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The Effectiveness of Inquiry-Based Learning with Multiple Representation to Improve Critical Thinking Skill in Learning Electrochemistry

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Abstract. This study aimed to determine the effectiveness of electrochemistry learning based on open inquiry with multiple representation approaches to improve students' critical thinking skills. The research used a quasi-experimental method with the control group pretest-posttest design. The study was conducted at a public vocational high school in Bontang. The study involved 30 students as the experimental group and 29 students as the control group. The instrument consisted of 8 short-answer questions to uncover students' conceptual mastery of electrochemistry. Critical thinking skills aspect was taken into account when constructing the questions. Questionnaires to reveal students' responses to the implementation of inquiry learning was also given. The results showed that inquiry learning was effective in improving students' critical thinking skills. This is indicated by the mean N-Gain score of critical thinking skill of the experimental group students which is 0.59 and the control group which is 0.37, the effect size fell in the high category with 1.19. The highest N-Gain was for the indicator of elementary clarification (N-gain = 0.81) and the lowest one for strategy and tactics (N-Gain = 0.35). Students responded positively to inquiry learning with multiple representations.

INTRODUCTION

Critical thinking emerges as an important skill that must be possessed by someone to compete with the development and change of the current information age [1]. This opinion is in line with what is written in Permendiknas No.22 of 2016 that teaching and learning must be carried out by considering the critical thinking aspect. Among high-level thinking patterns such as critical thinking, creative thinking, communication and collaboration, critical thinking needs to be mastered before reaching the other three high-level thinking patterns [2]. In other words, through critical thinking, a person will be easier to develop their creativity, to work together and also to be skilled in communicating with others. Therefore, critical thinking skills are very important to be developed and owned by students during and after the learning process.

The average critical thinking skill of vocational students is still low in almost all indicators of critical thinking, characterized by incomplete in explaining and solving problems, unable to provide relevant explanations, unable to solve problems, unable to evaluate answers, and difficulty to apply the concept [3].

An Appropriate learning step used to develop students' critical thinking skills is inquiry learning. In the last decade, the inquiry has become a focus in learning and research around the world and a positive response in term of students' learning outcomes as having been reported [4, 5, 6]. The inquiry has even become a recommended chemistry learning model in the Indonesian educational system.

Learning chemistry will be more meaningful if it is strengthened by the implementation of multiple representations which are macroscopic, submicroscopic, and symbolic. Teachers often fail to connect the three levels of representations, and even tend to ignore one level, especially at the submicroscopic level, which is precisely the most

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difficult aspect to understand because it involves the particulate nature of the material [7]. Several studies mention chemistry learning with multiple representation strategies positively influences students' understanding of the material being taught [7, 8], and also effective to increasing students' critical thinking skills on chemistry materials [9]. Thus learning chemistry with multiple representation approaches is very supportive in developing students' critical thinking skills.

METHOD

The design of this research is a quasi-experiment with pretest and post-test design and depicted in TABLE 1. below.

TABLE 1. The following design [10]:

Treatment Group	*O*	*X*	*O*
Control Group	*O*	*C*	*O*

Where X is the implementation of open inquiry learning with multiple representations (independent variable), and O is dependent variable: critical thinking skills with the indicators are elementary clarification, basic support, inference, advance clarification, strategy and tactics [11].

The sample of this research were 30 vocational students at SMKN 1 Bontang majoring Chemical Analysis. Another group (29 students) from the same school also were involved as the control group. The instrument for pretest and posttest consisted of 8 essay questions for each to uncover students' conceptual mastery of electrochemistry integrated with critical thinking skills and questionnaires on students' responses to the implementation of inquiry learning. The Increase in critical thinking skills before and after the application of learning was measured using N-Gain by the equation:

$$g = \frac{S_{Post} - S_{Pre}}{S_{Max} - S_{Pre}} \quad (1)$$

Where g is gain normalized (N-Gain), S_{post} and S_{pre} are posttests and pretest score, S_{max} is the maximum score. The interpretation of N-gain is presented in TABLE 2 below.

TABLE 2. N-gain Category [12]

N-gain	Category
$g \geq 0,7$	High
$0,7 > g \geq 0,3$	Medium
$g < 0,3$	Low

The effectiveness of learning compared to conventional learning was measured using the effect size by the equation [13]:

$$d = \frac{M_A - M_B}{\sqrt{\frac{Sd_A^2 - Sd_B^2}{2}}} \quad (2)$$

Where d is effect size, M_A and M_B are mean score N-Gain of the experimental and the control group, sd_A and sd_B are the standard deviations of the experimental and the control groups. Using the criteria proposed by Cohen [13], the category of the effect size is presented in TABLE 3.

