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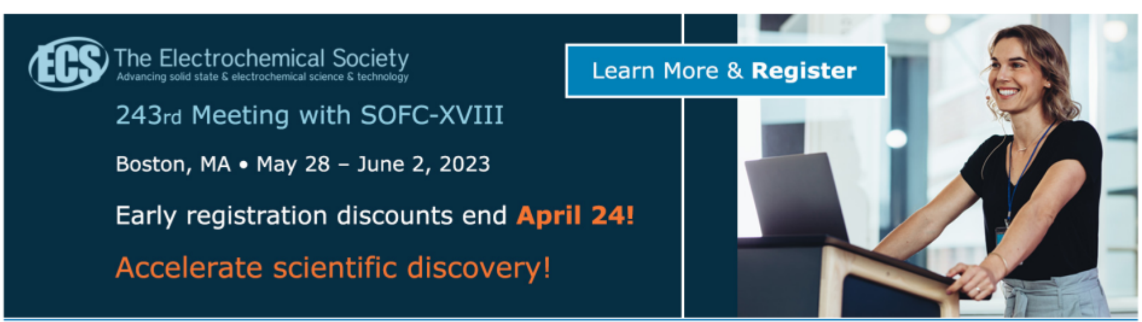

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Implementation of Green Chemistry-Based Electrolysis Learning Media to Develop Higher Order Thinking Ability

C Z Subarkah[1], A Trisnawati[1], C D D Sundari[1] and A Malik[2]

[1]Department of Chemistry Education, UIN Sunan Gunung Djati Bandung, Jl. Cimencrang, Cimenerang, Panyileukan, Bandung, West Java, 40292, Indonesia
[2]Department of Physics Education, UIN Sunan Gunung Djati Bandung, Jl. Cimencrang, Cimenerang, Panyileukan, Bandung, West Java, 40292, Indonesia

E-mail: zenabsc@uinsgd.ac.id

Abstract. In this paper, a green chemistry-based microscale kit and worksheets were made and implemented to develop higher-order thinking ability of students on electrolysis concept. The method used in this research was an experimental method with one-shot case study model implemented to the second-semester chemistry education students studying electrolysis. The ability to think at higher level, i.e. ability to analyze, evaluate, and create, were measured by referring to the revised Bloom taxonomy. The results showed that the average score achieved was 77 (categorize as good) for the ability to analyze, 82 (categorize as excellent) for the ability to evaluate, and 76 (categorize as good) for the ability to create. The as made learning media in the form of micro-scale kit and worksheet were able to develop higher-order thinking ability.
Keywords: Higher Order Thinking, Electrolysis, Green Chemistry

1. Introduction

Worksheet is one of learning media that can help students in understanding learning material provided through an experimental process [1]. Learning becomes more directed if students are given the opportunity to ask questions, conduct research, collect data, make conclusions, and discuss [2]. One of the media that can be implemented is STEM (science, technology, engineering, and mathematics)-based experimental worksheet. STEM-based worksheet is also able to provide challenges and motivate students in the experimental process so as to improve students' higher-order thinking ability [3].

Indicators of higher-order thinking ability include the ability to analyze, evaluate, and create on the basis of a process of remembering and understanding well [4]. Productive learning activities produce students who can elaborate and explain the concepts that have been given, to gain higher-order thinking ability [5]. In the process of developing higher-order thinking ability, students are not only required to memorize and imitate but also can gain a deeper understanding to be able to apply it to other contexts [6].

Electrolysis is one of the chemistry concepts that can develop higher-order thinking ability. Electrolysis concept is an abstract concept, which makes it difficult for students to understand the concept if learning is only done by the process of memorization [7]. Learning the concept of electrolysis requires a higher-order thinking process in analyzing the phenomena that occur [8] through experiments. However, in this case, educators have a problem in preparing electrolysis experiments because the equipment and materials needed are required large amounts [9], thus producing large amounts of chemical wastes. Therefore, we need a green chemistry-based experimental tool that can facilitate educators in preparing the experiment. One o the alternative is to make a simple tool in a smaller form than the commonly used device, called a microscale kit [10].

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Microscale kits implement the principle of green chemistry because less waste is produced [10]. Micro-scale kit in electrolysis experiments can be arranged by using coin cell lithium battery and filter paper. On each side of the coin cell lithium battery, an electrochemical process will occur, electrical energy from the cell will be converted into chemical energy [11]. Lithium battery has higher electrical capacity compared to other secondary batteries such as Nickel Cadmium (NiCd) or Nickel Metal Hydride (NiMH). Lithium battery cells consist of electrodes (anode and cathode), electrolytes, and separators [12]. The impact of micro-scale kit implementation in electrolysis learning on students' higher-order thinking ability is interesting to be studied. In this paper, students' higher-order thinking ability after electrolysis learning using micro-scale kit assisted with STEM-based worksheet will be described.

