Effectiveness of redox and electrochemical cell module based guided discovery learning on critical thinking skills and student learning outcomes of high school

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Abstract. This study aims to reveal the effectiveness of redox and electrochemical cell modules based guided discovery learning on critical thinking skills and learning outcomes of senior high school students. This research is a continuation of Research and Development research, that is in the develop phase. The effectiveness test was carried out through quasi experiment with pretest-posttest control group design. The population of this study were all students of XII class at Public Senior High School 1 (SMAN 1) Nan Sabaris, West Sumatra, Indonesia in 2018-2019 academic year. Samples were taken through simple random sampling technique. The research instruments used were a test of critical thinking skills and student learning outcomes. Critical thinking skills are analysed by percentage and learning outcomes with IBM Statistical Product and Service Solutions 23. This research found that the critical thinking skills were obtained at 92.8% in very high category and N-gain values of 0.72 in high category. It was concluded that redox and electrochemical cell modules based guided discovery learning were effective against critical thinking skills and improved learning outcomes of students in XII class at SMAN 1 Nan Sabaris. Therefore, redox and electrochemical cell modules based on guided discovery learning can be used in real learning in high schools to improve critical thinking skills and student learning outcomes.

1. Introduction

Effectiveness is used as a measure to express the level of achievement of learning objectives in the learning process. One way to measure the effectiveness in the learning process is through student learning outcomes. Good learning outcomes are influenced by teaching materials used in the learning process, such as modules. Module is one of the written learning media that serves to facilitate information processing in the learning process. Modules contain specific subject matter with structured components. A module is said to be effective if it can achieve learning outcomes that are in line with expectations [1] [2] [3]. Learning uses effective modules in improving students' thinking skills in constructing knowledge to improve cognitive abilities by 0.7 in colloidal material [4] and to improve critical thinking skills and to obtain good learning outcomes in circular material [5]. One of the other materials in chemistry learning is redox and electrochemical cells (voltaic cells) which are studied in the XII science class.

Redox and electrochemical cells material are factual, conceptual and procedural. Characteristics of redox and electrochemical cells have a subject with criteria for understanding concepts need

mathematical abilities. In addition, this material is basic of electrolysis cells material, so that errors often occur in understanding concepts [6]. Therefore, it is necessary to strengthen the learning process in accordance with the demands of the 2013 curriculum through a scientific approach that aims to provide student understanding in recognizing and understanding various materials through a scientific approach. The 2013 curriculum focuses on the essence of the scientific approach in the learning process. The information obtained in the learning process is not just knowledge. However, the information is processed to find solutions or problem solving [7].Information processing through a scientific approach applies several methods, media and learning techniques to improve student learning outcomes. The scientific approach is able to improve student learning outcomes by 18.34% in electromechanical control system material [8]. Therefore, the scientific approach is integrated in the learning process through learning models. One model of learning through a scientific approach that is compatible with redox and electrochemical cells is guided discovery learning.

Guided discovery learning is one type of discovery learning. The learning process is carried out by training and guiding students in learning, gaining knowledge and building concepts independently. The role of the teacher provides guidance in the form of suggestions, questions and instructions, so that students are more motivated in learning concepts that last a long time in memory. The concept is not only just remembered, but also understood and applied in everyday life [9] [10]. Guided discovery is needed to solve differences in reason through a variety of strategies, provide opportunities to observe student development, provide support for learning to work together, strengthen relationships and create valuable experiences and generate activeness so as to improve cognitive outcomes and high analytical skills [11] [12] [13] [14]. In addition, guided discovery learning is considered more challenging and takes less time during practical work, so it is effectively used to improve concept discovery and understanding on Ionizing Radiation Practical material in the Netherlands [15] and is considered as a strategy in motivating students to find and collect information creatively, and also supporting the learning process. Learning through this approach is more effective than conventional approaches. This method is more effective than problem-solving methods [16] [17] [18].

The advantages of guided discovery learning are supported by the stages in the guided discovery learning syntax. The stages in guided discovery learning include: (1) motivation and problem presentation; (2) selection of learning activities; (3) data collection; (4) data processing; and (5) closure [19]. These stages are implemented into the learning process by integrating into a module, so that it is called a module based on guided discovery learning.