TABLE 3. Effect Size Category

d – value	Category
$0 < d \leq 0,2$	Low
$0,2 < d \leq 0,8$	Medium
$d > 0,8$	High

Student responses to the learning were measured based on a Likert scale. The score ranges from 1 to 4 with (strongly agree), 3 (agree), 2 (disagree) and 1 (strongly disagree).

RESULT AND DISCUSSION

Improving Students' Critical Thinking

The N-Gain Test was conducted to determine the increase in students' critical thinking skills and the result is presented in Fig. 1 below.

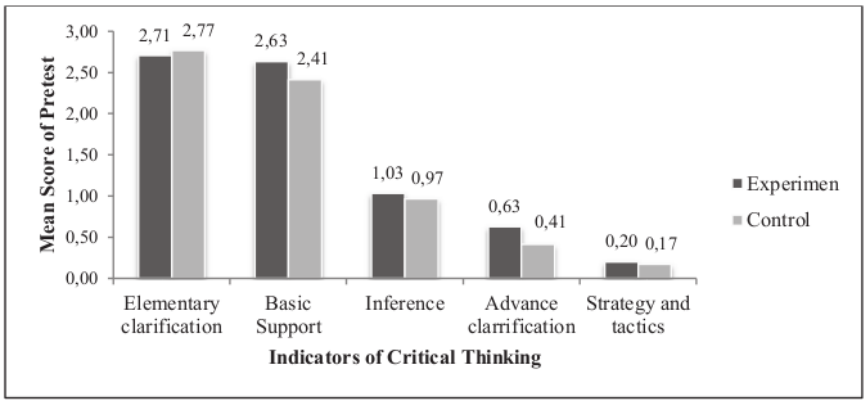

FIGURE 1. Mean Pretest Score for each Critical Thinking Indicator

Figure 1 shows that the average score of pretest for each indicator of the experimental group was almost the same as the control group. The results of Levene's test analysis on pretest scores (F = 0.275, Sig = 0.602) show that on average the initial abilities of the experimental group and the control group have the same homogeneity. Independent t-test analysis shows that t_{count} = 0.382 with Sig = 0.704, indicating that the initial ability of both groups to electrochemistry material did not differ significantly. The posttest average score of the experimental group is higher than that of the control group and it is shown in Fig. 2 below.

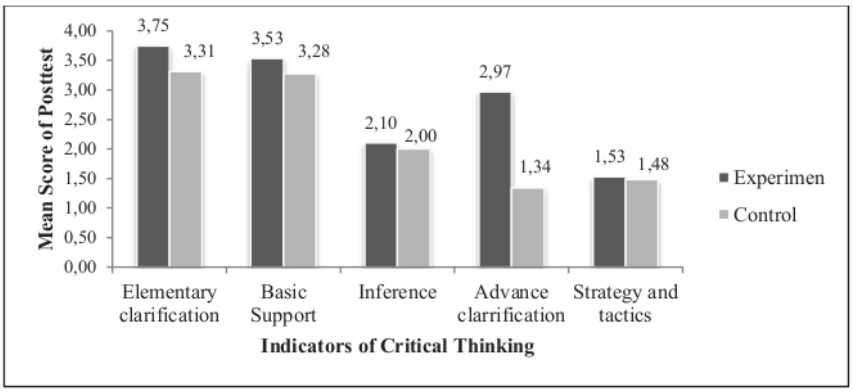

FIGURE 2. Mean of Post-test Scores for each Critical Thinking Indicator

Figure 2 shows that the highest posttest score for both the experimental and also the control group was for the elementary clarification's indicator. The lowest one was strategy and tactic's indicator for the experimental group and advance clarification's indicator for the control group. The Improvement in students' critical thinking skills for each indicator of critical thinking questions in the experimental group and the control group are shown in Fig. 3.

