The effect of science writing heuristic approach with multiple representation in improving students’ critical thinking skills

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Abstract. This study aims at investigating the effect of the integration of multiple auditory representation into heuristic approach on students’ critical thinking skills. A quasi-experimental method with Pretest-Posttest Control Group design which involved in 24 participants in the experimental and control classes was applied to answer the research problem. An essay test was used to collect the data, while the paired sample T test was carried out to evaluate the impact of the implemented approach on students’ thinking skills. Significant improvement of critical thinking skills was observed for students who have applied a heuristic approach with multiple representative hearing than those students who have experienced a heuristic approach without multiple representations. The large category of effect size (1.1), suggesting that the learning process in the experimental group was more effective compared to those in the control class. The current results show that the fusion of multiple auditory representation into heuristic approach provide an alternative learning approach for enhancing students’ critical thinking skills.

1. Introduction

Critical thinking skills is one of important skills that require to be developed in order to prepare students to deal with the 21st century’ challenges. The importance of mastering these skills is also affirmed in Ministerial Regulation No. 20 of 2016 relating the competency standards for primary and secondary students. This regulation is highlighting having thinking and acting skills which is covering: (1) creative, (2) productive, (3) critical, (4) independent, (5) collaborative, and (6) communicative, through scientific approaches in the learning process, including science lesson. There is an emphasis that science learning aims to develop inquiry and requires students to communicate the results of their activities. Science learning not only contains elements of application, process, and scientific attitude, but also mastery of good content. In the science material itself there are many graphics, images, formulas and other representations that are not commonly used by students. Science process provides the development of student competencies from all aspects, such as high-level thinking competencies and communication [1].

The preliminary results carried out in one of the private schools in Bogor, were found that the learning process carried out in class is still teacher-centred. The students found not actively involved in learning.
The concepts students get are not their own findings, students can only absorb the knowledge conveyed by the teacher. This approach does not facilitate students to explore the discovery experience and less stimulates the students to have communication and critical thinking skills. Additionally, the lack of mastery of the learning methods possessed by the teacher, learning will become monotonous and do not present a representation of a concept. The current results of our interviews with 15 students, information was obtained that 73% of students had difficulty learning science concepts. As many as 80% of students say they have difficulty learning science material. When students were asked about multi representations, 53% answered that they did not understand when science was presented mathematically, diagrams, graphs / tables. Therefore, it can be inferred that students have difficulty in learning science and are not accustomed to learning science by being presented in several representations. From interviews with teachers, students are not accustomed to being trained in 21st century skills and learning does not use much representation [2]. Learning only focuses on completing the material without considering the importance of training skills. Then students' critical thinking and communication skills do not develop. This is evidenced from the observations of researchers by giving 14 questions of critical thinking skills in different forms of representation, there are still many students who have difficulty in completing it, marked by the acquisition of an average value of 15 samples, 27.25

The concepts in science contain many complex abstract concepts that require explanation in various forms of representation that can visualize the material in order to observe the phenomena and symptoms that occur, analyze and draw conclusions that are more comprehensive. Then multi-representation learning is needed to support learning in order to run effectively and efficiently. Multi-representation-based science learning is needed to visualize abstract material and clarify the interrelationships between concepts. Multi representation is believed to minimize the difficulty of students in learning science concepts [3, 4]. Multiple representations are a method used to explain a material or chemical concept by describing it in a macroscopic, sub microscopic and symbolic manner, for example through images, text, diagrams, equations. Multi representation defines as the way to present the same concept with variative formats, including verbally, graphs and numbers [5,3].

Students can pour the knowledge they have gained through writing made in the form of multi-representation as a form of communication activities with writing to learn activitie activities. This learning strategy consists of five components, namely; writing subject, type of writing, aims of writing, interlocutor of written text and method of text production [6]. Activity of writing to learn has the potential to influence students’ learning and thinking skills. Writing to learn activity allows in-depth concepts comprehension, helps metacognitive development, train the students to make causal relationships contained in subject matter and enable them to become successful writers in forming scientific texts [6-8]. Science Writing Heuristic (SWH) involved in the writing to learn step in its strategy. The SWH is a learning approach that combines inquiry processes involving writing strategies and interactive group work contained in exploration, elaboration and confirmation activities. Integrated science learning using the SWH approach has an effect on improving the students’ communication skills. Other research on the application of the SWH approach mentions an increase in understanding, participation, thinking ability, writing ability, and students' ability to discuss topics about science [9-13].

