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

B.Bayharti*, OR.Azumar, A.Andromeda and Y.Yerimadesi*

Chemistry Education, Faculty of Mathematics and Science, Universitas Negeri Padang, Prof. Hamka street, Padang, 25131, Indonesia

*chembayharti@gmail.com,*yeri@fmipa.unp.ac.id

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
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.

\[
\% = \frac{\text{score obtained}}{\text{total score}} \times 100\% \tag{1}
\]

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:

\[
N - \text{gain} = \frac{\text{posttest} - \text{pretest}}{\text{skormax} - \text{pretest}} \tag{2}
\]

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](image)

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 |          | N-gain | Category |
|------------|----|---------|----------|--------|----------|
| 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  | N  | (sig)  | Conclusion    |
|------------|----|----|--------|---------------|
| Experiment | 0.05 | 34 | 0.153  | Normally distribution |
| Control    | 0.238 | 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   | H₀ rejected |
|            |    |              |         | H₁ 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.

![Average Score](image-url)

**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 $a_{\text{intrinsic}}(4,368) > t_{\text{table}}(1,671)$, 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 different. 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.

Acknowledgement
- Research and Community Service of Universitas Negeri Padang, which has funded this research through DIPA fund Universitas Negeri Padang in accordance with the Rector Decree No. SP UNP DIPA-042.01.2.400929 / 2017 Date May 29, 2017.
- Chemistry teacher and class XII science student at SMAN 1 Nan Sabaris 2018/2019 academic year who help in completing this research and article writing.

Reference
[1] Uno B H 2012 Belajar dengan Pendekatan PALKEN (Pembelajaran Aktif, Inovatif, Lingkungan, Kreatif, Efektif dan Menarik) (Jakarta: Bumi Aksara)
[2] Wena M 2012 Strategi Pembelajaran Inovatif Kontemporer: Suatu Tinjauan Konseptual Operasional (Jakarta: Bumi Aksara)
[3] Hamalik O 2004 Proses Belajar Mengajar (Jakarta: PT Bumi Aksara)
[4] Novilia L Srini M I dan Fauziatul F 2016 The Effectiveness of Colloid Module Based on Guided Inquiry Approach ti Increase Student’s Cognitive Learning Outcomes International Journal of Education 9 1
[5] Yuliani K 2015 The Development of Learning Devices Based Guided Discovery Model to Improve Understanding Concept and Critical Thinking Mathematically Ability of Students at Islamic Junior High School of Medan IISTE 6 24/2222-1735
[6] Jespersen N D dan James E B 2012 Chemistry The Molecular Nature of Matter 6th Edition (New York: Jhon Willey and Son’s)
[7] Permendikbud 2017 Kurikulum 2013 Sekolah Menengah Atas dan Madrasah Aliyah
[8] Hidayati N dan Endryansyah 2014 Pengaruh Penggunaan Pendekatan Ilmiah (Scientific Approach) dalam Pembelajaran terhadap Hasil Belajar Siswa Kelas XII TITL 1 SMK Negeri 7 Surabaya pada Standar Kompetensi Mengoperasikan Sistem Kendali Elektromagnetik Jurnal Pendidikan Teknik Elektro 3 02
[9] Hanafiah N 2012 Konsep Strategi Pembelajaran (Bandung: PT Refika Aditama)
[10] Hosnan 2014 Pendekatan Sainstifik dan Kontekstual dalam Pembelajaran Abad 21 (Jakarta: Ghalia Indonesia)
[11] Baroody A J David J P Michael D E dan Erin E R 2014 The Impact of Highly and Minimally Guided Discovery Instruction on *romoting the Learning pf Reasoning Startegies for Basic Add-1 and Double Combinations Early Childhood Research Quarterly 30 93-105
[12] Loo J L 2013 Guided and Team-Based Learning for Chemical Information Literacy The Journal of Academic Librarianship 39 252-259
[13] Makoolati N 2015 The Effectiveness of Guided Discovery Learning on the Learning and Satisfaction of Nursing Student Hormozgan Media Journal 18 6
[14] Akanmu M A 2014 Guided-discovery Learning Strategy and Senior School Students Performance in Mathematics in Ejigbo, Nigeria IISTE Journal of Education and Practice 4 12/2222-1735
[15] Kortland J Joolingen W R dan Bakker A 2016 Increase Conceptual Learning a Guided Discovery Approach of the ISP Master Research (30 ECTS) for the Master Science Education (Universiteit Utrecht: Freudental Institute for Science and Mathematics Education)
[16] Bahari S 2015 The Influence of Learning Model Guided Findings of Students Learning Outcomes International Journal of Scientific & Technology Research 4 03
[17] Achera L J Rene R B dan Marc D G 2015 The Effect of Group Guided Discovery Approach on The Perfomance of Students in Geometry International Journal of Multidiciplinary Research and Modern Education 1 2454-6119
[18] Lasisi N Omotayo T A dan Munlikat B S 2016 Comparison of the Effects of Guided Discovery, Problem Solving, and Conventional Teaching Methods on Retention of Secondary School Chemistry Students in Minna Metropolis, Niger State The American Journal of Innovative Research and Applied Science 2 98-104
[19] Smitha 2012 Inquiry Training Model and Guided Discovery Learning (Kozhikode:Vilavath Publication)
[20] Yerimadesi Bayharti Risa O 2018 Validitas dan Praktikalitas Modul Reaksi Redoks dan Sel Elektrokimia Berbasis Guided Discovery Learning untuk SMA Jurnal Eksakta Pendidikan 2 1
[21] Riduwan 2015 Belajar Mudah Penelitian untuk Guru, Karyawan dan Peneliti Pemula (Bandung: Alfabeta)
[22] Hake R R 1999 Analyzing Change/Gain Score American Educational Research Methodolog
[23] Ennis, R.H. 1985. A logical basis for measuring critical thinking skills. Educational Leadership, 43(2), 44-48.
[24] Elida P (1991) Perkembangan Peserta Didik (Jakarta:Dirjen Dikti)
[25] Lai, E Y 2011 Critical Thinking: A Literature Review. Research Report (Person: Always Learning)
[26] Lee T T and Kamisah O 2011 Effectiveness of Interactive Multimedia Module with Pedagogical Agent (IMMPA) in Learning of Electrochemistry: A Preliminary Investigation Asia Pasific Forum on Science Learning and Teaching (APFSLT) 11 2
[27] Olorade and Jide J 2016 Effectiveness of Guided Discovery Learning Strategy and Gender Sensitivity on Student’s Academic Achievement in Financial Accounting in Colleges of Education Academic Research Journal 4 6/2360-7866