Based on the background of the above problems, this study aims to reveal the effectiveness of redox and electrochemical cell modules based on guided discovery learning on critical thinking skills and student learning outcomes. The selection of research samples was conducted on students of class XII science in high school who studied redox and electrochemical cells. Based on the results of the prior study, the redox and electrochemical cell modules based on guided discovery learning are valid and practical. Module validity has a very high category ($k = 0.83$) and practicality is based on the answers of the teachers and students in the high category ($k = 0.79$ and $k = 0.80$) [20]. However, the effectiveness of redox and electrochemical modules is based on guided discovery learning on critical thinking skills and student learning outcomes have not been tested, so it cannot be used in the learning process at school. This study aims to reveal the effectiveness of redox and electrochemical cell modules based on guided discovery learning on critical thinking skills and student learning outcomes, so that the module can be used in the learning process in schools.

2. Methods

Type of research is Research and Development (R & D) research at the development stage using the 4D model (defines, design, develop, disseminate). Define, design, and develop phases have been carried out, but only to test the validity and practicality, while the effectiveness of the module has not been tested yet. Therefore, this study aims to reveal the effectiveness of redox and electrochemical cell modules based on guided discovery learning on critical thinking skills and student learning outcomes. The effectiveness testing of this module involved 34 students of XII 5 science class as an

experimental class and 34 students of XII 4 science class as a control class at Public Senior High School (SMAN) 1 Nan Sabaris. The instrument used in this study is a test of critical thinking skills and student learning outcomes. Indicators of critical thinking skills are integrated into the module at each stage of the syntax of guided discovery learning on student activity sheets, and critical thinking skills are analysed through the contents of students' answers sheet. While student learning outcomes were analysed through pretest-posttest in the form of multiple choice questions consisting of five choices and supported by the contents of student answers through activity sheets and student worksheets. The multiple choice questions have been tested before and an analysis of validity, reliability, differentiation and level of difficulty has been carried out.

The effectiveness of redox and electrochemical cell modules based on guided discovery learning is analysed for critical thinking skills and student learning outcomes. The value of critical thinking skills is determined based on equation (1) and the values obtained are concluded based on criteria of critical thinking skills [21].The equation used is as follows.

$$\% = \frac{score\ obtained}{total\ score} x100\% \quad (1)$$

While learning outcomes are determined through the N-gain equation (2) and the value obtained is determined based on the classification of the N-gain score [22]. The equation used is as follows:

$$N - gain = \frac{posttest - pretest}{skormax - pretest} \quad (2)$$

3. Results and Discussions

3.1. Results

3.1.1. *Critical Thinking Skill Analysis.* Results of the analysis of critical thinking skills include ten indicators of critical thinking skills. The average value for each indicator of critical thinking skills is shown in Figure 1.

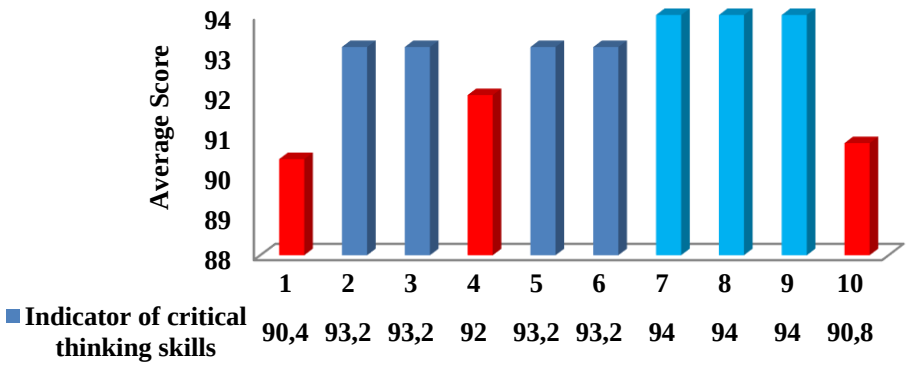

Figure 1. Test results of students'

Critical thinking skills Indicators of integrated critical thinking skills in the guided discovery learning syntax contained in the module. Indicators of critical thinking skills analysed include: (1) formulating hypotheses, (2) recording observations, (3) defining terms and considering a definition, (4) reporting experimental results, (5) giving simple explanations, (6) making definitions, (7) write arguments, (8) prove hypotheses, (9) provide further explanations and (10) write conclusions.

