Journal of Physics: Conference Series

Developing a discovery learning module on chemical equilibrium to improve critical thinking skills of senior high school students

IOP Conf. Series: Journal of Physics: Conf. Series **1185** (2019) 012145 doi:10.1088/1742-6596/1185/1/012145

Developing a discovery learning module on chemical equilibrium to improve critical thinking skills of senior high school students

E Ellizar*, S D Putri , M Azhar and H Hardeli

Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang, Jl. Prof Hamka, Padang 25131, Indonesia

*non_jalius@yahoo.com

Abstract. This research was based on an observation which was found that the learning instruction was not yet optimal to train students to think critically. The purpose of this research is to develop a discovery instructional module on chemical equilibrium to improve critical thinking skills of senior high school students. This research belongs to research and developments that use Plomp Model with three stages: the preliminary research, prototyping and assessment phase. Assessment phase was conducted in two schools: students with high and low academic ability. The instrument used was critical thinking test consisting of nine essay questions. The results showed that generated discovery learning module on chemical equilibrium was effective to improve critical thinking skills, both for students with high and low academic ability.

1. Introduction

Discovery learning is one of the recommended instructional models in implementing the 2013 curriculum because the syntax of this model is in accordance with the scientific approach. Discovery learning model is a learning model that encourages students to be actively involved in finding their own learned concepts [1]. Stages of the discovery learning model are stimulation, problem statement, data collecting, data processing, verification, and generalization. Some researches have proven that the application of discovery learning model in learning can improve learning outcomes [2], investigation ability [3], mathematical analogy ability [4], reduce misconception [5] and increasing understanding of the concept and critical thinking skills [6].

The ability to think critically is one of the skills developed in 21st-century learning. Critical thinking is an organized process that allows students to evaluate evidence, assumptions, logic, and language underlying other people's statements. By thinking critically students will discover the truth between the number of events and information they receive. If students are given the opportunity to use higher-order thinking, they will be used to constructing arguments using reliable evidence and reasonable logic [7]. Critical thinking skills can be developed by teaching students how to search for answers to questions and problems objectively and with an open mind, then teaching them how to investigate the cause of an event [8]. The learning process should be able to train students to think critically. By thinking critically about how a concept applies to real-life situations, it can deepen the quality of students' understanding and ability to apply prior knowledge to new situations [9]. Based on research, Ellizar and Djamas concluded that broadly indicator of critical thinking in public senior high

school of Padang is still far expected, so overall the average of each indicator is still below 40%, this is very concerning. This indicates that students have not been trained to deal with problems that require them to apply critical thinking skills such as conducting the process of analysis, evaluation, inference, deductive, inductive and student findings in this aspect is still in enough and moderate categories [10].

One of the teaching materials that can be used in the learning process is the module. Learning with the module enables students to be more independent [11], learning activities are structured to help students achieve a number of clearly defined and specific objectives [12] and students can measure their own degree of mastery over the material discussed in module [13]. In addition, lessons learned using modules can improve students' understanding better than conventional learning (without modules) [14]. The use of modules can improve students' motivation to learn because the module is equipped with concept maps, colour charts, and drawings. The existence of concept maps in the module allows students to remember information, focus and increase understanding. Charts and colour drawings make the brain more active and enhance students' sense of enjoyment [15].

Based on the results of interviews with some chemistry teachers and the results of questionnaires given to students it is known that the teaching materials used in the school describes all concepts in detail so that students do not find their own concepts learned, while the expected process of learning curriculum is the students find their own concept through a scientific approach (observing, questioning, gathering information, associating and communicating). Thus, the existing teaching materials have not been maximal in supporting the implementation of the learning process based on the 2013 curriculum. In addition, the existing teaching materials have not described the full three levels of chemical representation (macroscopic, sub-microscopic and symbolic).

