Students' Higher-Order Thinking Ability in Electrolytic Cell

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Abstract: One of the chemistry concepts that require the development of higher-order thinking ability is the electrolytic cell, the concept is widely applied in dailylife, related to technology and is a continuation course. This study aimed to analyze the students ability of higher-order thinking in electrolytic cell concept. The method used was pre-experiment with one group pretest-posttest which is applied to 41 first-year chemistry students in undergraduate level as research subject. Data were obtained from the answers to the higher-order thinking ability essay test. The students' higher-order thinking ability in the dimension of analysis was deficient, their ability in the dimension of evaluation was adequate, and their ability in the dimension of creation was decent. The cognitive dimension of analysis requires the ability to build relationships between information provided, in this case most of the students have not be able to reach that stage. In general, the results of this study informed that students' higher-order thinking ability on the concept of electrolytic cell was categorized adequate. Thus, for the improvement, problem solving exercises require complex thinking are necessary.

1 INTRODUCTION

The rapid development of science and technology makes education a challenging demand (Danumiharja, 2014). To compensate for the necessary qualified human resources, one of the demands is to have higher-order thinking ability. Higher-order thinking ability is the ability to connect, manipulate, and transform the knowledge and experience they already have to think critically and creatively in deciding and solving a problem (Rofiah et al., 2013). Higher-order thinking ability allows a person to solve the problems faced in his life (Pantiwati, 2014). Therefore, higher-order thinking ability is important to be embedded and developed during learning process as it could impact the learners' learning outcomes, including undergraduate students.

Higher-order thinking ability is the highest level cognitive process hierarchy based on Bloom's Taxonomy which includes the ability to analyze, evaluate, and create (Yee et al., 2015; Gunawan, 2012). Indicators of higher-level cognitive dimension still often escape the attention of educators, and the majority of the given test questions is on the basic or lower cognitive dimension. The previous research result (Syahida, 2012) stated that the high schools' national chemistry exam questions of 2012/2013 academic year involve only 15% of the problems that require higher-order thinking ability in the cognitive dimension of analysis, while the rest of the problems require only the ability to think in lower-level cognitive dimensions. This shows that the cognitive dimension that is developed in general is still in the lower-level cognitive dimension. Preliminary study results for the first-year undergraduate students showed that the students' higher-order thinking ability is still untrained because the students still cannot reason with the various questions given. In addition, the student's analytical skills in answering the various problems was deficient. Research conducted by Gani, et.al (2011) stated that the mastery of declarative knowledge of students was categorized quite well, but the ability of higher-level thinking of students in solving the problem was still relatively low.

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Therefore, it is very important to develop higher-order thinking skills in learning. One of the chemistry concepts that require higher-order thinking is the electrolytic cell. This concept is related to daily life and its application is widely used in line with the development of science and technology. Thus, the development of higher-level cognitive dimension in learning of this concept is needed. In addition, this concept deals with advanced chemistry courses such as inorganic chemistry and physical chemistry, therefore it is important to be learned and able to build students' skill through completing the course. The results of Najwa's research (2016) concluded that the students' ability of higher-level thinking on the concept of signs of global warming is categorized as good by providing open ended questions; Stone's research (2012) concluded that the flipped classroom learning model can achieve learning outcomes in higher-level cognitive dimensions and deepen the understanding of the concepts.

Based on the background that has been presented and supported by previous research, the authors are interested to take the research about higher-order thinking ability of students on electrolytic cell. The novelty aspect in this research was in terms of giving the higher-order thinking skill test with different pretest and posttest but with the same problem indicator through the flipped classroom learning model to measure the students' higher-order thinking ability.

2 METHODOLOGY

The method used in this research was pre-experiment with one-group pretest-posttest research design that is conducted to one group only without any comparison group (Fraenkel, 2012). The plot of this research design was: 1) the researcher gave pretest problems to the group that will be given treatment to investigate the students' cognitive dimension of the higher level in the beginning of the research, and then 2) the researcher gave the treatment of the application of the flipped classroom learning model to the group. After completion of treatment, 3) the researcher gave posttest problems to investigate the improvement of students' higher cognitive dimension. The extent of treatment effect was measured by comparing pretest results with posttest results (Sukmadinata, 2007).