2. Methods
The research method that will be used is quasi experiment. This research method has the characteristic of examining the practical state of an object that does not allow researchers to control all relevant variables except the variables to be studied. The research design that will be used is Pretest-Posttest Control Group Design, meaning group taking without random placement procedures because the class has been formed beforehand, so it is not possible to randomly group students [14]. Learning is done using two groups, namely experimental and control group. In the experimental group, there were 9 male students and 15 female students, while the group control consisted in 8 male students and 16 female students. The experimental group is group of students who get learning using the SWH approach with multi representation while the control group is a group of students who use the SWH approach without
multiple representations. This study involved all class VIII students in one of the Private SMPs in Bogor. The number of class VIII in the school consists of six classes. The samples used in this study were class VIII students as much as one experimental class and one control class selected by purposive sampling, namely determining the sample of the population with certain considerations [15]. The study was conducted in three meetings. Each meeting is held for two hours of study.

The instrument used for data collection was a critical thinking skill test. The test was constructed in the form of essay test and was applied at the beginning and at the end of the study. The results obtained will be empirical data which then analyzed the validity, reliability, differentiation and level of difficulty of the instruments used in the study. Validity analysis showed that the instrument fulfilled the validity criteria of 0.91 categorized as very valid. Additionally, the instrument reliability is 0.95, indicating the instrument can give reliable data when used. At the level of difficulty, from 24 questions there are 2 questions with Difficult criteria and 22 questions with Medium criteria. Pretest and posttest data were also analyzed using n-gain to determine the improvement of critical thinking skills between the experimental class and the control class. More further, a statistical test was conducted to see students' critical thinking skills in the experimental group better or not significantly than students in the control group. All analyzes with the help of IBM SPSS Statistics 22 and Microsoft Office Excel.

Analysis of the effect size data is used to determine the extent of the influence of the science writing Heuristic approach with multi representation to improve students' critical thinking skills. According to Cohen the magnitude of the effect size is the average difference expressed in standard deviation units:

\[
d = \frac{\bar{X}_{GE} - \bar{X}_{GK}}{sd}
\]

Where, \( d \) is Effect Size, \( \bar{X}_{GE} \) is Experimental Class Gain Score Average, \( \bar{X}_{GK} \) is Control Class Gain Score Average, and \( sd \) is Average Standard Deviation of the Experimental Class and the Control Class [16].

| Table 1. Classification of Effect Size |
|---------------------------------------|
| Effect Size | Interpretation |
| 0.8 ≤ \( d \) ≤ 2 | High |
| 0.5 ≤ \( d \) < 0.8 | Middle |
| 0.2 ≤ \( d \) < 0.5 | Low |

3. Result and Discussion

3.1 Students' critical thinking skills

The improvement of students' critical thinking skills from the pre-test and post-test data can be seen in Table 2.

| Table 2. Pre-test, Post-test, and N-Gain Values |
|-----------------------------------------------|
| Experiment Class | Control Class |
| Pre-test | Post-test | N-Gain | Pre-test | Post-test | N-Gain |
| Amount of value | 283 | 1931 | 20,10 | 288 | 1724 | 17,61 |
| Average | 11.8 | 80,5 | 0.84 | 12.0 | 71.8 | 0.73 |
| Interpretation | High | High |
| Std. Deviation | 0,09061 | 0,09856 |
Data in the Table 2 showed there is an increased of students’ average score for critical thinking about 69.3 point from 11.8 point before the implementation of SWH with multiple representation and 80.5 point after the implementation. Normalized-gain (N-gain) analysis reached to 0.8, suggesting that there is an improvement of students' critical thinking skills after the treatment. Similar increased of students' critical thinking skills was also observed in the control group with the value of N-gain lower compared than those achieved by students in the experimental group. These current findings showed that the integration of multiple representation contributed on the better improvement on students’ thinking skills.

3.2. Students' critical thinking skills on each indicator

Table 3 showed the average score of students' critical thinking skills on each indicator.