Discovery learning module with scientific approach is expected to be an alternative to solving the problem. Discovery learning module with scientific approach is equipped with teaching materials that contain stimulation, where students are introduced to the problem and they are led to solving the problem systematically and teachers act as facilitators and motivators of student learning. Based on Ellizar's research, it was concluded that discovery-learning module with the scientific approach on electrolyte and non-electrolyte solution and acid-base for high school students were valid, practice, and effective to help the students to understand the content of the learning materials [16].

2. Methods

This research is a development research using Plomp development model, which consists of three phases: the preliminary research, prototyping and assessment phase. In the assessment phase, the field test was conducted in two schools: SMAN 3 Padang and SMAN 13 Padang with high and low academic ability. The field test was conducted to determine the effectiveness of modules to train students' critical thinking skills. School selection is done by classifying the school based on the average value of students received at each public senior high school in Padang. The data is obtained from the New Student Admission Committee 2016. In each school, there is an experimental group and control group. The experimental group learns using chemical equilibrium module based discovery learning which has been tested for validity and practicality, while the control class does not.

The research instrument used is critical thinking ability test using essay problem which is adjusted with critical thinking indicators, as shown in Table 1 [17]. After tested the validity and reliability, then selected nine questions. Analysis of critical thinking skills is done by scoring the answers given. Scoring is done by referring to the modified scoring rubric, as shown in Table 2 [18].

Table 1. Critical thinking skills aspects (CTSA) and indicators (CTSI)

Aspects	Indicators
Basic Clarification	1. Focus on a question
	2. Analyze arguments
	3. Ask and answer clarification and/or challenge questions
The bases for a decision	4. Judge the credibility of a source
Inference	5. Induction
	6. Make and judge value judgments
Advanced Clarification	7. Define terms and judge definitions, using appropriate criteria
	8. Attribute unstated assumptions
Strategy and tactics	9. Determining an action

Table 2. Critical thinking rubrics

Score	Descriptors
5	• All concepts are true, clear and specific • All the description of the answer is true, clear, and specific, supported by a strong reason, true, clear argument • Thinking well, all concepts are interrelated and integrated • The grammar is good and correct • All aspects appear, good and balanced evidence
4	• Most concepts are true, clear but less specific • Most of the description of the answer is correct, clear, but less specific • The flow of thinking is good, most concepts are interrelated and integrated • Grammar is good and right, there is a small mistake • All aspects are visible, but not yet balanced
3	• A few concepts are true and clear • A small part of the answer is true and clear but the reasons and arguments are not clear • The flow of thinking is good enough, a small part is interrelated • Grammar is good enough, there is a spelling mistake • Most aspects seem right
2	• The concept lacks focus or excessive or dubious • The answer description is not supported • The flow of thinking is not good, the concept is not interrelated • Good grammar, incomplete sentences • A few aspects seem right
1	• All concepts are incorrect or inadequate • The reason is not true • Flow of thinking is not good • Grammar is not good • Overall aspect is not sufficient
0	• No answer or wrong answer

The scores obtained were then converted into percentages with the criteria in Table 3 [19].

Table 3. Criteria of student's ability

Score (%)	Criteria
81 – 100	Excellent
61 – 80	Good
41 – 60	Adequate
21 – 40	Less
0 – 20	Very Less

Analysis of the data is done to test the truth of the hypothesis proposed in the research that is the effect of the use of module to the ability of critical thinking in schools with high and low student ability.

$$H_0 \quad : \mu_1 = \mu_2 \tag{1}$$
$$H_1 \quad : \mu_1 > \mu_2 \tag{2}$$

where μ_1 is the average score of the experiment group and μ_2 is the average score of the control group. Before testing the hypothesis, first tested the basic assumption of normality and homogeneity test by using SPSS software.

2.1. Normality Test

Normality test is done to know the distribution of both data groups (normal or not). The normality test used was Kolmogorov-Smirnov. The statistical hypothesis for the normality test is

H_0: data is normally distributed

H_1: data is not normally distributed

Criteria for decision making is based on the value of significance (probability), accept H_0 if the value of significance > 0.05, and reject H_0 if otherwise.