2. Methods

The method used in this study is one-shot case study [13], the application of STEM-based worksheets in this study requires groups to be treated, then the results can be observed. The research subjects were 38 students of Chemistry Education Study Program in their first-year college. The research subjects were divided into eight groups. Members of each group are heterogeneous, constituting a combination of representatives of medium and high achievement groups. The determination of achievement groups is based on basic chemistry courses score in their previous semester. The subjects were chosen because they were in the process of learning electrolysis at the time of this research conducted. The micro-scale kit for electrolysis experiment was compiled in the form of a box containing coin cell lithium batteries, three vial bottles containing 5 mL of electrolyte solution, dropper pipettes, metallic paper clips, filter paper, small LED lamp as a current indicator, tweezer, and litmus paper. The experiment design stated in the STEM-based worksheet was modified from a research article by Kamata and Yajima [14], current regulator and Pt foil were omitted in this research for simplicity. The produced microscale kit for electrolysis experiment and the experiment design can be seen in Figure 1 and Figure 2, respectively.

Figure 1 Microscale kit for electrolysis experiment

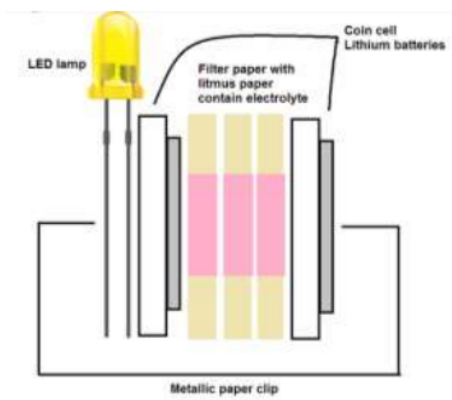

Figure 2 Experiment design/tools arrangement

3. Results and Discussions

STEM-based worksheet, which was arranged to assist the electrolysis experiment, consist of four phases, i.e., science phase, engineering phase, technology phase, and mathematics phase. In the science phase, students were required to formulate problems and stating hypotheses based on discourse/text about micro-scale kit for electrolysis experiment, provided in the worksheet. The engineering phase was intended to direct students in designing the experiment that will be carried out by themselves. The technology phase includes the technical aspects in the execution of experiments, while the mathematics phase requires students to analyze the quantitative aspects of the experiments, such as calculating the mass of experiment products, etc. The analysis results on the students' ability in completing worksheet at each stage of STEM are categorized as very good with an average score of 92, details of the data for each stage can be seen in Table 1. The highest average score was obtained in phase two (engineering), with an average score of 98.75. This shows that the cognitive process dimensions of creating can be developed very well. This phase provides an opportunity for students to develop cognitive processes dimensions of creating in solving problems and expressing them in the form of experimental procedure designs [15]. In the phase of designing an experiment, students express ideas or ideas so that cognitive abilities can be trained and students' enthusiasm in conducting an experiment can be increased [16].

Table 1. Analysis results of students' capabilities in completing STEM-based worksheet

Group	Score on each STEM stage/phase				Average score	Category
	Science	Engineering	Technology	Mathematics		
A	89	100	100	100	97.25	Excellent
B	89	90	100	80	89.75	Excellent
C	89	100	100	95	96	Excellent
D	78	100	100	95	93.25	Excellent
E	67	100	100	95	90.5	Excellent
F	78	100	100	100	94.5	Excellent
G	100	100	67	95	90.5	Excellent
H	89	100	67	80	84	Excellent
Average score	**85**	**98.75**	**91.75**	**92.5**	**92**	**Excellent**

The average score of the worksheet completion in the phase of science was 85, and this ability shows that the cognitive process dimensions of analyzing can be very well developed. The cognitive dimension in this phase of analyzing involves the ability to identify incoming information and then structure information into smaller sections to recognize patterns and relationships [15]. The achieved average score of the science phase is different from the other phases because some students still have difficulties in connecting hypotheses with the formulation of the problem.

The highest average score achieved in the completion of STEM-based worksheet was obtained by group A with an average score of 97.25, while the lowest average score was obtained by group H with a score of 84. This was because the group H was less careful when conducting the experiment and also had incomplete work on the worksheet. Researchers should be able to direct students to foster interest during the learning process so that whatever the difficulty in filling the worksheet, solutions can be sought together without leaving blank answers to questions [17]. Group A has the highest average score because of their activeness, togetherness, and enthusiasm in conducting the experiment was very high.