3.1.2. *Learning Outcomes Analysis.* Student learning outcomes in the sample class are determined through N-gain scores as presented in Table 1.

Table 1. N-gain test results for the class class

Class	N	Average			Category
		Pretest	*Posttest*	N-gain	
Experiment	34	19,92	85,68	0,72	High
Control	34	22,55	72,38	0,54	Medium

Table 1 shows that the average value of N-gain in the experimental class is higher than the control class. To see the differences in learning outcomes of both sample classes statistically, begins with the normality test used Saphiro-Wilk test as in Table 2.

Table 2. Test results of the normality of the sample

Class	α	f	(sig)	Conclusion
Experiment	0,05	34	0,153	Normally distribution
Control		34	0,238	Normally distribution

Based on Table 2, both classes of samples are normally distributed. Therefore, the homogeneity test is then carried out used F-test. Based on the results of the homogeneity test, the two sample classes have a homogeneous variance with a significance value (0.082)> α (0.05). Furthermore, the hypothesis is tested using the t-test as in Table 3.

Table 3. The results of hypothesis testing of the sample class

Class	df	t arithmetic	t table	Conclusion
Experiment	60	4,368	1,671	H_0 rejected H_1 accepted

Student learning outcomes are supported by the acquisition of activity sheets and student worksheets contained in the module. The average score for the five learning meetings is shown in Figure 2.

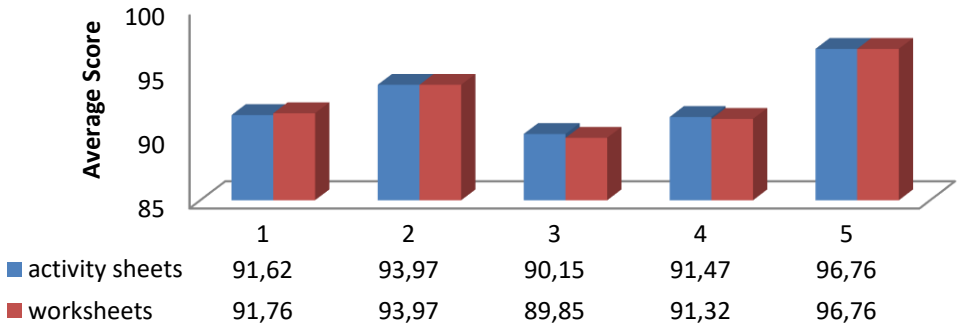

Figure 2. Assessment of student worksheets and student worksheets

3.2. Discussions

Effectiveness of redox and electrochemical modules based on guided discovery learning is determined based on the results of analysis of critical thinking skills and student learning outcomes. The assessment of critical thinking skills is integrated into each syntax stage of guided discovery learning contained in student activity sheets on modules that are assessed based on indicators of critical thinking skills [23]. Based on Figure 1, this module can be used effectively against students' critical thinking skills, because the average value for each indicator has a very high category. Figure 1 shows students' critical thinking skills for the ten indicators assessed, that the lowest indicator of critical thinking skills is (1) formulating the problem, (4) reporting the results of the experiment and (10) writing a conclusion. Even though the problem already exists, students still have difficulties in formulating the problem. In addition students also have difficulty in reporting the results of the experiment. Students can only report the results of experiments that are seen macroscopically without

knowing what happened on the microscopic. Furthermore, students also have difficulty in writing conclusions, because the conclusions contain the connection between one concept and another. This is in accordance with Piaget's learning theory of cognitive development theory, that high school students still need guidance in constructing inductive knowledge because every high school student has a cognitive development stage with different characteristics [24]. The highest indicators of students' critical thinking skills are in (7) writing arguments, (8) proving the hypothesis and (9) providing further explanations. This is consistent with previous research, that critical thinking skills are able to make students provide the right answers or logical arguments that are supported through proof, choice, emphasis and determination [5] [25].

