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The Application of STEM Project-Based Learning Model to Improve Critical Thinking Skills and Learning Outcomes of Year 10 Students of MAS Darul Ihsan

Susi Yanti[1],Hafnati Rahmatan[2*], M Ali Sarong[2]
[1]*StudentofMasters in BiologyEducation, Syiah Kuala University, Banda Aceh, Indonesia*
[2]*Lecturer of masters in BiologyEducation, Syiah Kuala University, Banda Aceh, Indonesia*

Abstract:
Background*: The students' skills in analyzing a problem to practice critical thinking skills are lacking. Therefore, the STEM Project-based Learning model was used to improve the students' learning outcomes and critical thinking skills.*
Materials and Methods*: This study aimed to determine the improvement of students' critical thinking skills and learning outcomes using a STEM Project-based Learning model on environmental pollution topic in the Year 10 classroom of MAS Darul Ihsan, Aceh, Indonesia. It employed a quantitative method with an experimental research approach. The research design used was a one-group pretest-posttest design. The population of this study was all Year 10 students of MAS Darul Ihsan (159 students), which was then used as the sample using a total sampling method. The instrument used to measure critical thinking skills was a multiple-choice reasoning test consisting of 30 items and a learning outcome test consisting of 30 multiple-choice items. Data analysis involved the N-gain test and paired sample t-test at a significant level of 0.05.*
Results*: The results showed that: 1) the STEM Project-based Learning model improved students' critical thinking skills on environmental pollution topic in Year 10 of MAS Darul Ihsan, and 2) STEM Project-based Learning models also improved students' learning outcomes on the environmental pollution topic in Year 10 of MAS Darul Ihsan.*
Conclusion: *The STEM Project-based learning model improves students' critical thinking skills and learning outcomes on the environmental pollution topic in Year 10 of MAS Darul Ihsan.*
Key Word*: Model Project-Based Learning, STEM, Critical thinking skills, Learning outcomes*

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I. Introduction

The critical thinking skill was first developed by Edward Glatserin 1941[1]. The skill is ways of thinking about subjects, contents, or problems to prove the quality of thinking and the skill of drawing conclusions based on problems. Someone who thinks critically should have these indicators: focus, reason, inference, situation, clarity, andoverview[2]. This critical thinking should be trained to create students who can compete in the workforce after completing their education.

The preliminary study conducted in MAS Darul Ihsan indicated some problems in learning;(1) the learning method did not provide opportunities to the students to ask inquiries for things that they have not understood, (2) the students were not able to develop their ideas to solve problems about environmental pollution which the teacher asked. It impacted the poor students' critical thinking skills and learning outcomes. In addition, it cannot meet the minimum mastery criteria of Year 10 at MAS Darul Ihsan, namely 75 for the environmental pollution topic. The data of learning outcomes showed that 25 out of 81 students meet the minimum mastery criteria. Thus, a learning innovation was carried out using STEM Project-Based Learning to improve the learning process to develop students' critical thinking skills and upgrade their learning outcomes.

The Project-Based Learning (PjBL) model helped students understand the concept of creating a product; meanwhile, STEM learning has a planning process that enables students to produce the best products as solutions to the environmental pollution topic. The implementation of the STEM learning approach improved students' critical thinking skills. Critical thinking is reflective thinking that focuses on making decisions about what they believe and what to do next[2]. STEM approach is a conceptualization of disciplines as a cohesive entity. Its teaching method is integrated and coordinated when applied in real-world problem solving[3]. Thus, STEM education is a model that promotes and improves discipline learning[4].

The Project-Based Learning (PjBL) model and STEM have strengths. PjBL enables students to understand concepts by creating products. STEM learning has planning and engineering design process that

enable students to produce their best products. Integrating STEM aspects contributes to learning outcomes, specifically improving the students' learning outcomes in science and technology[5]. Implementing the STEM Project-Based Learning aims to positively influence the students' critical thinking skill and their learning outcomes.

Several previous studies were relevant to this research (based learning project implementation) conducted by Insani et al. (2018). They explained that implementing the Project-Based Learning model enhanced the students' critical thinking skills effectively in SMP Negeri 2 Malang. There was a difference in average critical thinking ability in the experimental and control class. The average of the experimental class was higher than those in the control one[6]. This was in line with Gandhi et al.'s (2021) research finding; it indicated that the STEM Project-Based Learning model contributed to the critical thinking skill[7].