The subject of this research was 41 chemistry students in their first year of undergraduate study. In this research, the data retrieval technique was carried out through the students' answer to the higher-order thinking ability test before and after treatment. The obtained data were in the form of higher-order thinking ability before and after the application of flipped classroom learning model on the cognitive dimension of analysis, evaluation, and creation. The data processed through the following stages: (1) raw scores on each student's answer for pretest and posttest based on the assessment criteria were summed up and then converted into the final score by dividing the sum of raw score by maximum score and multiply it by factor 100. The achieved final scores were categorized according to score achievement predicate in table 1; and (2) higher-order thinking ability improvement was analyzed via Normal Gain (d) value which is obtained according to equation 1. Normal gain (d) value was interpreted based on table 2.In addition, to determine whether or not there is an increase in higher-order thinking skills, hypothesis testing was performed.

$$d = \frac{posttestscore - pretestscore}{idealscore - pretestscore} \qquad \text{(equation 1)}$$

Table 1:Score achievement predicate (Syah, 2008).

Final Score	Predicate
80-100	Very good
70-79	Good
60-69	Adequate
50-59	Deficient
0-49	Failed

Table2: N-Gain index criteria (Herlanti, 2012).

N-Gain (d)	Interpretation
d < 0.3	Low
0.3 ≤ d ≤ 0.7	Moderate
d ≥ 0.7	High

3 RESULTS AND DISCUSSION

In this study, the content of the tests was used as the dependent variable, which is the electrolytic cell concept in the form of its application in life, such as in metal purification and metal coating. The results of the analysis of higher-order thinking ability is presented in table 3.The posttest analysis results of higher-order thinking ability based on revised Bloom's taxonomy on the cognitive dimension of analyze, evaluate, and create can be seen in figure 1 and 2.

Table3:N-gain value in each higher level cognitive dimension.

Cognitive Dimension	Total Score of 41 Students (max score 100 per student)			Interpreta-tion
	Pretest	Posttest	N-gain	
Analyze	696.43	2307.14	0.47	Moderate
Evaluate	1051.92	2517.86	0.54	Moderate
Create	1626.92	3234.62	0.65	Moderate
Sum	3375.27	8059.62	1.66	
Average	1125.09	2686.54	0.55	Moderate

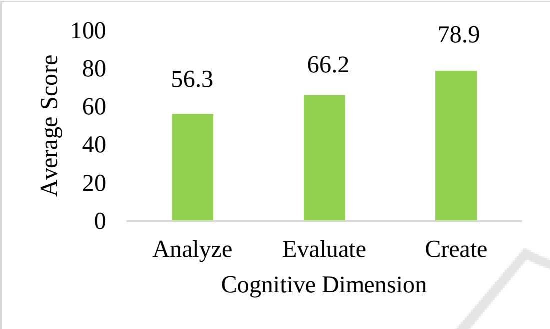

Figure 1: Average posttest score in higher-order cognitive dimensions.

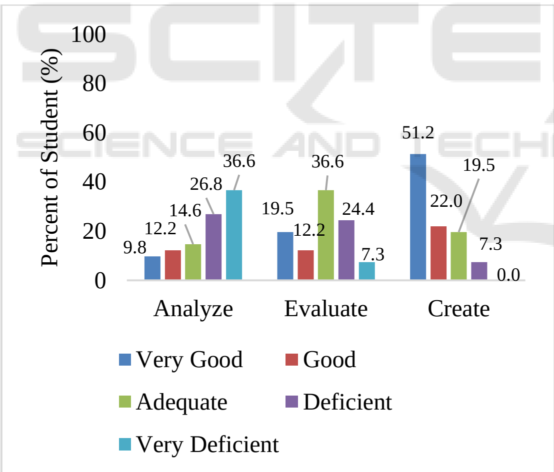

Figure 2: Percentage of students by predicate of posttest score in higher-order cognitive dimensions.

Based on table 3 and criteria in table 2, the improvement of students' higher-order thinking skills had a moderate gain with average N-gain value 0.55. The highest improvement of the skills was in the cognitive dimension of create with N-gain 0.65, and the lowest improvement was in the cognitive dimension of analyze with N-gain 0.47. In addition, figure 1 shows that the highest cognitive dimension that reaches the highest average post test score was the cognitive dimension of create that is 78.9, while the lowest average post test score was on the cognitive dimension of analyze, that is 56.3. This was caused by the number of students that was able to answer well at the cognitive level of analyze was only 22% from total 41 students (figure 2, 9.8% could answer very well and 12.2% well).

In the question for measuring the cognitive dimension of analysis, students were required to discover and describe the concept of electrolytic cells in metal purification and coating, such as describing the process of metal purification by mentioning the reaction possibilities that could occurred in each salt metal solution when an electric current is passed through and describing the type of metal coating used in the given text. As Anderson & Krathwohl (2010) described, the cognitive dimension of analysis involves the ability to crack/divide a problem into its units/small components of the problem and determines the interrelationships between the units to form a clear linkage. In addition, according to Kuswana (2012), the ability to analyze requires student to be able to decipher a case problem into major parts and describes how the parts are connected to each other and become a whole structure.

