the environmental contamination material. The type of this research was a quasi-experimental one group pretest posttest design. Istikomah [11] also investigated the effect of PBL with FD on the critical thinking skill of Vocational High School students majoring in Computer Engineering. The material used in this research was problem diagnosis of computer network. A quasi-experimental pretest-posttest non-equivalent control group design was adopted in this research. The result demonstrated that the implementation of PBL with FD was effective on the students' critical thinking skill.

Referring to the previous studies, the researchers want to investigate the effectiveness of PBL with FD in the Biology learning. The similarity of the present study with Meylani et al. [15] and Prasasti [20] is that the material used – either the present study or the previous studies focus on the topic of environmental change for Senior High School students majoring in Mathematics and Science. The present study, however, differs from the previous studies by Meylani et al. [15] and Prasasti [20] in terms of the dependent variable and research design. In addition, comparing to Istikomah [11], the present study embodies both the similarity and difference. The similarity was apparent in the dependent variable and research design, yet this present study is different in terms of the learning materials as the focus of this study. The novelty of this study lies in the effectiveness of PBL in Biology with FD on the students' critical thinking skills in State Senior High School 1 of Pundong, which was conducted by adopting quasi-experimental non-equivalent group design. This research is crucial to provide novel information about the effectiveness of Problem Based Learning in Biology with Fishbone Diagrams on the students' critical thinking skills in State Senior High School 1 of Pundong.

Based on the elaboration above, the effectiveness of PBL with FD on the students' critical thinking skill is essential to be explored. This research aims to investigate the effectiveness of PBL with FD on the students' critical thinking skill in the Biology learning about environmental change di State Senior High School 1 of Pundong.

## 2. Method

This research used a quasi-experimental design notably pretest-posttest nonequivalent control group design. This design is called nonequivalent because the experimental and control groups are not randomly selected. This research applied experimental group and control group that were given different treatments. The experimental group received the treatment of Problem Based Learning (PBL) with Fishbone Diagram (FD), whereas the control group obtained 5M scientific approach as the treatment in the learning process of Biology focusing on environmental change. This research was carried out in the State Senior High School 1 of Pundong. The subjects were 49 students of grade X in the academic year of 2018/2019. The population in this research used target population, and the sample was determined by using random sampling technique. To collect the data, the researchers used testing technique. It adopted 11 essay questions to measure the students' critical thinking skill. Before the instrument was used, the validation of instrument was performed to identify the content validity and construct validity. This validation process involved the expert lecturers (*the expert judgment*). Subsequently, it was performed the empirical validity and instrument reliability tests by using Alpha Cronbach. The data of critical thinking test were then analyzed by using independent sample t-test from SPSS 22 when the result of prerequisite tests were met, that is, the data were normally distributed and homogeneous.

## 3. Result and Discussion

Before the instrument was applied, the expert validation was undertaken by two expert lecturers (expert judgment). The quantitative data were transformed into the mean score, and converted to scores ranging from scale 1-5. Table 1 displays the conversion from quantitative data to qualitative data adopted from [22].

**Table 1.** The Conversion of Five-Point Score

Score Interval	Category
$X > X_i + (1.80.Sb_i)$	$X > 4.2$ Very Good (A)
$X_i + (0.60.Sb_i) < X \leq X_i + (1.80.Sb_i)$	$3.4 < X \leq 4.2$ Good (B)
$X_i - (0.60.Sb_i) < X \leq X_i + (0.60.Sb_i)$	$2.6 < X \leq 3.4$ Fair (C)
$X_i - (1.80.Sb_i) < X \leq X_i - (0.60.Sb_i)$	$1.8 < X \leq 2.6$ Worse (D)
$X < X_i - (1.80.Sb_i)$	$X \leq 1.8$ Poor (E)

The result of validity test obtained the mean of 4.95 from the scale of 1-5; thus, it belonged to a very good category. The validation result by two validators showed that the critical thinking test was decent to be used without any revision.

The empirical try-out of the test was conducted in State Senior High School 1 Pundong to know which critical thinking questions were valid. An empirical try-out was conducted on a sample of the students of grade XI at the school. The assumption was that the students have studied the subject of Environmental Change. The validity test was done by benefiting SPSS 22. Referring to the result of analysis, it was obtained 11 valid questions of 17 questions in total. The questions were valid if  $r$  obtained  $> r$  table (0.3673) for  $n = 29$ .

In this research, the reliability test was performed by using Alpha Cronbach formula. SPSS 22 was utilized in the reliability test. The result of reliability test showed a reliability coefficient of  $0.666 > 0.6$  for the variable of critical thinking skill. The reliability degree of Alpha Cronbach of 0.6 has been declared as the minimum level of acceptance [12]. Based on the reliability test, it can be concluded that the instrument was reliable.

The data of the students' critical thinking skill comprised of pretest and posttest scores from the experimental and control groups. The students reached the minimum criteria of success if they attained the score of 68. Table 2 depicts the descriptive analysis of pretest and posttest of the students' critical thinking skill.

