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# Enhancing Students' Logical-Thinking Ability in Natural Science Learning with Generative Learning Model

✉**Henni Riyanti, Suciati, Puguh Karyanto**

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[1]Master Program of Science Education, Universitas Sebelas Maret, Indonesia
[2]Faculty of Teacher Training and Education, Universitas Sebelas Maret, Indonesia

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## Abstract

The logical-thinking ability is one of the important competencies of 21st century that should be empowered. It is one of the aspects in a cognitive science domain that has not been implemented effectively in teaching and learning. Then, this study aimed to analyzed the influence of generative learning model to enhance students' logical-thinking ability. This study was also conducted by using a quasi-experimental study with pretest-posttest non-equivalent control group design. The sample was chosen by using simple random sampling technique. This study involved two classes which had 67 participants consisting of 34 students in Class VIII.9 as an experimental group and 33 students in Class VIII.7 as a control group. The researcher used the instrument of logical-thinking ability formulated in the form of multiple choice tests with five alternative answers that had been tested for its validity and reliability. The analysis of data employed t-test using SPSS 21. The result indicated that the t-count > t-table (2.44 > 1.99) and p-value = 0.017 (p <0.05). It could be concluded that the application of generative learning model resulted in a significant influence on students' logical-thinking ability. The result of the analysis could be used by the schools for evaluating the quality of natural science learning to encourage students' logical-thinking ability.

## How to Cite

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✉ Correspondence Author:
Jl. Ir. Sutami No.36 A, Pucangsawit, Jebres, Surakarta, Jawa Tengah 57126
E-mail: henniriyanti@yahoo.co.id

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## INTRODUCTION

The development of science and technology in the 21st century requires individuals who are responsive to making decisions to solve problems encountered in the community (Voogt & Roblin, 2012). The ability to make decisions based on mindset and cognitive knowledge is an important skill in the logical-thinking ability (Pezzuti *et al.*, 2014; Seyhan 2015). Ministry of Education and Culture formulates a set of paradigm for 21st century learning whereby it orients to emphasize students' skills at exploring information, making hypotheses, thinking logically, and collaborating to solve problems (Ministry of Education and Culture, 2013). That makes one of the objectives of science learning is to empower students' logical-thinking abilities (Parmin *et al.*, 2017). The ability to think logically is needed by each individual in order to be able to solve a variety of complex problems (Sezen & Bülbül, 2011).

However, in fact, based on the data from Trends in the International Mathematics and Science Study (TIMSS), students' science achievements in Indonesia tend to decline. Indonesian students' science achievements are ranked 32 of 38 (1999), 36 of 46 (2003), 35 of 49 (2007), 40 of 45 (2011), and 44 of 47 (2015). The results of TIMSS 2011 and 2015 data analysis on cognitive domains (knowing, applying, and reasoning) indicate that the percentage of Indonesian students who answered correctly, especially in the aspect of reasoning ability which represents the part that has not been able to be optimally developed (Martin & Mullis, 2015).

In line with this, the Education Assessment Center conducted an analysis of TIMSS Indonesian students' answers. The results show that in the case of TIMSS which requires the ability to think logically namely the ability to evaluate, there are only 4% of Indonesian students who are able to answer the questions correctly (Puspendik, 2018). These results show that Indonesian students have not been able to solve high category problems that require logical-thinking ability.

Natural Science is a subject that studies about humans and their environment. There are many abstract physiological concepts in the natural science that require the ability of students to be able to think logically (Çimer, 2012). A way that can be done to empower logical-thinking is by using a learning model. The application of a learning model in the classroom is one way to provide the opportunities for students to develop their abilities and achieve the learning goals (Sufairoh, 2016; Sadi & Çakıroğlu, 2015).

One of the learning models that is able to facilitate students to develop their logical thinking ability is a generative learning model (Grabowski, 2007; Wittrock, 2016). Generative learning model in accordance with the criteria of logical-thinking activities consist of students' activities in facing problems, the activities that raise questions and doubts from students, the activities connecting facts and relevant information, the activities to draw conclusions based on generalization of data, and the evaluation towards students' logical reasoning (Pamungkas & Setiani, 2017).

Based on the description of the problem, research on generative learning model needs to be done to find out the influence of the model on enhancing students' logical-thinking ability. The direct implication of the ability to think logically is responsiveness in taking action. Students who have the ability to think logically will be able to solve the problems they encounter in the society.

## METHODS

This study was carried out at one of junior high schools in Indonesia in the even semester of 2017/2018 academic year. This study was a type of quantitative study employing a quasi-experimental method. The design used in this study was pretest-posttest non-equivalent control group design.

The population used in this study referred to the eighth-grade students of Junior High School consisting of 9 classes, namely grades VIII.1 to VIII.9. Sampling was done using simple random sampling technique. The sample of this study consisted of 67 eighth-grade students with a sample distribution of 34 students in class VIII.9 as an experimental group and 33 students in class VIII.7 as a control group. The experimental group would be given treatment using the generative learning model and the control group using the expository learning model.

The main data in this study were the data on students' logical-thinking abilities. Data collection was done by using a logical-thinking ability test. The test instrument was designed in the form of multiple choice test including 20 questions with 5 alternative answer choices. The logical-thinking ability test referred to the indicators as proposed by Stevens (2012), namely: 1) ordering; 2) comparing; 3) contrasting; 4) evaluating; and 5) selecting. The test was integrated into the material of the excretion system.