2.2. Homogeneity Test

The homogeneity test of variance aims to see whether the two groups of data have a homogeneous variance or not. The hypothesis in this test is

$$H_0 \quad : \sigma_1^2 = \sigma_2^2 \tag{3}$$
$$H1 \quad : \sigma_1^2 \neq \sigma_2^2 \tag{4}$$

where σ_1^2 is variance of experiment group and σ_2^2 is variance of control group. The acceptance criterion H_0 is based on the significance value in the test of homogeneity of variance table. If the value of significance > 0.05, then accept H_0 and reject H_0 otherwise.

2.3. Hypotheses Test

If the data is normally distributed and homogeneous, then the hypothesis is tested by using T test. The value of significance taken is the value for the equal variances assumed. If the data is normally distributed but not homogeneous, then hypothesis testing is also done with T test, but the value of significance taken is the value for equal variances not assumed. Statistical hypothesis for T test:

$$H_0 \quad : \mu_1 = \mu_2 \tag{5}$$
$$H_1 \quad : \mu_1 > \mu_2 \tag{6}$$

The acceptance criterion H_0 is accept H_0 if the value of significance > 0.05, and reject H_0 otherwise. If the data is not normally distributed, then the hypothesis is tested using the Mann-Whitney Test (U Test). Statistical hypothesis and criterion of acceptance U test is same as T test, but at U test does not need to fulfill normal and homogenous assumption.

3. Results and Discussion

3.1. Results

The ability to think critically viewed from five aspects which are basic clarification, the bases for a decision, inference, advanced clarification and strategy, and tactics. The critical thinking ability is assessed from students' ability to answer questions designed based on critical thinking indicators. Comparison percentage of critical thinking skills between experimental group (EG) and control group (CG) in both schools can be seen in Figure 1.

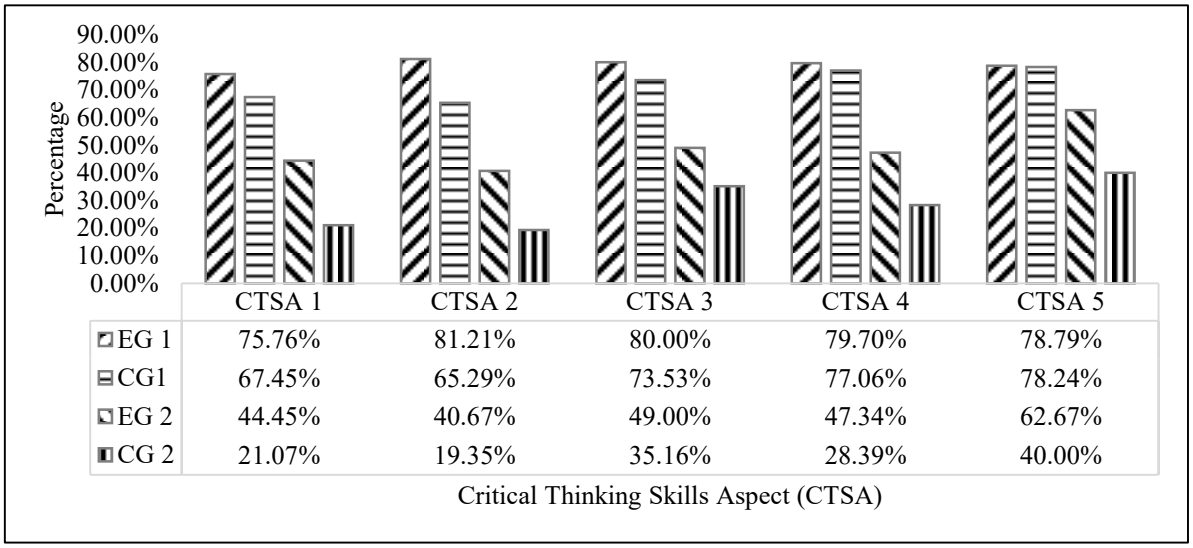


Figure 1. Comparison percentage of critical thinking skills between experimental group (EG) and control group (CG)

The results of normality (Table 4) and homogeneity test (Table 5) of the sample groups showed that the experimental group (EG) and control group (CG) data in both schools were normal distributed (sig. > 0.05) and had non-homogeneous variance (sig < 0.05).