Based on the problems, the researcher will conduct research entitled"The implementation of STEM Project-Based Learning model in improving critical thinking skill and learning outcomes of students Year 10 at MAS Darul Ihsan".

II. Material and Methods

This study used a quantitative method using an experimental approach. It investigated the students' critical thinking skills and learning outcomes.

Study Design: One-group, Pretest-posttest design.
Study Location: MAS Darul Ihsan
Study Duration: Second semester in 2020/2021, Year 10 of MAS Darul Ihsan
Sample: 159 students
Subjects & selection method: Year10 students at MAS Darul Ihsan

Proceduremethodology: Data was collected by a test. The paper-based test was conducted to examine the students' critical thinking skills and learning outcomes after learning the environmental pollution topic using STEM Project-Based Learning.

Statistical analysis

The data analysis included these activities: clarifying, analyzing, using, and drawing a conclusion from the data collected. The data of students' critical thinking skills and learning outcomes were analyzed in the following stages:

1. Critical thinking skills

The scores of critical thinking skills ranged from 0 to 3; the percentage was calculated as follows:

$$\text{Percentage value} = \frac{\text{Student's Score}}{\text{Maximum Score}} \text{ x } 100\%$$

The percentage of critical thinking skills based on the calculation was categorized and presented in Table 1.

Table 1. The guidelines of critical thinking skillscategory[8]

Number	Interval	Category
1	81-100	Very high
2	61-80	High
3	41-60	Medium
4	21-40	Low
5	0-20	Very low

2. N-Gain Test

The data were analyzed to examine the improvement of critical thinking skills and student learning outcomes using the N-gain test, using the formula proposed by Meltzer (2002) is as follows[9]:

$$\text{N} - \text{Gain} = \frac{\text{Posttest} - \text{pretest}}{\text{Maximum probable score} - \text{pretest}} \text{x } 100$$

The N-Gain criteria are presented in Table 2.

Table 2. N-Gain Criteria[9]

No	Score	Category
1	N-Gain > 0.7	High
2	0.3 ≤N-Gain ≤ 0.7	Medium

3	N-Gain < 0.3	Low

3. Paired-Sample T-test

Paired Sample t-test is used to examine the difference between paired samples, assuming that the data is normally distributed. Paired samples come from the same subject; each variable is taken in different situations and circumstances. In this study, a paired-sample t-test was used to examine the improvement of students' critical thinking skills and learning outcomes after experiencing the STEM Project-based learning.

III. Results

Critical Thinking Skills

Data collection results comprise the pretest and posttest scores of students' critical thinking skills on the environmental pollution topic in Year 10 of MAS Darul Ihsan before and after implementing the STEM Project-based learning. The average increase in each indicator of students' critical thinking skills on the environmental pollution topic consisting of six indicators: focus, reason, inference, situation, clarity, and overview, can be seen in Figure 1.

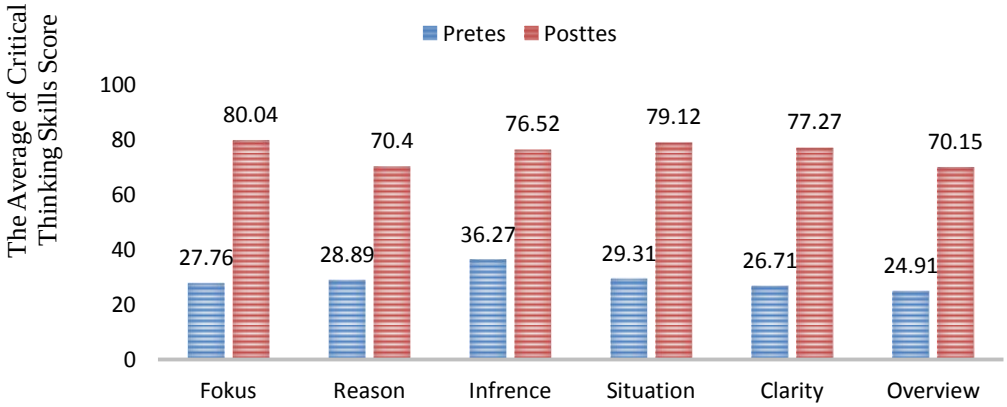

Figure 1. The Average Indicators of Students' Critical Thinking Skills using the STEMProject-Based learning

The improvement of each indicator of students' critical thinking skills was analyzed using N-Gain, and the results are presented in Table 3.