Student learning outcomes are determined based on the N-gain score. Based on Table 1, the experimental class N-gain score is 0.72 with the high category and the control class 0.54 with the medium category. That is, the N-gain score for the experimental class is higher than the control class. This is due to the influence of teaching materials used in the learning process. Experimental classes are taught using modules and control classes without using modules. The results of the research that have been carried out in accordance with previous research, that student learning outcomes learned by the module obtain better learning outcomes in colloidal material taught by the module have a high N-gain 0.7 score [3], multimedia modules with electrochemical material scores N-gain 0.87 [24]. Learning to use multimedia modules further enhances students' motivation and learning outcomes, because multimedia modules are computer-based electronic modules with better designs than print modules [24]. The N-gain score in this study is lower, because the modules used are computer-based or known as electronic modules (e-modules) which are developed to increase students' motivation in the learning process. The study revealed that learning with modules facilitates students in understanding abstract concepts that involve macroscopic, microscopic and symbolic on electrochemical material, making it easier for students to visualize understanding information.

The difference in the learning outcomes of the sample class can be proven by a statistic test which begins with the normality test. Table 2 shows that the two classes of samples are normally distributed with values for the experimental class (sig) 0.153> α 0.05 and the control class (sig) 0.238> α 0.05. then the homogeneity of the sample class was tested. Based on the results of the homogeneity test, the two sample classes have a homogeneous variance with a significance value (0.082)> α (0.05). Furthermore, differences in learning outcomes are analysed through hypothesis testing using the t test. Table 3 shows the value of $a_{rithmetic}(4,368)>t_{able}(1,671)$, meaning that the hypothesis is accepted. The hypothesis is proven, that the experimental class student learning outcomes that are taught using modules are significantly higher than those of control class students without using modules. Students in the experimental class are more facilitated in the learning process because they are guided by the module so that students can find their own concepts based on the syntax sequence of *guided discovery learning*. Whereas in the control class, students' ability to find concepts is guided by the teacher itself.

Student learning outcomes are supported by the average value of activity sheets and student worksheets contained in the module. Student worksheets are done after students work on student activity sheets. Student worksheets can also be used as a formative test, which is a test given at the end of each lesson. This is in accordance with one of the advantages of using modules, which is the possibility of formative testing [3] Based on Figure 2, the average lowest score is at the meeting (3). This is because the practical work is not implemented in the material that should be practiced. While the highest average value is obtained at the meeting (5). At this meeting students have been able to apply the material they have learned into their daily lives.

Redox and electrochemical cell modules based on guided discovery learning have syntax that allows students to understand concepts so as to improve student learning outcomes. This is evident if the experimental class learning outcomes are higher than the control class. This is consistent with previous studies, that the application of models guided discovery learning increases student learning outcomes by 76% with a high category of financial accounting material at Tai Solarin University [26].

The constraints faced during the study were the lack of motivation of students in learning, even though they were active in the learning process. Therefore, for further learning students whose

learning motivation is low are grouped with students whose learning motivation is high so that all students are motivated to learn. Based on the description above, it can be concluded that the student learning outcomes of the sample class is significantly difference. Students who are taught using redox modules and electrochemical cells based on guided discovery learning have significantly higher learning outcomes than control classes that are taught without using modules. That is, redox and electrochemical cell based modules guided discovery learning effectively improve student learning outcomes.

4. Conclusions and Recommendations

Redox and electrochemical cell modules based on *guided discovery learning* for XII science class in Public Senior High School (SMAN) 1 Nan Sabaris effective against critical thinking skills with a percentage of 92.8% (very high category). This module also effectively improves student learning outcomes with an N-gain value of 0.72 (high category). Thus, it can be concluded that redox and electrochemical cell modules based on guided discovery learning are effective to be used in the actual learning process in senior high school to improve critical thinking skills and learning outcomes of students in class XII science.

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