The use of microscale kit with lithium battery in the electrolysis of Na2SO4 solution and KI solution is related to the phase of technology with higher-order thinking indicator on evaluating (C5). Through the use of micro-scale kit, students were led in conducting scientific activities and scientific attitudes. Students are more active in learning activities and have an impact on learning outcomes [10]. In addition, micro-scale kit in electrolysis experiment several other advantages, i.e., able to replace experiment activities in the laboratory (experiment can be conducted in a regular classroom) and can improve students' understanding of electrolysis concepts [18]. Micro-scale kit aims to make experiment tools and materials easily stored and arranged properly in the kit box [19]. Microscale kit is a media-based on green chemistry due to the use of chemicals in small amounts, so the amount of waste produced is minimized [20]. This was proven when the experiment conducted, the students only need 5 mL of each chemical, instead of no less than 50 mL in regular electrolysis experiment.

Students' higher-order thinking ability were measured through test after students have conducted electrolysis experiment with STEM-based worksheets. The test questions contain queries that measure each cognitive dimension of analyze, create, and evaluate. These questions are useful to strengthen students in understanding concepts and to measure the extent of their higher-order thinking ability. Higher-order thinking ability developed in each test item are the ability to create (C6) in question number 6, analyze (C4) in questions number 2 and 3, and the ability to evaluate (C5) in questions number 1 and 4. The average score of higher-order thinking ability of students based on achievement groups are listed in Table 2.

Table 2. Recapitulation of average scores on higher order thinking ability based on achievement groups with higher level thinking ability indicators

Cognitive Process Dimension	Achievement Group			Average	Interpretation
	High	Moderate	Low		
C4 (analyze)	84.5	78	69	77	Good
C5 (evaluate)	81.5	76	89	82	Excellent
C6 (create)	80	81	68	76	Good
Average	**82**	**78**	**75**	**78.5**	**Good**

Based on the assessment results of the higher-order thinking ability test, the cognitive processes dimension of evaluate (C5) reached the highest average score of 82 and categorized as excellent. The students were able to understand each question given in the cognitive process dimension of evaluating [6]. Meanwhile, the cognitive process dimension of creating (C6) has the lowest average score, i.e., 76. This is because the cognitive process of create are generally in line with previous learning experiences, wherein previous experiments, not all of the groups perform metal purification electrolysis [21].

Based on the higher-order thinking ability tests assessment results, several students who have high test scores in completing STEM-based worksheet were also have high scores on test results. One of the students got a high average score in worksheet completion i.e., 97.25; and the results of the test of higher-order thinking ability scored 87. Therefore, through the STEM approach, students can easily transfer knowledge to each other so that learning with the STEM approach is more effective, which has an impact on achieving learning objectives [22]. In addition, based on observations, it turned out that several students who have high test scores were also active in the learning process. On the contrary, the students' who scored low on the higher-order thinking ability were also not participated actively in the learning process. A student who scored 89 in higher-order thinking ability test, turned out that during the learning process, the student was actively answering questions raised by researchers, and also actively asking questions about concepts which not yet understood. Meanwhile, students whose activities in the learning process were low turned out to get a low average score of 75. This shows that good activities will produce good grades too [23].

Overall, the use of micro-scale kit based on STEM approaches in the electrolysis experiment can improve student learning outcomes. This can be seen in the results of the higher-order thinking ability test of students after the learning process, that can be said to have reached a good category with average score achieved 78.5. The students' ability to think in higher-order developed well after the application of STEM-based worksheet on electrolysis experiment using micro-scale kit. Electrolysis experiment learning using micro-scale kit and STEM-based worksheet provides challenges and motivation to students in the experiment process so as to be able to develop higher-order thinking ability [3]. Thus, the development of higher-order thinking ability needs to be supported by a variety of appropriate media that can activate and develop students' thinking ability.

4. Conclusion

The electrolysis learning process using micro-scale kit with coin cell lithium battery equipped with STEM-based worksheet can increase student activity. Student activity reviewed based on the experiment process, and the ability to complete the worksheet reached an average score of 92, which categorized as excellent. The average score of the higher-order thinking ability test for each cognitive process dimension of analyzing, evaluate, and create was categorized as good, with an overall average score of 78.5. The results showed that the learning media used in the learning process had an impact on higher-order thinking abilities and activities.

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