Table 3. The N-Gain score of students' critical thinking skills

No	The Indicators of Critical Thinking Skills	Mean of Pretest Score	Mean of Pretest Score	N-Gain	Category
1	Focus	27.76	80.04	1	High
2	Reason	28.89	70.4	0.81	High
3	Inference	36.27	76.52	0.92	High
4	Situation	29.31	79.12	0.98	High
5	Clarity	26.71	77.27	0.95	High
6	Overview	24.91	70.15	0.82	High
	Total	173.85	453.5	5.48	-
	Mean	28.98	75.58	0.91	High

Table 3 shows that the use of STEM Project-based learning is highly effective in improving students' critical thinking skills on the environmental pollution topic in Year 10 of MAS Darul Ihsan. Besides, the results of the paired-sample t-test on students' critical thinking skills on the environmental pollution topic at MAS Darul Ihsan indicate a significant difference between pretest and posttest scores (p=0.000). The results of the paired-sample t-test are presented in Table 4.

Table 4.Paired Sample t-test results of students' critical thinking skills

Test	N	Mean	Normality Test *)	Significance level **)
Pretest	159	29.02	Sig (0.001)	Sig (0.000)
Posttest	159	75.09		

*) = Kolmogorov-Smirnov Test (Normal, Sig >α 0.05)

**) = Paired-sample t-test (Ha is accepted, Sig <α 0.05)

Students' Learning Outcomes

The data collection results on learning outcomes on environmental pollution topic in Year 10 students of MAS Darul Ihsan were pretest and posttest scores. The average pretest and posttest scores of students' learning outcomes before and after the application of STEM Project-based learning on the environmental pollution topic at MAS Darul Ihsan are presented in Figure 2.

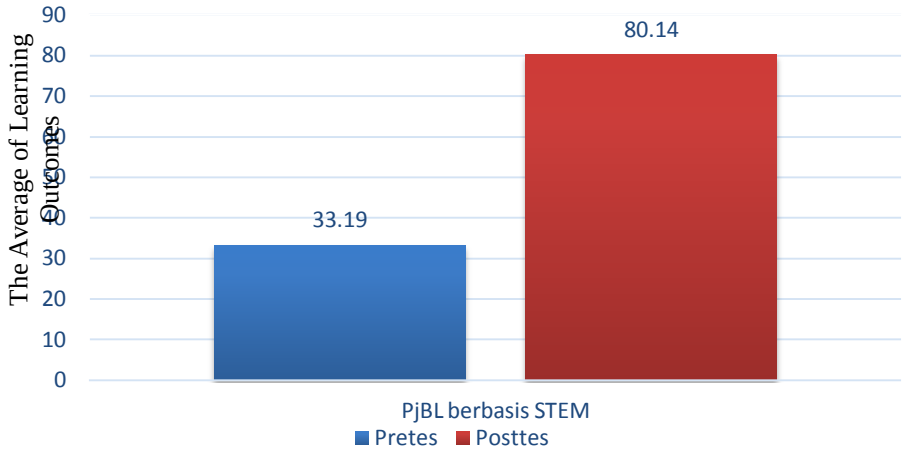

Figure 2. The average pretest and posttest scores of students' learning outcomes implementing STEM Project-based learning.

The paired sample t-test results of students' learning outcomes on the environmental pollution topic at MAS Darul Ihsan are presented in Table 5.

Table5.Paired Sample t-test of students' learning outcomes

Test	N	Mean	Normality Test *)	Signifi cant**)
Pretest	85	32.51	Sig (0.000)	Sig (0.000)
Posttest	85	80.04		

*) = Kolmogorov-Smirnov Test (Normal, Sig >α 0.05)

**) = Paired Sample t-tes (Ha is accepted, Sig <α 0.05)

IV. Discussion

Critical Thinking Skills

Table 4showsthattheuseof STEM Project-based learning effectively improves Year 10 students' critical thinking skills on the environmental pollution topic at MAS Darul Ihsan. This finding aligns with Daywan and Gamaliel (2020), stating that using the STEM Project-based learning model is more effective in improving students' critical thinking skills[10].