**Table 2.** The Result of Descriptive Analysis of the Students' Critical Thinking Skill

Analysis of	PBL+FD Class		Control	
	<i>Pretest</i>	<i>Posttest</i>	<i>Pretest</i>	<i>Posttest</i>
Mean	42.04	78.16	37.92	59.33
The highest score	67	91	67	79
The lowest score	15	64	15	45
Deviation standard	13.268	7.116	13.161	9.635
N	25	25	24	24

As Table 2 shows, the results of pretest of experimental group and control group were nearly similar. The difference between the two groups was 4.12. The mean difference was also tested by using SPSS program resulting in the significance value of 0.280 ( $p > 0.05$ ). Thus, it can be said that  $H_0$  was rejected and  $H_a$  was accepted. It indicated that the students' critical thinking skill in either experimental group or control group was alike before the treatment was given. Therefore, both groups met the criteria to participate in this research. The difference of posttest result regarding the students' critical thinking skill was 19.43. The mean obtained by the experimental group was higher than that of the control group. Based on Table 2, it is known that the mean of posttest of PBL with FD class FD, 78.16, has reached the Minimum Completion Criteria (KKM), that is, 68 (mean  $78.16 > 68$ ), whereas the mean of posttest of the control class, 59.33, has not yet reached KKM (mean  $59.33 < 68$ ). The mean of posttest was then interpreted in the form of qualitative data [3]. The criteria of critical thinking skill are presented in Table 3.

**Table 3.** Criteria of Critical Thinking Skill

Interval Score	Criteria	
$X > Mi + 1.5 Si$	$X > 75$	Very Good (A)
$Mi + 0.5 Si < X \leq Mi + 1.5 Si$	$58.33 < X \leq 75$	Good (B)
$Mi - 0.5 Si < X \leq Mi + 0.5 Si$	$41.67 < X \leq 58.33$	Fair (C)
$Mi - 1.5 Si < X \leq Mi - 0.5 Si$	$25 < X \leq 41.67$	Worse (D)
$X \leq Mi - 1.5 Si$	$X \leq 25$	Poor (E)

Explanation:  $Mi$  : Ideal mean;  $Si$  : Ideal standard deviation, where

$$M_i = \frac{1}{2} \times (\text{ideal maximum score} + \text{ideal minimum score}) = \frac{1}{2} \times (100 + 0) = 50$$

$$S_i = \frac{1}{6} (\text{ideal maximum score} - \text{ideal minimum score}) = \frac{1}{6} \times (100 - 0) = 16.67$$

As depicted in Table 3, the result of posttest of PBL with FD class was very good (A), while the posttest result of the control class was good (B). Although the experimental results were classified into a very good category, the mean score was far from the maximum score of 100. This is due to the students' unfamiliarity with PBL. Therefore, the application of PBL needs to be carried out continuously by teachers in schools so that the results can be more optimum. The high standard deviation in the experimental and control groups was owing to the varied students' thinking skills; some were low, and some others were high. Data that are far from the mean will produce deviation greater than close to the mean. After being given treatment, the results of the students' critical thinking skills in the experimental and control groups also varied.

Once the descriptive analysis had been performed, the prerequisite tests including normality test and homogeneity test were carried out before analyzing the data by using independent sample t-test. The data analysis adopted SPSS 22 to test the normality and homogeneity. The normality test of the data was performed by adopting Saphiro-Wilk test. Table 3 shows the result of normality test of the students' critical thinking skill.

**Table 4.** The Normality of the Data of the Students' Critical Thinking Skill

Groups	Data	Significance	Conclusion of Data Distribution
PBL+FD	<i>Pretest</i>	0.335	Normal
	<i>Posttest</i>	0.364	Normal
CONTROL	<i>Pretest</i>	0.442	Normal
	<i>Posttest</i>	0.415	Normal

As depicted in Table 4, the result of normality test of the students' critical thinking skill resulted in the significance value of  $> \alpha$  (0.05); thus,  $H_0$  was rejected. This finding indicated that the data of the students' critical thinking skill was normally distributed.

The homogeneity of data variance of the students' critical thinking skill in both the experimental group and control group was analyzed by using Levene test. Table 5 demonstrates the result of homogeneity test of data variance of the students' critical thinking skill.

**Table 5.** The Result of Homogeneity Test of Data Variance of the Students' Critical Thinking Skill

The Data of the Students' Critical Thinking Skill	Significance	Conclusion of Data Variance
<i>Pretest</i>	0.916	Homogeneous
<i>Posttest</i>	0.218	Homogeneous

Referring to Table 5, the result of homogeneity test of data variance of the students' critical thinking skill revealed sig. *based on mean* mean pretest  $0.916 > \alpha$  (0.05) and posttest  $0.218 > \alpha$  (0.05); therefore,  $H_0$  was rejected. This finding suggests that the data of the students' critical thinking skill in pretest and posttest came from the homogeneous population – in other words, the data had the same variance.