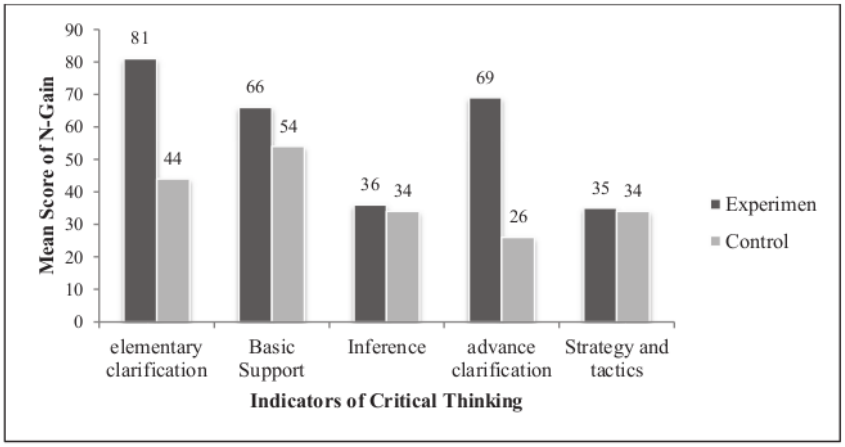

FIGURE 3. Mean of N-Gain (%) for each indicator of critical thinking in the experimental and the control group

Figure 3 shows that the mean N-Gain in each critical thinking indicator in the experimental group was higher than the control group. The N-Gain index for elementary clarification indicator in the experimental group was highest among all indicators for both groups and falls in the high category, while the strategy and tactics indicator is the lowest and falls in the medium category.

In the elementary clarification indicator, students think critically through habits that are trained in the form of formulating problems and answering questions that require explanation. The experimental group obtained an increase in the ability to think critically in the high category, while the control group in the medium category. The high N-Gain average in elementary clarification indicators is caused by the inquiry learning process that they experienced, wherein the phase of formulating the problem and the phase of proposing a hypothesis, students are always encouraged to express many ideas, questions and various solutions to solve problems.

In the Basic Support Indicator, students were asked to observe and consider the results of observations. The increase of critical thinking skills on this indicator for the experimental group was higher than that of the control group. Based on the acquisition of N-Gain both the experimental group and the control group are included in the medium category. These results are relevant to the research that mention the basic support indicators in the groups who learned by the inquiry was in the medium category [14].

In the inference indicator, students were asked to draw a conclusion based on the data of an experiment. Figure 3 shows that the experimental group and the control group obtained an increase in critical thinking skills that is almost the same and both fall in the medium category. This is due to the characteristics of the questions that require mastery of concepts and the answers given by the average students are still not quite right, the flow of students' thinking is still low and the concepts they have are still lack of focus. These results are relevant to the research that the inference indicators in the group room learned by inquiry compared to the learning of other models was in the medium category [14].

An indicator of advance clarification (giving a further explanation), students were asked to define terms and consider using appropriate criteria and identifying assumptions. In this indicator, the increase in critical thinking skills for the experimental group was much higher than that for the control group. The acquisition of N-Gain experimental group included in the medium category and the control group included in the low category. From the results of the N-Gain on the advanced clarification indicator, it shows that open inquiry learning through a multiple representation approach is better applied to the learning process to improve students' thinking abilities in giving further explanation.

In the indicator of strategy and tactics, students were asked to design an experiment based on electrolysis cells. Student answers to these problems were still not good, the flow of thought and concepts that were not related. The Improvement students' critical thinking skills on this indicator fall in the medium category. The results of this study are relevant to research that increasing students' critical thinking on strategy and tactics indicators is included in the medium category [15]. The acquisition of N-Gain in the indicator of strategy and tactics in the experimental group is among the lowest compared to other indicators. The low increase in critical thinking skills on this indicator is due to several reasons, including 1) students are accustomed to conventional lecture or learning methods, so that when learning with the open inquiry method through multiple representation approaches is applied students are required to

adapt first in order to adapt with the learning process, 2) limited research time, and 3) students need to be an independent learner because this method requires students to be able to learn independently and actively.

The overall N-Gain mean of the experimental group and the control group fall in the medium category. The improvement of students' critical thinking skills between the control group and the experimental group is described in Figure 4 below.

