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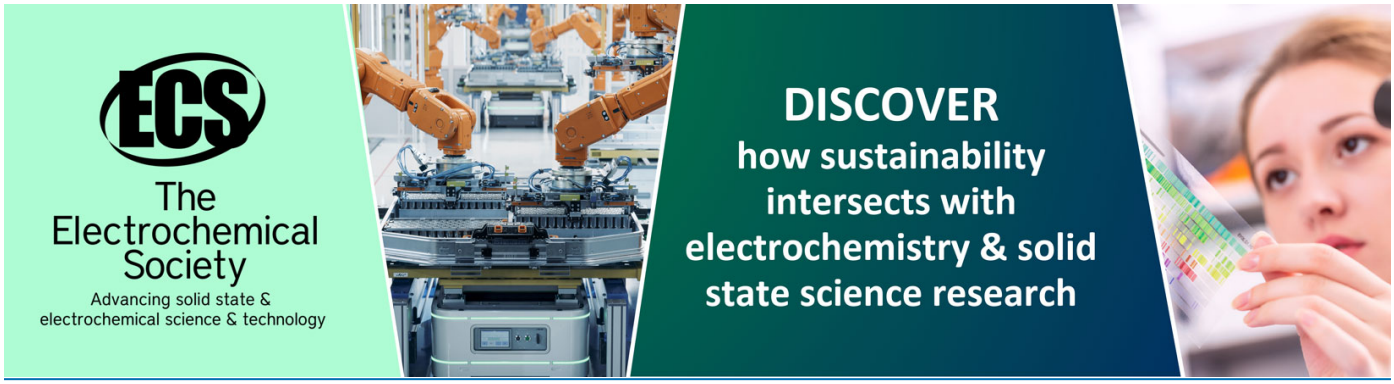

Implementation of guided inquiry learning oriented to green chemistry to enhance students' higher-order thinking skills

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Abstract. This research aims at determining the effectiveness of the implementation of guided inquiry learning oriented to green chemistry towards the higher-order thinking skills (HOTS) in buffer material. The research population of this study was all students of science class in one of the senior high school in Banda Aceh, Indonesia. The sample of this study was taken by using purposive random sampling. The test instrument used in the form of multiple choices. The increase of student's HOTS is measured at the level of cognitive regarding analyzing, evaluating and creating. Data analysis used N-Gain and t-test in terms of homogeneity and normality test. The results showed that HOTS of students at the level of cognitive related to analyzing, evaluating and creating increased by 4.68%, 65.26% and 53.68% respectively. Statistical analysis with t test on all cognitive parameters analyzing, evaluating and creating showed the value of $t_{count} > t_{table}$ at $\alpha = 0.05$. In conclusion, the implementation of a guided inquiry learning oriented to green chemistry is able to improve student's HOTS in experimental class than control class. Guided inquiry learning oriented to green chemistry can increase the HOTS of students in senior high school.

1. Introduction

The quality of the nation's next-generation is always related to the higher-order thinking skills (HOTS). HOTS can improve the ability of someone in relation to make decisions, solve problems, think critically and creatively [1]. HOTS activities are very important and appropriate to be developed for students so that they can face real and complex life problems and need the right solutions [2]. HOTS are not the ability to memorize but involve thinking at a higher level namely analyzing (C4), evaluating (C5) and creating (C6) [3,4]. In addition, HOTS can develop critical thinking skills and the ability to think creatively so that students can solve problems independently in their lives [5] especially solving the problem of natural science including chemistry.

Chemistry is one of the subjects that require HOTS. Chemistry deals with abstract concepts and involves reaction equations and mathematical calculations. The chemical materials are related to these characteristics include buffer. This buffer solution is a material that is relatively difficult for students to understand; as a result, it influences students' learning outcomes [6]. The low learning outcomes achieved by students are mostly found in Aceh Province including in Banda Aceh municipality.

