Students’ critical thinking skills comparison in discovery learning based on constructing concept mapping and mind mapping

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Abstract. This research focused at analyzing the differences of students’ critical thinking skills who learned Basic Chemistry II via discovery learning based on constructing concept mapping and based on mind mapping. This quasi-experimental research used non-equivalent pre-test post-test control group design. The subject was students in Science Education Study Program, the Ganesha University of Education on 2nd semester, consists of 34 students who were divided equally into two groups (A and B). Class A and class B correspond to a group who learned Basic Chemistry II through discovery learning based on concept mapping and mind mapping construction, respectively. A test was conducted to examined students’ critical thinking skills. The results demonstrated that there is no significant differences in critical thinking skills of both groups. However, there are differences in their indicators i.e. interpretation, analysis, evaluation, inference, and explanation indicators.

1. Introduction
Critical thinking is one of the ability needed for human life [1-3]. It is an essential part of successful study for all learners [4]. Critical thinking as foundations of the essential learning outcomes which students should achieve across their school or college experience [5]. Critical thinking had its role in the applications or processes: (1) research, observation, and exploration; (2) problem invention, identification, and definition of a scientific issues; (3) problem solving, finding appropriate solutions for problems; (4) decision making; (5) obtaining information; (6) critique, critical questioning, and question formulation; (7) construction of reliable knowledge; (8) argumentation; defending ideas, discussion and debate; (9) evaluation, careful and rigorous testing; (10) rejecting, accepting hypothesis; (11) solving, clarifying discrepancies and concluding true statements; and (12) clarifying meaning [6]. Critical thinking consists of several skills, those are the ability to analyze arguments, to make inferences using inductive or deductive reasoning, to judge or to evaluate information, and to make decisions or to solve problems [7]. These skills can be created by observation, experience, reasoning, reflection, or communication, as a preference to belief and action [8, 9].

However, most of the human resources, especially the learners or students have low critical thinking skills. Senior high school students in Kediri, Indonesia have poor critical thinking skills. The average score of students’ critical thinking skills in aspects of: interpretation 46.03 (low category), analysis 60.20
Many factors can influence the low of students' critical thinking skills. One of them is the teaching and learning activity that facing a series of problems such as (1) asked sequential questions to students, (2) asked self-answered questions, (3) gave inadequate information, (4) gave ambiguous information, (5) did not ask for students' reasons, (6) less significant of the context, and (7) did not provide the new conceptions that guided the inquiry on the wider fields [16]. To improve students' critical thinking skills, many learning models have been proposed and implemented by many researchers. Many results of the learning models that can develop students’ critical thinking skills such as: (1) discovery learning model [17-22], (2) local culture-based 7E learning cycle model [23], (3) contextual teaching and learning model [18], and (4) RMS (reading, mind mapping, and sharing) model [24]. These models can be combined to other learning tools. Concept mapping as a road to think critically [25] can be combined to the discovery learning model. The students who use concept mapping can improve their critical thinking skills [26-30]. Problem-based learning model with mind mapping can improve students' critical thinking [31]. Differentiated science inquiry model combined with mind mapping can improve students' critical thinking better than differentiated science inquiry model, and conventional model [32].

Based on the description above, discovery learning is a models that can improve students' critical thinking skills. To support this model in improving students' critical thinking skills, the model is combined with concept mapping or mind mapping. This article analyses the differences of students’ critical thinking skills who learned through discovery learning based on constructing concept mapping and mind mapping.

2. Methods
The quasi-experimental method with non-equivalent pre-test post-test control group design was used in this study. The subject was students who programmed Basic Chemistry II in Science Education Study Program, the Ganesha University of Education on even semester in academic year 2018/2019. The subject consists of 34 students that were divided into two classes (class A and class B). Each class consists of 17 students. Class A as the experimental-1 group learned through discovery learning based on constructing concept mapping. Class B as the experimental-2 group learned through discovery learning based on constructing mind mapping. The students’ critical thinking skills was collected by a test that developed from the California critical thinking skills test indicators [33]. Prior to learning process, both of groups were given pre-test to obtain information of the students’ prior knowledge and the equality of them. The pre-test score was analyzed by the Mann Withney U-test with a 5% significance level. Data of students' critical thinking skills were analysed descriptively and inferentially, namely the independent sample t-test with 5 % significance level. The normality of data distribution was tested using the Kolmogorov-Smirnov Test. The homogeneity of variance data was tested using the Levene’s Test of Equality of Error Variances.

3. Result and Discussion
The learning was begun by giving the students pre-test to know their prior knowledge and the equality of both groups. The normality of students’ prior knowledge distribution in the experimental-1 and the experimental-2 groups were tested using the Kolmogorov-Smirnov Test. The variance homogeneity of them was tested using the Levene’s Test of Equality of Error Variances. The average pre-test score, the results of the normality and homogeneity test are shown in Table 1.

Table 1. The average pretest score, the results of normality and homogeneity test

| Group          | Average Pre-test Score | Normality Statistic | Normality Sig | Homogeneity Levene Statistic | Homogeneity Sig |
|----------------|------------------------|---------------------|---------------|------------------------------|-----------------|
| 1. Experimental-1 | 35.0                   | 0.239               | 0.011         | 5.245                        | 0.029           |
| 2. Experimental-2 | 33.1                   | 0.103               | 0.200         |                              |                 |

Table 2 shows the data on the students’ prior knowledge in the experimental-1 group are not normally distributed (sig normality < 0.05), but the data in the experimental-2 group are normally distributed (sig normality > 0.05). The data on the students’ prior knowledge is not homogeneous (sig homogeneity < 0.05). These data have not fulfilled the requirement to be analyzed using the independent sample t-test, but these data can be analyzed using the Mann-Whitney U-test.