Table 3. Pretest, Posttest and N-Gain Value for Each Indicator Students' critical thinking skills

| Indicator of critical thinking skills | Experiment Class | Control Class |
|--------------------------------------|------------------|---------------|
|                                      | pre test | post test | n-gain | Criteria | pre test | post test | n-gain | Criteria |
| Give a simple explanation            | 0.58     | 3.79     | 0.94    | High     | 0.57     | 3.30     | 0.80    | High     |
| Build basic skills                   | 0.48     | 3.19     | 0.77    | High     | 0.54     | 2.96     | 0.70    | High     |
| Inference                            | 0.44     | 3.23     | 0.78    | High     | 0.37     | 2.95     | 0.71    | High     |
| Give further explanation             | 0.29     | 3.21     | 0.79    | High     | 0.54     | 2.54     | 0.58    | Middle   |
| Set strategy and tactics             | 0.56     | 3.39     | 0.82    | High     | 0.57     | 2.82     | 0.66    | Middle   |

It is shown in Table 3 that the improvement of critical thinking skills of students in the experimental class for each indicator has increased with the High criteria. Meanwhile, in the control class the indicator provides further explanation, and regulates strategies and tactics experiencing a moderate increase. This shows that students in the Control class have difficulty in answering questions compared to the students in the experimental class. In the experimental class students are accustomed to using images, graphics, tables in their learning. Therefore, the students in the experimental class have a better understanding of the control class.

Indicators provide simple explanations, build basic skills, and inference get the greatest increase in both the experimental class and the control class, which is expressed by N-Gain of 0.94. This is because in the learning process students have facilitated activities or stages that lead to providing appropriate explanations and arguments as scientific evidence and are able to use interpretations in various modes as outlined in the SWH approach stage. One of the stages in the SWH approach that trains indicators to provide a simple explanation is at the Claim and Evidence stage, where students are trained to provide an explanation of the results of observation activities in the form of claims and must provide evidence. Here students will think of giving explanations related to the results of their observations and try to provide evidence.

From these results, the science heuristic writing (SWH) approach can improve students’ critical thinking skills when combined with many representations. In the experimental class there were 23 students who experienced an increase in the high category, while in the control class many students experienced an increase with a high category of only 17 students. Learning using the SWH approach with multiple representations makes students more active and easier to understand the subject matter.

3.3 Hypothesis Testing
Hypothesis testing is done to find out whether $H_0$ is accepted or rejected. However, the normality test is first carried out to test whether the data obtained is normally distributed or not. This will determine which statistical test will be used to test the hypothesis. The recapitulation of normality test can be seen in Table 4.

### Table 4. Test of Normality

| Class              | Kolmogorov-Smirnov<sup>a</sup> | Shapiro-Wilk |
|--------------------|-------------------------------|--------------|
|                    | Statistic | Df | Sig. | Statistic | df | Sig. |              |
| Experiment Pre-Test| .155      | 24 | .139 | .934      | 24 | .120 |              |
| Experiment Post-Test| .102      | 24 | .200* | .965      | 24 | .558 |              |
| Control Pre-Test   | .139      | 24 | .200* | .963      | 24 | .501 |              |
| Control Post-Test  | .136      | 24 | .200* | .965      | 24 | .536 |              |

Based on the statistics analysis, it is known that the significance value (sig.) for all data both in the Kolmogorov-Smirnov test and Shapiro-Wilk test is greater than the alpha value of 0.05. It can be inferred that the research data is normally distributed. The analysis then continued by carried out the parametric statistics by testing the independent sample t test. This test showed the differences in the average of two samples. From the results of data processing using IBM SPSS 24, the results of hypothesis testing are presented in Table 5.

### Table 5. Independent Samples Test

| Equal variances | t-test for Equality of Means |
|-----------------|-----------------------------|
|                 | F   | Sig. | T   | Df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Assumed         | .386 | .537 | 3.519 | 46 | .001          | 8.625          | 2.451             |
| not assumed     | 3.519 | 44.947 | .001 | 8.625 | 2.451 |              |                  |

Based on the data above, it is known that the significance value (sig.) of 0.001 is smaller than the alpha value of 0.05, indicating that there is a significant difference in the improvement of critical thinking skills between students who have applied the science writing heuristic approach and mutually auditory representation with students who have applied the science writing heuristic approach without multi representation of hearing. So that the hypothesis can be concluded $H_0$ rejected and $H_a$ accepted.

### 3.4 The effectiveness of learning

To find out the effectiveness of learning using the science writing heuristic approach with multi representation, an effect size (ES) calculation is performed. The calculation results can be seen in the Table 6.