The results of observation conducted in MAN 1 Banda Aceh showed that the students were interested in learning that was lacking in chemistry learning especially in buffer solution materials. From the result of interviews conducted with the chemistry teacher found that the average daily test scores of students on buffer solution material were still low category because it was still below the average minimum completeness criteria, which is 75. National examination results in the school especially the absorption capacity of the buffer solution material in 2018 with average value was 32.83 [7]. The data showed that there were fluctuations in the absorption of students from year to year to buffer solution material which still showed a low value. Thus, students in this senior high school haven't completely answered HOTS questions due to difficulties.

Many factors contribute to the student's HOTS in learning activities such as teacher-centred and lack of laboratory experiments. The laboratory has a positive impact on chemistry learning because students feel happy with chemical material, easy to understand chemical concepts, able to think scientifically, be more skilled and can interact socially with peers [8].

Efforts made to increase HOTS in buffer solution material are guided inquiry learning oriented to green chemistry. Guided inquiry learning is expected to develop HOTS of students so that they can solve problems in everyday life [9]. This model is expected to be able to improve students' learning outcomes in the buffer solution material [10]. In addition, guided inquiry learning oriented to green chemistry is also able to improve basic understanding of chemistry [11]. The guided inquiry learning model combined with the green chemistry approach makes students understand the importance of preserving the environment, learning the process of processing material into a useful product, encouraging students to experiment by utilizing, designing and developing a product that is environmentally friendly [12]. Based on the problems described above, this research was conducted.

2. Methods

The research design used was the non-equivalent control group design. The sampling technique used was purposive random sampling technique. The sample of research was two science classes. One class was as experimental group that consisted of 38 students and the other class was as control class contained 37 students. Both classes were chosen as samples because they had the same level of understanding. The research design can be shown in Table 1 [13].

Table 1. Non equivalent control group design.

Class	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_3	Y	O_4

[a]O_1 and O_3: Pretest in the experiment and control groups
[b]O_2 and O_4: Posttest in the experiment and control groups
[c]X: Treatment by applying a guided inquiry model oriented to green chemistry
[d]Y: Treat by applying the learning model commonly used in school

Data collection techniques include HOTS test before treatment (pretest) and after treatment (posttest). Data analysis used normality, homogeneity and t-test with the help of SPSS 20. The normality test used the Kolmogorov-Smirnov Test, the homogeneity test with the Levene's Test and the t test used the Independent sample Test. If the data were normally distributed and homogeneous then a t-test was carried out to see the influence of the application of the guided inquiry learning oriented to green chemistry. Conversely, if one or both of the data were abnormal and homogeneous, the non-parametric hypothesis test was done namely the Mann Whitney test.

3. Results and discussion

3.1 Identification of HOTS improvement

The increase of students' HOTS can be seen from the difference between the average pretest and posttest scores, while; the results of HOTS analysis can be seen from the posttest average value at the analyzing, evaluating, and creating. The average of N-Gain score based on each cognitive level developed in each question number. The percentage of N-Gain scores for each cognitive level is shown in Figure 1.