The STEM Project-based learning model improves students' critical thinking skills. The activities carried out in learning are more oriented to students' active engagement to stimulate students to think critically. This finding agrees with Capraro et al. (2013, in Africa et al., 2016). They revealed that stem Project-based learning challenges and motivates students because it trains students to think critically, analyze and improve higher order thinking skills1[11,12].

In the application of the STEM Project-based learning model, at the focus stage, students were allowed to identify problems based on the facts of environmental pollution clearly. Thus, students are trained to focus their attention on identifying problems regarding environmental pollution. STEM learning can develop skills to analyze and solve real-life problems. The problems are presented to encourage students to think deeply to solve current problems[13].

In addition, by using the STEM Project-based learning model, students can explain the reasons for the conclusions drawn. When drawing conclusions (inference), students can also make the right and relevant conclusions. Besides, at the situation stage, students can use all the important information.

At the clarity stage, students can provide further explanations (justify or clarify) about the conclusions based on the experiments conducted on environmental pollution. At the overview stage, students can check whether the solutions are correct by relating them to the context of the problem. This finding is in accordance with previous research stating that all indicators of critical thinking skills were categorized as adequate.

Compared to the previous critical thinking skills using a student worksheet based on the STEM approach, several indicators have increased[14]. The integration of STEM aspects positively impacts student interest, especially in increasing students' critical thinking[15].

The use of STEM-based worksheets can improve students' critical thinking skills (high category) because STEM-based worksheets facilitate the development of the skills that ultimately become habits[16]. STEM-based worksheets also have a significant effect on the development of critical thinking in students because the experience of STEM research is supported by question-based collaborative learning strategies[17]. STEM in problem-solving revealed that students' critical thinking and problem solving had significantly affected. In addition, the application of the STEM approach affects students' attitudes, interests, and motivation [18].

Students' Learning Outcomes

Table 5 indicates that the use of STEM Project-based learning is highly effective in improvingstudents'learningoutcomesonenvironmentalpollutionTopic in Year 10 of MAS Darul Ihsan. The learning process activities applying STEM project-based learning enables students to focus on the topic of water pollution. Students made plans regarding the projects to be carried out on water pollution, such as making water filters using the tools and materials found in the worksheet. Students discussed in their groups making a water filter making project by paying attention to the STEM components, namely science: the process of changing cloudy water into clearwater, technology: using tools, such as fibers and cloth, engineering: assembling work, and mathematics: the volume of water. Next, each group had to present the results of their discussions about the project. Other groups expressed their opinions on the presentations made and then the presenting group responded. This is supported by the results of research conducted by Mayasari et al. (2014), revealing that integrating learning in STEM positively influenced students' achievement. The results of the questionnaire data analysis also showed positive results, that in general, students felt that the learning was beneficial for them[19]. In STEM Project-based learning, students are invited to do meaningful learning in understanding a concept. Students are encouraged to explore through a project activity so that they are actively engaged in the process. These activities foster students to think critically, creatively, analytically[11]. STEM Project-based learning requires collaboration, peer-to-peer communication, problem-solving skills, and self-management. STEM Project-based learning helps students bridge the gap between the knowledge learned in school and the real world. The integration between several fields of science (mathematics with knowledge, technology, and engineering) in STEM Project-based learning helps students understand that one field of science is closely related to other fields.

The application of the STEM approach is required to develop student's abilities in the cognitive, manipulative, design, use of technology, and application of knowledge. Even the application of STEM can encourage students to think creatively, and 80.54% of students also give a positive response to the application of STEM[20]. Some advantages of the STEM approach are that the approach makes students solve problems better, innovatively, and independently using logical mind and technology literacy[21]. Thus, using the STEM approach is proven to improve students' learning outcomes, especially in Physics.

V. Conclusion

Based on the study results, it can be concluded that the STEM Project-based learning model can improve students' critical thinking skills and learning outcomes on the environmental pollution topic of Year 10 in MAS Darul Ihsan.

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