The cognitive dimension of analyze has the lowest increase compared to the cognitive dimension of create and evaluate. This is indicated by the absence of students who achieve maximum scores in the pretest and posttest. Most students described the processes that occur in metal purification not thoroughly and does not cover all the criteria, as there are students who do not involve the electrical current that encourages the oxidation reduction reaction in electrolytic cell. In addition, based on the posttest result, the highest percentage of students who have a very low score is in the dimension of analyze with a percentage of 36.6% (figure 2). This is due to many students who have not been able to decipher the process of electrolysis of metal purification to explain the possibilities that occur in each metal in the anode. Most students simply answer by elaborating on the occurrence of metal purification because of the electrolysis process that causes Sn metal to settle at the cathode undergoing a reduction reaction when the electrode is immersed in the solution. There are also those who answer up to the possibilities that occur on any metal, but do not fit the criteria that the metal impurity in the anode having a more positive standard reduction potential than the metal to be purified (Pt, Au, etc.) will not dissolve in the anode, but the metal impurity will form precipitate at the base of the cell, while the metal which has a more negative standard reduction potential will dissolve and accumulate in an electrolyte solution (Ettel & Tilak, 1981: 328).

On the problem that requires students to analyze the type of coating used, most students only mention one type of coating that occurs, whereas the expected answer was more than one type of coating. Thus, most students do not get the maximum score. In thinking skills that measure the cognitive dimension of analysis, some students were able to identify the most important and relevant elements of the problem, but some students have not yet reached the stage of establishing appropriate relationships of the provided information (Gunawan, 2012: 28). Thus, this cognitive dimension reaches the lowest average posttest score and N-gain.

To measure students' skill in the cognitive dimension of evaluation, students were given several questions which require them to assess a conclusion. Students have to make a consideration based on existing criteria and standards to show their skill in evaluating (Widodo, 2005).N-gain value for evaluate cognitive dimension was lower than create due to some students failed to state the conclusion o the problems in pretest and posttest. The highest number of students (36.6%) was giving adequate answers to the problems (figure 2). Only six students almost achieved the maximum score. This was due to many students were mistaken with the concept, so that no one reaches the maximum score. Many students assumed the amount of charge is same as the number of electrons involved, and most students mistakenly convert units.

In measuring the ability of higher-level thinking for cognitive dimension of evaluation, the students have been directed to the conclusion assessment stage based on the existing criteria with good problem solving planning stage, i.e. solving the problem by applying the concept of Faraday law calculation first, but still incomplete in proving the conclusion . Evaluating leads to the testing or assessment activities of a product that can be linked to the process of thinking, planning and implementing so that it can lead to the determination of the extent to which a plan is going well and a criteria is produced (Gunawan, 2012).

Cognitive dimension of creation was measured by a set of problems that require the students to design simple procedures and series of electrolytic purification or electrolytic coating appropriately based on the given text in the worksheet. From students' answers, it was found that some students still believed that the current source is the same as the voltmeter. This error is caused by some students were not be able to understand in detail the difference of Voltaic cell and electrolytic cell, and also caused by the students' knowledge about the name of the instruments commonly used as the current source in the electrolysis is lacking. In addition, some students had inappropriately designed the procedures and circuits of electrolysis components, including wrong choice of electrodes. This means there were still some students who are less able to generalize an idea or perspective towards something and devise a way to solve the problem (Krathwohl, 2010).

Based on the N-gain analysis, the cognitive dimension of creation has a higher improvement than the cognitive dimension of evaluation and analysis. In addition, posttest results on the question of measuring cognitive dimensions of create, the highest percentage of students has a very good predicate with a 51.2% percentage (figure 2). This shows that most of the students think very well. In this cognitive dimension of create, the way of thinking of the majority of students has led to the organization of parts to form a functional unity and to produce a new product by organizing some elements into a different form or pattern than before (Gunawan, 2012).

4 CONCLUSION

The improvement of students' higher-order thinking skills in electrolytic cell concept measured from the pretest and posttest score with flipped classroom treatment was resulting in the medium category with N-gain 0.55. The improvement of students' higher-order thinking ability on the cognitive dimension of analyzing was smaller than the improvement of the cognitive dimensions of evaluating and creating. Meanwhile the improvement on cognitive dimension of create was the highest. Overall, the high-level thinking ability of the undergraduate students was sufficient, so for the improvement, exercises to solve problems that require higher-order thinking is necessary. In addition, educators should familiarize themselves to recheck the students' conceptual understanding of the prerequisite concept in order to avoid mistakes in concepts by providing retention tests on a previously learned material.

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