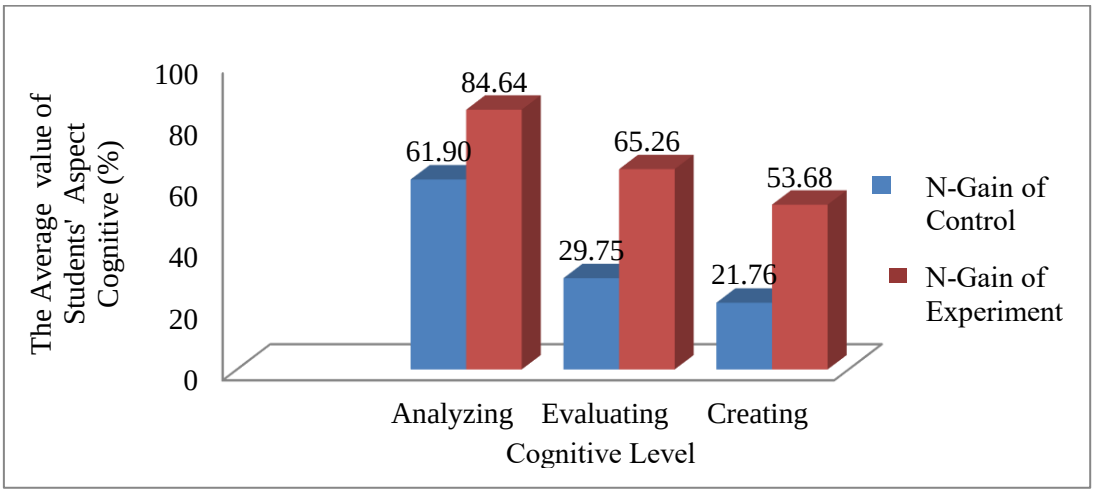

Figure 1. HOTS comparison for each cognitive level between experiment and control classes.

Based on Figure 1 can be seen that the acquisition of the N-Gain score of the control class at the analyzing, evaluating and creating cognitive levels was 61.90% (medium category); 29.75% (low category) and 21.76% (low category) respectively. On the other hand, the N-Gain score of the experiment class at analyzing, evaluating and creating cognitive levels was 84.68% (high category); 65.26% (medium category) and 53.68% (medium category). Based on these data the overall increase in N-Gain score of students in experimental class was higher than the N-gain score of students in control class. The increase of students' HOTS can be seen clearly in the learning process where students were more active, independent and eager to take part in learning [14]. Guided inquiry learning is innovative learning that can encourage active participation and cognitive involvement, and also improve students' high-level thinking skills [15]. The teacher only acts as a facilitator while students actively look for and solve existing problems so that students can find answers to problems independently [16]. This model can also enhance conceptual understanding and problem-solving skills [17].

During this time students had never done a buffer solution because of the lack of laboratory facilities and infrastructure. Therefore, learning of buffer solution material was not very interesting. Students only learned formulae and calculations during learning since they were not invited to think about what the buffer solution and how can be formed. Learning with guided inquiry models oriented to green chemistry creates learning more interesting and fun. Learning oriented to green chemistry makes students more actively participate in practical activities and cooperate with friends to create pleasant learning [18]. Students who are taught with conventional models experience many difficulties with chemistry lessons. It is difficult to understand the relationship between scientific facts and concepts. In contrast, guided inquiry learning encourages students to be more confident to conduct their own investigations so that they can understand what is being done and learning becomes more meaningful [19].

Guided inquiry learning oriented to green chemistry in this research covers 4 principles from 12 principles of green chemistry. At the time of practicum, students used environmentally friendly materials namely use of renewable feedstocks and easily found in everyday life. Students also used fewer lab

materials to reduce the waste produced. The saving chemical materials used were included in the principle of green chemistry namely prevention. In addition, the other principle of green chemistry that was used is designing safer chemicals namely students provided treatments to the waste produced by neutralizing the pH of the waste so that the pH of the resulting waste solution was not too acidic or alkaline and safe for the environment or can dilute with water solvents so chemicals that may be harmful to the environment will be reduced to a level that did not cause damaging effects on the environment. Then students used materials that were safe and easily obtained in everyday life to make a buffer solution. In addition, students also used masks and gloves while practicing. The principle of green chemistry is inherently safer chemistry for accident prevention which is to choose materials that are safe to use in practicums in order to minimize the potential for chemical accidents which include exposure, explosion and fire. Green chemistry in learning buffer solution materials can minimize the disposal of hazardous waste so that it can have a positive impact on students [20].