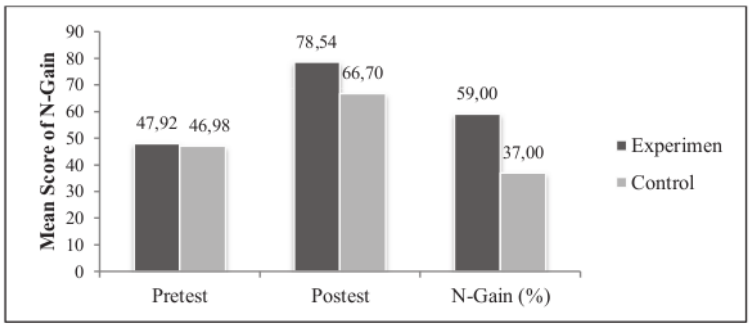

FIGURE 4. Mean of pretest, posttest and N-Gain score on students' critical thinking skills.

Figure 4 shows that the average posttest score was greater than the pretest score in both groups. The N-Gain value of the two groups was in the medium category. The results of the t-test analysis (t_{count} = 4.577, Sig = 0.000), showed that the mean N-Gain mastery of concepts and critical thinking skills of the two groups were significantly different where the experimental group had a much larger N-Gain value than the control group.

The results show the increase in critical thinking skill of students who got electrochemistry learning with an open inquiry through a multiple representation approach were higher than students who got conventional learning. The results of this study were also supported by the following previous studies: 1) students who were taught with open inquiry will be able to improve learning outcomes, could ask high-level questions and also have a better scientific attitude than students who were taught with conventional methods [16], 2) students were able to improve the ability of scientific work and higher thinking during learning with open inquiry[17], 3) students who learn with open inquiry was able to apply learning and the process of scientific thinking [18], 4) inquiry showed high levels of student satisfaction and a significant increase in students' learning outcomes [5].

The Effectiveness of Inquiry-Based Learning with Multiple Representation to Improve Critical Thinking Skill

The effectiveness of the learning studied was measured using the effect size. The effect of size test results is presented in TABLE 4.

TABLE 4. Learning effectiveness data based on effect size

Group	Mean N-Gain	Standard Deviation	Effect Size (d)	Category
Experiment	0,59	0,14	1,19	High
Control	0,37	0,22		

Based on Cohen's category [13], the effectiveness of electrochemistry learning with an open inquiry through multiple representation approaches compared to conventional methods fall in the high category. This shows that learning was effective in improving students' critical thinking skill. This result is in line with some researcher who argued that the ability to ask questions with inquiry learning in laboratories is superior to conventional learning [16], learning chemistry in laboratory-based inquiry formed conceptual understanding, chemical attitude and encouraged students to express their opinions [19], inquiry learning with multiple representations was more effective than the application of conventional learning [20].

Students' Responses

The attitude scale aimed to determine student attitudes toward open inquiry learning through a multiple representation approach. The attitude scale consists of 12 questions given to students who took the learning. Students' responses to learning are presented in Fig. 5.

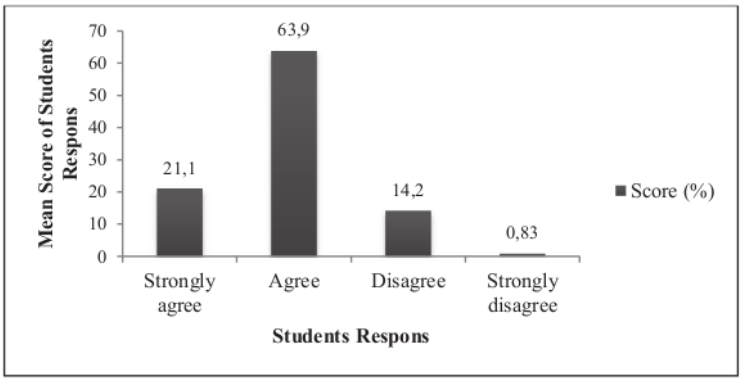

FIGURE 5. Average Students' Responses to the Inquiry Learning

Figure 5 shows that most students agreed to the open inquiry-based learning through multiple representation approach in learning electrochemistry. Students who responded disagree because they have not been able to adapt to the learning applied and prefer conventional learning.

CONCLUSIONS

The open inquiry-based learning through multiple representational approaches improved critical thinking skills of vocational students in the medium category with N-Gain 0.59. The highest N-Gain was on the elementary clarification indicator with a high category and the lowest N-Gain was on the strategy and tactics indicator with the medium category. The inquiry learning was also effective in improving students' critical thinking skills compared to conventional methods with an effect size in the high category. Most Students gave the agreed response to electrochemical learning with the open inquiry through a multiple representation approach.

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