### Table 6. Result of calculation of effect size

|                  | Group experiment | Group control |
|------------------|------------------|---------------|
| Mean N-Gain score| 0.8374           | 0.7338        |
| Std. Deviation   | 0.09061          | 0.09856       |
| Average Standard Deviation (SD) | 0.094585 |              |
| d cohen          | 1.1              |               |
| Criteria         | Large            |               |

When viewed from the magnitude of the effect size which is 1.1, the category of learning effectiveness is relatively large. Learning by using the science writing heuristic approach with multi representation has a major influence on students' critical thinking skills. This can be seen from the results of calculations using the Effect size formula. From the calculation obtained 1.1. Judging from the criteria, the number is relatively large ($0.8 \leq d \leq 2$). It can be occurred because the science writing
heuristic approach with multiple representation provides memorable learning to students by making them actively write and explore knowledge. Coupled with the multiple representations presented by the teacher make students better understand the material being studied. So, they have the provision to think critically. Learning with the SWH approach with multiple representation is more effective than without multiple representation because multiple representation students get many modes of learning in class. Material is presented in the form of many modes of representation. we know that students have their own way of capturing the concepts given by the teacher. There is an easy one when using picture mode, some feel learning younger if with graphical mode, and some require verbal mode. Therefore, learning with the SWH approach is more effective in improving critical thinking skills by using multiple representation.

4. Conclusion
The implementation of Science Writing Heuristic (SWH) approach with several representations has significantly improved students' critical thinking skills. This is indicated by the value of N-Gain in the experimental class which is greater, 0.84, than in the control class which has an average N-Gain of 0.73. From the results of the Independent Samples Test, the significance value is smaller than the a-value, which is 0.001 <0.05. Because the significance value is smaller than a value then Ha is accepted, suggesting the integration of multiple representation on the SWH approach has significantly increased students’ critical thinking skills in the experimental class than those students in the control group. The size effect of 1.1, reached to high category, is suggesting that the fusion of multiple representation promote more effective for the students.

5. References
[1] Sriyati S 2016 Pembelajaran IPA terpadu menggunakan pendekatan science writing heuristic untuk meningkatkan kemampuan komunikasi tulisan siswa SMP Edusains 8 1-9-17
[2] Insani and Metri D 2016 Studi Pendahuluan Identifikasi Kesulitan dalam Pembelajaran Pada Guru IPA SMP se-Kota Malang J. Pend. Biologi 7 81-93
[3] Amran A, Perkasa M, Satriawan M, JasIn I and Irwansyah M 2019 Journal of Physics: Conference Series IOP Publishing 1157 2 022025
[4] Rizal M 2014 Pengaruh Pembelajaran Inkuiri Terbimbing dengan Multi Representasi terhadap Keterampilan Proses Sains dan Penguasaan Konsep IPA Siswa SMP J. Pend. Sains 2 159-165
[5] Janssoon N, Coll R K and Somsook E 2009 Understanding Mental Models of Dilution in Thai Students Int. J. of Environmental & Sci. Edu 4 147-168
[6] Hand B and Prain V 2002 Teachers implementing writing-to-learn strategies in junior secondary science: A case study Sci. Edu 86 737-755
[7] Sampson V and Walker J P 2012 Argument-driven inquiry as a way to help undergraduate students write to learn by learning to write in chemistry Int. J. of Science Education 34 1443-1485
[8] Tolppanen S, Rantaniitty T, McDermott M, Aksela M and Hand B 2013 Effectiveness of a Lesson on Multimodal Writing in Science Education Lumat 1 503-522
[9] Cronje R 2011 Using the Science Writing Heuristic to Improve Undergraduate Writing in Biology Int. J. of science education 1745-1765
[10] Nam J, Choi A and Hand B 2011 Implementeation of the science writing heuristic (SWH) approach in 8th grade science classroom Int. journal of science and math. edu 9 1111-1133
[11] Burke K A and Greenbowe T J 2006 Implementing the science writing heuristic in the chemistry laboratory J. of Chem. Edu 7 1032-1038
[12] Erkol M, Kisoglu M and Buyukkasap E 2010 The effect implementation of science heuristic on student’s achievement and attitudes toward laboratory in introductory physics laboratory Procedia Social and Behavioral Science 2 2310-2314
[13] Gunel M, Hand B and McDermott M A 2009 Writing for different audiences: effects on high-school students’conceptual understanding of biology Learning and instruction 9 354-367
[14] Creswell J W 2010 Research Design Pendekatan Kualitatif, Kuantitatif, dan Mixed Edisi Ketiga (Yogyakarta: Pustaka Pelajar)
[15] Fraenkel J A, Wallen N T and Hyun H H 2011 How to Design and Evaluate Research in Education (New York: McGraw Hill)
[16] Aarts S, Akker M V, and Winkens, B 2013 The Importance of Effect Size European Journal of General Practice