Guided inquiry learning oriented to green chemistry can be applied to a chemistry lesson effectively. Learning with green chemistry can resolve difficulties in chemistry lessons and is directed at creating and implementing effective learning so that it can improve students' understanding of the concept of chemistry. Some of the principles of green chemistry can be integrated into learning [21]. The design of learning towards green chemistry can be applied to improve learning achievement and train students to be ready to face the challenges of the 21st century, especially environmental problems [22,23]. Students can also learn to apply the principles of green chemistry to provide opportunities for students to learn dynamically and be creative so they can contribute to maintaining a green environment [24].

HOTS is the ability of students to analyze, evaluate and create. Students who are accustomed to conducting guided inquiry learning oriented to green chemistry can develop their HOTS for the better. Students are trained to work on student worksheets that contain step of guided inquiry accompanied by practicum so that students are able to improve their thinking skills in analyzing and evaluating and being able to be creative in learning [25,26].

The steps of guided inquiry learning contain presenting problem, creating hypothesis, collecting data, analyzing data and reflecting. This step of the learning involved investigation so that learning condition is more interesting and more meaningful [27]. The relation between HOTS and guided inquiry stage can seen in Table 2.

Table 2. The relation between HOTS and guided inquiry stage.

No	Stage of Guided Inquiry	Description	HOTS activities	Aspects of HOTS
1	Presenting the problems	At this stage, a phenomenon is presented so that the students' desire to ask questions and formulate problems arises		
2	Arranging hypothesis	Students make hypotheses that are relevant to the problem and decide hypotheses that will be used as a priority research	Analyzing	Critical thinking skill
3	Investigating and collecting data	Determine and carry out experiment steps and collect data		
4	Analyzing the data	Students process data that has been collected and test hypotheses that have been formulated previously	Evaluating	
5	Reflection or conclusion	Students decide, predict, interpret and explain by making conclusions based on the data analysis	Creating	Creative thinking skill

Students' HOTS in the control class was lower than the experiment class because students in the control class only used conventional learning in the form of lectures and discussions. More students were directed and given an explanation, thus; they can't focus on the learning delivered by the teacher.

In addition, students were only given regular work on student worksheets without inquiry steps. In addition, students were less trained in formulating and resolving their own problems in the learning process. However, students only memorized the material and this made them difficult when they faced with a high-level question (HOTS). This caused learning with conventional models were less able to develop students' HOTS.

3.2 Analysis of HOTS improvement

Analysis of data on normality, homogeneity and hypothesis testing of increase HOTS of students at the analyzing cognitive level using a guided inquiry learning oriented to green chemistry can be seen in Table 3.

Table 3. The results of the normality, homogeneity and HOTS t-test results of students at the analyzing cognitive level.

Analyzing of level Cognitive	Class	Normality[a]	Homogeneity[b]	t_{test}[c]		Conclusion
				t_{count}	t_{table}	
N-Gain	Experiment Control	0.07 0.45	0.24	6.68	1.99	Significance

[a] Kolmogorov-Smirnov Test, If Sig. > 0.05 (Normal)
[b] Levene Test, If Sig. > 0.05 (Homogeneity)
[c]Test = If t count> t table (there are significant differences)

Hypothesis testing for the ability to analyze in Table 3 showed the value of $t_{count} > t_{table}$ (6.68> 1.99). Analysis of the data showed a significant difference between the control class and experimental class. Students who had high analytical skills can be said to have critical thinking skills. Guided inquiry models can improve students 'ability to solve problems, so they are able to develop students' critical thinking skills [28].

In the early stages of guided inquiry learning oriented to green chemistry, students involved directly to find their own problems made hypotheses and conducted investigations. This stage included analyzing cognitive level, the students' ability to analyze the problem can be found in the learning process of buffer solutions. Students trained to have intellectual skills to solve problems and students acted as subjects of learning. At the stage of presenting the problem, students challenged to find answers to what happened and formulated it in a question that was answered by themselves. In formulating a hypothesis, the students were trained to make a temporary answer to the problem. The hypothesis formulated was not really necessary, thus encouraging students were not afraid in formulating the hypothesis.