Table 4. SPSS output of normality test

One-Sample Kolmogorov-Smirnov Test					
		EG 1	CG 1	EG 2	CG 2
N		33	34	30	31
Normal Parameters[a]	Mean	78.55	71.82	47.70	27.61
	Std. Deviation	10.035	8.837	15.890	11.500
Most Extreme Differences	Absolute	.101	.136	.240	.236
	Positive	.077	.136	.240	.236
	Negative	-.101	-.123	-.113	-.153
Kolmogorov-Smirnov Z		.578	.790	1.315	1.315
Asymp. Sig. (2-tailed)		.892	.560	.063	.063

[a] Test distribution is Normal.

Table 5. SPSS output of homogeneity test

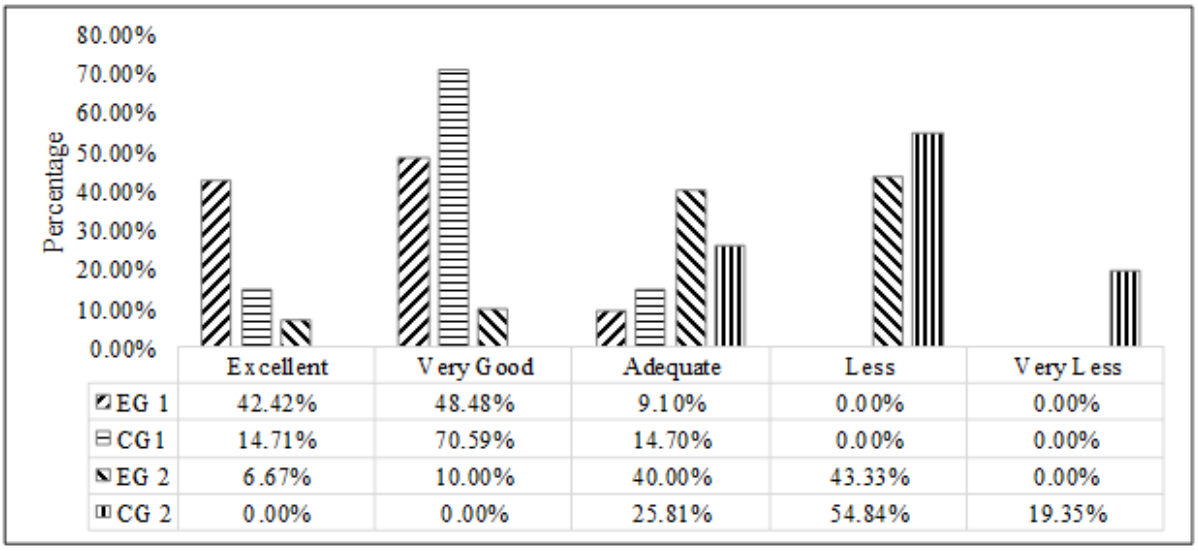
Test of Homogeneity of Variances			
Levene Statistic	df1	df2	Sig.
3.091	3	124	.030

The result of T test of the students' critical thinking ability with high and low ability can be seen in Table 6. The decision to reject H_0 (Sig. <0.05) means that the critical thinking ability of students who learn by using module and without module differ significantly. The average critical thinking ability of students using modules is higher than students who do not use modules.