Once the prerequisite tests were accomplished, hypothesis testing was then performed by using independent sample t-test. The hypothesis testing was done to figure out if there was any effect of PBL with FD on the development of the students' critical thinking skill. Table 6 displays the result of independent sample t-test of the students' critical thinking skill.

**Table 6.** The Result of Independent Sample T-Test of the Students' Critical Thinking Skill

Type of Data	t	Df	Sig. (2-tailed)	A	Decision	Detail
<i>Posttest</i>	7.802	47	0.000	0.05	H <sub>a</sub> was accepted	Significantly different

As showed in Table 6, the value of sig. (2-tailed) was  $0.000 < 0.05$ ; hence, it can be concluded that  $H_0$  was rejected while  $H_a$  was accepted. This finding indicated the significant difference of the mean score of the students' critical thinking skill in the experimental and control groups. The result showed that there was a significant effect of Problem Based Learning (PBL) with Fishbone Diagram (FD) on the students' critical thinking skill.

The students in the experimental group were more active comparing to those involved in the control group. The students were more attracted to make FD with their groups [11]. The real problems in PBL stimulate the students to actively construct new knowledge that strongly allied with their prior knowledge. The learning process, therefore, can be constructive and contextual [7]. In addition, the complex problems in PBL boost the students' critical thinking since the students must solve the problems by evaluating some valid solutions [5].

According to [6], FD is an assistant tool to solve problems. FD identifies factors causing a problem in a structured way by using a technique focusing on the identification and completion of the problem. FD makes the students more straightforward in finding, identifying and analyzing the root causes that relate to the materials, and identifying which parts have the interrelated problems [13]. Each student involved in the learning process adopting FD can participate in providing solutions concerning on the potential causes of a problem or the core of the problem. Active learning in groups can enhance the students' critical thinking skill since the students can be open-minded, and they can communicate effectively with other students [8], [18].

The use of Fishbone Diagram as a graphic organizer can help the students understand the entire information, in addition to enhancing the students' creativity. Besides, Fishbone Diagram assists the students in clarifying and organizing the relationship between concepts and ideas; helps the students focus on the materials; facilitates the students in doing brainstorming of the possible causes of a problem; aids the students in solving a problem, making decision or action, and helping the students enhance memory skill and understanding; and guides the students in communicating their thinking process in either spoken or written form [26], [14].

The implementation of PBL with FD in the form of fishbone makes the discussion more directed to a problem and its causes, whereas in the implementation of PBL without FD, it was not found the same finding. The students in the experimental group were more enthusiastic in learning comparing to the control group. This is seen from the students' behavior that was more active, careful, and collaborative during the learning process. Not to mention, the students performed better in making and answering questions in presentations [15].

PBL with FD facilitates the students in understanding the root causes of a problem. This way, they can be more straightforward in determining the solutions. When the students were accustomed to analyzing, organizing, evaluating, and solving problems, their critical thinking skill will improve. Based on a research done by [20], PBL with FD enhanced the students' critical thinking skill notably analyzing skill because the students were encouraged to analyze the root of a problem related to the materials. Besides, the students were actively urged to develop analyzing skill through experimentation or direct observation. The development of the students' critical thinking skill can be seen from the students' willingness to ask questions, respond to questions with unpredictable answers, propose varied solutions, and numerous alternatives of correct answer the students have.

The finding of this study is in line with [2] stating that PBL enhanced the students' achievements. In their experimental study, the experimental group performed better than the control group. This study is also consistent with [11] revealing that PBL with FD was effectual on the students' critical thinking skill since PBL trained the students to solve a problem, and FD helped the students undertake the problem.

#### 4. Conclusions

This research suggests that Problem Based Learning with Fishbone Diagram was effective in developing the students' critical thinking skill. Based on the mean of posttest, the critical thinking skill of the experimental class has reached the KKM (Mean 78.16 > 68), while the control class has yet to reach the KKM (mean 59.33 < 68). After converting quantitative data to qualitative data, the mean of posttest of the critical thinking skill in the experimental class belonged to a very good criteria (A), whereas the control class was classified into a good criteria (B). Although the experimental result was very good, the mean score was still far from the maximum score of 100. It happened since students were unfamiliar with PBL. Therefore, teachers should continually apply PBL so that the result can be more optimal. The high standard deviation was due to the diverse students' thinking skills; some were low, and some were high. After the treatment was given, the result of the students' critical thinking skills in the experimental class also varied. Although the pretest score between the experimental group and control group was the same, there was a significant difference in posttest in which the experimental group achieved a higher score comparing to that of the control group. The result of independent sample t-test showed the significance value of  $0.00 < 0.05$ .

The researchers expect this study can be a source of information for teachers in applying Problem Based Learning with Fishbone Diagram in schools, thus students can construct their knowledge. The implementation of this model should be done continuously to improve the students' critical thinking skill. Before the class begins, teachers should prepare everything well mainly the selection of real problems appropriate with the materials. Therefore, students can analyze and solve problems accordingly. Teachers also need to manage their time to better implement Problem Based Learning with Fishbone Diagram. Further researchers can conduct the similar study focusing on other materials, and even other fields of study.

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