Table 2. The result summary analysis using Mann-Whitney U-test

| Prior Knowledge |         |         |         |         |         |
|-----------------|---------|---------|---------|---------|---------|
| Mann-Whitney U  | 130.000 |         |         |         |         |
| Wilcoxon W      | 283.00  |         |         |         |         |
| Z                | -0.500  |         |         |         |         |
| Asymp. Sig. (2-tailed) | 0.617 |         |         |         |         |
| Exact Sig. [2*(1-tailed 1Sig.)] | 0.634 |         |         |         |         |

Table 2 shows the value of sig is 0.617 > 0.05, meaning that the prior knowledge of the students in the experimental-1 group is not remarkably different from the experimental-2 group so both groups had the similarity prior knowledge. The similarity prior knowledge does not influence toward the learning models in improving students’ critical thinking skills.

Table 3. The Distribution of students’ critical thinking skills

| No | The score of Critical Thinking Skills | Experimental-1 Group | Experimental-2 Group |
|----|--------------------------------------|-----------------------|----------------------|
| 1  | Sum of Samples (N)                   | 17                    | 17                   |
| 2  | Mean                                 | 56.7                  | 54.1                 |
| 3  | Standard Deviation                   | 11.9                  | 11.4                 |
| 4  | Minimum                              | 36.0                  | 36.0                 |
| 5  | Maximum                              | 76.0                  | 72.0                 |

Table 3 shows the mean (average) score of students’ critical thinking on the experimental-1 and experimental-2 groups is not so different. To test the significance of the difference of students' critical thinking between experimental-1 and experimental-2 groups, it was analyzed using independent sample t-test. Before doing the analysis, the normality data distribution and the homogeneity of variance data must be tested.

Table 4. The result summary of normality and homogeneity test

| Group          | Normality Statistic | Normality Sig | Homogeneity Levene Statistic | Homogeneity Sig |
|----------------|---------------------|---------------|-------------------------------|-----------------|
| 1. Experimental-1 Group | 0.183               | 0.135         | 0.136                         | 0.715           |
| 2. Experimental-2 Group  | 0.109               | 0.200         |                               |                 |

Table 4 shows the data of the students’ critical thinking skills (CTS) on the experimental-1 and experimental-2 groups are normally distributed (sig normality > 0.05) and homogeneous (sig normality > 0.05).
homogeneity > 0.05). These data have fulfilled the requirement to be analyzed using the independent sample t-test.

Table 5. The result summary of analysis using the independent sample t-test

| Description | Levene’s Test for Equality of Variances | t-test for Equality of Means | 95% Confidence Interval of the Difference |
|-------------|----------------------------------------|-----------------------------|------------------------------------------|
|             | F          | Sig. | t  | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| CTS         |            |      |    |    |                |                 |                         |       |       |
| Equal variances assumed | 0.136 | 0.715 | 0.646 | 32 | 0.523 | 2.58824 | 4.00519 | -5.57006 | 10.74653 |
| Equal variances not assumed | 0.646 | 31.936 | 0.523 | 2.58824 | 4.00519 | -5.57071 | 10.74718 |

Table 5 shows the value of sig is 0.523 > 0.05, meaning that the critical thinking skills of the students who learned through discovery learning based on constructing concept mapping is not significantly different from mind mapping.

However, if they analyze more detail in each indicator of critical thinking skills, there are differences in their indicators. The indicators of critical thinking skills are interpretation, analysis, evaluation, inference, and explanation. T

![Figure 1](image1.png)

Figure 1. The comparison of average score students’ critical thinking skills for each indicator on experimental-1 and experimental-2 groups

Figure 1 shows the skills in aspects of interpretation, analysis, evaluation, and explanation that students learned through discovery learning based on constructing concept mapping better than mind mapping. However, the skills in aspect of inference that students learned through discovery learning based on constructing mind mapping better than concept mapping.

In learning, the students in both groups learned using discovery learning model. Syntax of this learning model is (1) stimulation, (2) problem statement, (3) data collecting, (4) data processing, (5) verification, and (6) generalization [34]. In the experimental-1 group, the learning began with giving the students assignment to construct concept mapping, but in the experimental-2 group, the students constructed mind mapping. In constructing concept mapping, the students must find out the concepts of the subject and think of their arrangement. These activities train the students to: (1) interpret, analyze, evaluate, concept and non-concept when the read references; (2) do the inference of arrangement hierarchical concepts; and (3) explain conception every concept below the concept mapping. All of these activities constitute critical thinking skills. Many researchers found that constructing concept mapping
could increase students’ critical thinking skills [26-30]. Contrary, in constructing mind mapping by the students in the experimental-2 group, they arrange the concepts or themes freely according to their understanding. In constructing mind mapping, the students train to formulate, interpreting, analyzing concepts or themes and doing inference the relationship among concept or themes. Constructing mind mapping could improve critical thinking skills [31, 32]. The improving of students’ critical thinking skills are still low since the students ability in constructing concept mapping and mind mapping not optimal yet. The could not explain their concept mapping and mind mapping clearly.

4. Conclusion
It can be summarized that is not significant differences in students’ critical thinking skills that learning through discovery learning based on constructing concept mapping and mind mapping with the average score are 56.7 and 54.1 respectively. However, there are variations in students’ critical thinking skills in each indicator. Critical thinking skills in indicators of interpretation, analysis, evaluation, and explanation that students learned through discovery learning based on constructing concept mapping better than mind mapping. Critical thinking skills in indicator of inference that students learned through discovery learning based on constructing mind mapping better than concept mapping.

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