Table 6. Hypothesis test results of critical thinking skills

Group	N	$\bar{x}$	St.Dev	Asymp. Sig	Decision
Experiment 1	33	78.55	10.035	.0025	Reject H_0
Control 1	34	71.82	8.837		
Experiment 2	30	47.70	15.890	.000	Reject H_0
Control 2	31	27.61	11.500		

In addition, students are also grouped into the category of critical thinking and calculated the number of students (percentage) that are in certain categories. Comparison percentage of the number of students who are in each critical thinking categories can be seen in Figure 2.



	Excellent	Very Good	Adequate	Less	Very Less
EG 1	42.42%	48.48%	9.10%	0.00%	0.00%
CG1	14.71%	70.59%	14.70%	0.00%	0.00%
EG 2	6.67%	10.00%	40.00%	43.33%	0.00%
CG 2	0.00%	0.00%	25.81%	54.84%	19.35%

Figure 2. Comparison percentage of student in each critical thinking categories.

3.2. Discussion

Effectiveness is assessed on the results of applying the product as desired [20]. If the module is operationally showing the results as expected, then the module is said to be effective [21]. In this research, the effectiveness of chemistry discovery learning based equilibrium module is seen from students' critical thinking ability.

The result of hypothesis testing shows that the critical thinking skills of students who are learning by using discovery learning based chemical equilibrium module is significantly higher than that of students who do not use module, either at school with high or low academic ability. Discovery learning improves students 'reasoning, the ability to think critically, trains students' cognitive skills to find and solve problems [22]. Learning activities on the discovery learning model can support the students in finding the concept of the problem given then the students do the investigation through

scientific method from observing, formulating the problem, making hypothesis, collecting data and concluding, where this activity can improve students' critical thinking skills [23].

In each learning activity in the module there is a critical thinking skill trained. The students' critical thinking skills can be trained by teaching students to find answers to questions and problems objectively and with an open mind [8]. At the stage of stimulation is given a problem and students are led to formulate the problem and then make a hypothesis that related to the problem. Then the experimental group students who use the modules are trained to collect data from various sources such as drawing, experimenting, or reading information. Based on data collected, students then answer the questions contained in the module to find their own concepts learned. In addition students who learn by using modules are trained to induce, students are confronted with facts then they draw conclusions based on his findings. The use of discovery learning based chemical equilibrium module can improve students' critical thinking skills. The implementation of the discovery learning model enhances the understanding of the concept and the ability to think critically [6].

The number of experimental group 1 students who are in the 'excellent' category is much more than the control group as shown in Figure 2, while the number of experimental group 2 students who are in the category 'enough' more than the control group 2. Thus, both in schools with high and low student abilities, the use of discovery learning module can improve students' critical thinking skills because learning activities in the module train students to think critically.

There is a relationship between critical thinking and academic achievement or student learning outcomes. Students with a high level of critical thinking have a high ability to receive and process information and organize it in an appropriate way. They also have reasoning ability, curiosity, tolerance and open mind, have the ability to detect and avoid prejudices, fulfill tasks and educational challenges better and therefore they have higher academic achievement than those with lower critical thinking skills [24].

Critical thinking means thinking logically and systematically. The ability to think logically is the ability to discover truth based on certain rules, patterns or logic. Logical thinking can be obtained by students when providing a logical argument to determine conclusions based on the scientific method [23]. This ability can help students to improve conceptual understanding. The ability to think logically can bridge the improvement of student learning outcomes through correct conceptual understanding [25]. In other words, students who are learning with the discovery learning model are trained to think logically that causes their conceptual understanding to be better so that the learning outcomes increase.

4. Conclussion

This research is a development research that produces chemical equilibrium module based discovery learning. Based on the research, can be concluded that chemical equilibrium module based discovery learning was effective to improve critical thingking skills, both for students with high and low academic ability. Discovery learning model train students to think logically that causes their conceptual understanding be better so that the learning outcomes increase.