Results test for normality, homogeneity and hypothesis testing increasing students' HOTS at the evaluating cognitive level using a guided inquiry learning oriented to green chemistry can be seen in Table 4.

Table 4. The results of the normality, homogeneity and HOTS t-test results of students at the evaluating cognitive level.

Evaluating cognitive level	Classes	Normality[a]	Homogeneity[b]	t_{test}[c]		Conclusion
				t_{count}	t_{table}	
N-Gain	Experiment Control	0.08 0.96	0.56	8.58	1.99	Significance

[a] Kolmogorov-Smirnov Test, If Sig. > 0.05 (Normal)
[b] Levene Test, If Sig. > 0.05 (Homogeneity)
[c]Test = If t count> t table (there are significant differences)

Statistical analysis based on Table 4 showed $t_{count} > t_{table}$ (8.58>1.99) then there was a significant difference meaning guided inquiry learning can improve the ability to evaluate. Then students test the hypothesis by collecting data obtained from practical activities and discussing the data. This stage included the evaluating cognitive level, which is the ability to evaluate. Evaluating is the ability to assess something that involves the ability to examine and investigate [29]. Guided inquiry can develop thinking skills and improve student psychomotor and student encouragement to collaborate with friends during learning [30].

Students' HOTS at creating a cognitive level using a guided inquiry learning oriented to green chemistry was also analyzed by using normality, homogeneity and Z test which can be seen in Table 5.

Table 5. The results of the normality, homogeneity test and HOTS *Z* student test at the cognitive level create (C6).

Creating cognitive level	Classes	Normality[a]	Homogeneity[b]	Z_{test}[c]		Conclusion
				Z_{count}	Z_{table}	
N-Gain	Experiment	0.67	0.01	4.93	1.99	Significance
	Control	0.23				

[a] Kolmogorov-Smirnov Test, If Sig. > 0.05 (Normal)
[b] Levene Test, If Sig. > 0.05 (Homogeneity)
[c]Test = If t count> t table (there are significant differences)

Normality test of creating cognitive level showed that Sig.> 0.05 (0.67> 0.05) then the data were normally distributed, while homogeneity showed Sig. <0.05 (0.01<0.05) then the data were not homogeneous. Non-homogeneous data were analyzed using the Mann-Whitney test. The Mann Whitney test results showed that $Z_{count} > Z_{table}$ (4.93> 1.99). It can be concluded that students' HOTS in experimental class at creating cognitive level was better than students' HOTS in the control class. Students were not accustomed to solving HOTS questions, so they can only answer problems at the memorization stage, consequently; students' thinking patterns are more limited.

Creating cognitive level is the ability of students to create and design called the ability to create. Guided inquiry learning oriented to green chemistry can train students to develop the ability to create because at the final stage guided inquiry students were trained to do their own reflection by making their own conclusions based on the data that had been analyzed and the ability to create including in the aspect of the ability to think creatively. Hence, the guided inquiry does not only improve critical thinking skills but also increases the ability to think creatively.

Students' HOTS in each cognitive aspect can be seen by analyzing the question sheets used to measure students' HOTS. The ability to analyze based on the ability of students to answer questions in analyzing cognitive level. Students are able to decipher information by writing down what was known and asked in the question and being able to connect with the concepts that had been understood. The ability to evaluate can be seen if students can answer questions at evaluating cognitive level. The ability to create was very lowest than analyzing and evaluating cognitive level. Students were asked to make decisions to solve existing problems by designing a method that can be used to solve the problem. Therefore students need to be trained to develop their abilities in creating concepts that require students to be creative.

4. Conclusion

Based on the research results obtained the average N-Gain score of experimental class at analyzing, evaluating and creating cognitive levels were 84.68%, 65.26% and 53.68% respectively; while the N-Gain score of the experiment class at analyzing, evaluating and creating cognitive levels were 61.90%, 29.75% and 21.76%. It can be concluded that students' HOTS can be improved by applying guided inquiry learning oriented to green chemistry.

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