Acknowledgments

This research is funding by Kementerian Riset, Teknologi dan Pendidikan Tinggi Republik Indonesia (KEMENRISTEK DIKTI). Thank to Mr. Budhi Oktavia, S.Si, M.Si, Ph.D and Mr. Alizar, S.Pd, M.Sc, Ph.D as validators; Mr. Yunis Eka Putra, M.Pd and Mrs. Elni, M.Si as validators and provide practicality assessment; Students 11 grade of public senior high school 3 and 13 Padang and all parties who have assisted in completion of the research and this article.

References

[1] Hosnan M 2014 *Pendekatan Saintifik dan Kontekstual dalam Pembelajaran Abad 21: Kunci Sukses Implementasi Kurikulum 2013* (Bogor: Ghalia Indonesia) p 282
[2] Uside B and Abura 2013 *Asian J. of Social Sciences & Humanities* **2** p 351-358
[3] Balım A G 2009 *Eurasian J of Educational Research* **35** p 1-20

[4] Maarif S 2016 *Int. J. of Research in Education and Science* **2** p 114-124
[5] Tompo A and Muris 2016 *Int. J. of Environmental & Science Education* **11** p 5676-5686
[6] Yuliani K and Saragih S 2015 *J. of Education and Practice* **6** p 116-128
[7] Johnson E B 2002 *Contextual Teaching and Learning: Menjadikan Kegiatan Belajar Mengajar Mengasyikkan dan Bermakna* Translated by I Setiawan 2006 (Bandung: Penerbit MLC) p 184
[8] Lang H R 2006 *Models, Strategies, and Methods for Effective Teaching* (Boston: Pearson Education Inc) p 461
[9] Zivkovic S 2016 *Proc. Social and Behavioral Sciences*. **232** p 102 – 108.
[10] Ellizar dan Djamas D 2012 *Laporan Akhir Penelitian Profesor* (Padang: Universitas Negeri Padang) p 49
[11] Direktorat Tenaga Kependidikan 2008 *Penulisan Modul* (Jakarta: Departemen Pendidikan Nasional) p 3
[12] Nasution 2015 *Berbagai Pendekatan dalam Proses Belajar dan Mengajar* (Jakarta: Bumi Aksara) p 205
[13] Prastowo A 2014 *Pengembangan Bahan Ajar Tematik: Tinjauan Teoritis dan Praktik* (Jakarta: Kencana) p 209
[14] Ellizar 2009 *J. Kependidikan Triadik* **12** 7-16
[15] Ellizar, Bayharti and Andromeda 2013 *Proc. Semirata FMIPA Universitas Lampung* (Lampung) p 117-124
[16] Ellizar, Hardeli, Beltris S and Suharni R 2018 *IOP Conf. Ser.: Materials Science and Engineering* **335** 012101
[17] Ennis R H 2011 *The Nature of Critical Thinking: An Outline of Critical Thinking Dispositions and Abilities* (University of Illinois) p 2
[18] Zubaidah S, Corebima AD , Mistianah 2015 *Sym. on Biology Education* (Malang: Universitas Negeri Malang) p 200-213
[19] Arikunto S 2009 *Manajemen Penelitian* (Jakarta: Rineka Cipta) p 44.
[20] Plomp T and Nieveen N 2013 *Educational Design Research: An Introduction* (Enschede: Netherlands Institute for Curriculum Development (SLO) p 28
[21] Nieveen N 1999 *Design Approaches and Tools in Education and Training* (Netherlands: Kluwer Academic Publishers) p 128
[22] Dahar R W 2011 *Teori-Teori Belajar dan Pembelajaran* (Jakarta: Erlangga) p 84
[23] Martaida T, Bukit N, Ginting E M 2017 IOSR *J. of Research & Method in Education* **7** p 1-8
[24] Kamaei A and Weisani M 2013 *Indian J. of Fundamental and Applied Life Sciences* **3** p 121-127
[25] Usdiyana D, Purniati T, Yulianti K and Harningsih E 2009 *J. Pengajaran MIPA* **13** p 1-14