Before being used in this study, the instrument had firstly been tested to reach its validity and reliability. Data analysis technique used was descriptive quantitative. The data of students' logical-thinking ability in the experimental class and in the control class was interpreted into several categories (Oliva, 2003) namely: 1) 0 – 3 (Low); 2) 4 – 7 (Moderate); and 3) 8 – 10 (High). The effectiveness of generative learning model to enhance students' logical-thinking ability was seen from the gain score according to Hake (2007).

The pre requisite test was firstly done before conducting the hypotheses testing. It was a normality test using the Kolmogorov-Smirnov and homogeneity test using the Levene. Hypothesis testing used in the study was the independent t-test on the gain data between the experimental class and the control class.

## RESULTS AND DISCUSSION

### The Students' Logical-thinking Ability

The data obtained in this study are the data of students' logical-thinking ability (LTA). The description of students' logical-thinking conducted in this study is presented in Table 1 and Figure 1.

**Table 1**. The Data of Students' Logical-Thinking Ability

| | Experimental | | Control | |
|---|---|---|---|---|
| | High | Moderate | High | Moderate |
| Number of students | 25 | 9 | 15 | 18 |
| Standard deviation | 5.75 | 3.63 | 4.58 | 4.04 |
| Mean | 76.80 | 62.22 | 74.33 | 61.11 |
| Minimum | 70 | 55 | 70 | 50 |
| Maximum | 85 | 65 | 85 | 65 |
| Average Gain | 0.48 | | 0.37 | |

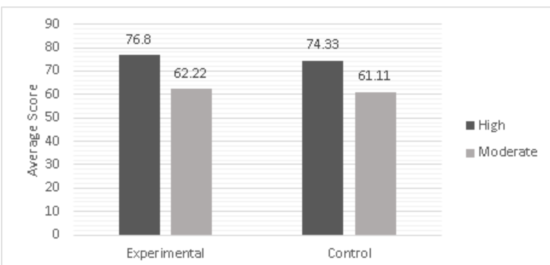


**Figure 1.** The Histogram of Students' Logical-thinking Ability

Table 1 shows the results of students' level of logical-thinking ability after the treatment in the natural science learning of both experimental and control class. The number of students who have high-level of logical-thinking ability in the experimental class was 25 students while the control class was 15 students. Then, there were 18 students in control class who have moderate-level of logical-thinking ability and the experimental class was 9 students. It could be concluded that most of the students in the experimental class obtained the high-level of logical-thinking ability, while the students in control class obtained the moderate-level.

Based on Figure 1, the average score of students who have high and low level of logical-thinking ability in the experimental class was higher than the average score in control class (76.8 > 74.33 and 62.22 > 61.11). Students in the experimental class that use generative model obtain higher logical-thinking because in the learning process they are trained to be able to optimize their reasoning (Lee *et al.*, 2007).

Natural science learning begins by exposing students to an event of human that sweat, and this is categorized at Selecting and Attention syntax (Anderman, 2010). This event is closely related to students' real experiences. Giving this kind of phenomena is carried out with the aim to train students to explore their cognitive abilities, and generate motivation and confidence to bring up their ideas (Ridlo & Alimah, 2013).

Students in the experimental class were then trained to be able to conduct the practicum so that they were able to answer the problems given. The activity was carried out on the syntax of generating links and constructing meaning. This process aimed to train students to find the core and facts of the experiments carried out so that they were able to answer the hypothesis they put forward. Generative learning model is one of the model that focuses on the active role of students during the learning process so that it can create a student-centered learning environment (Zulkarnain & Rahmawati, 2014). However, in the control class, the involvement of students was not too active compared to the experimental class. In the learning proses of the control group, it tended to occur in one direction (teacher centered). Students were seen to rely on each other to answer the problems given.

### The Prerequisite Test of Students' Logical-thinking Ability

The prerequisite test was conducted on the results of the pretest and posttest of the experimental class and control class. The normality test used in this study is the Lilliefors test using

**Table 2**. The Result of Normality and Homogeneity Test

| Class | | Normality | | | Homogeneity | | | |
|---|---|---|---|---|---|---|---|---|
| | | Statistic | df | Sig. | Levene Statistic | df1 | df2 | Sig. |
| Pretest | Experimental | .109 | 34 | .200 | .808 | 1 | 65 | .372 |
| | Control | .808 | 33 | .147 | | | | |
| Posttest | Experimental | .127 | 34 | .183 | .092 | 1 | 65 | .762 |
| | Control | .151 | 33 | .054 | | | | |

Kolmogorov-Smirnov and the homogeneity test is the Levene test. The normality test used to find out whether the data obtained were normally distributed or not, while the homogeneity test used to find out whether the data obtained were derived from a homogeneous population or not. The result of the normality and homogeneity test is presented in Table 2.

Based on Table 2, the result of normality test with Kolmogorov-Smirnov obtained the significance value of pretest in the experimental class was 0.200 and the posttest was 0.147, while the significance value of pretest score of control class was 0.184 and the posttest was 0.054. All of the significance value obtained in the normality test was higher than 0.05. Thus, it can be concluded that the data is normally distributed.

Table 2 also showed the result of the homogeneity test with Levene on pretest and posttest data. The significance value obtained in the homogeneity test is 0.372 and 0.762. The significance value obtained in this analysis was higher than 0.05. Hence, it can be concluded that the result of pretest and posttest in both experimental and control class is homogeneous.

**The Hypothesis Test of Student's Logical-thinking Ability**

In this study, hypothesis testing was done by employing t-test. The t-test was carried out on the gain data obtained between the two study groups. In this study, the t-test was calculated using SPSS 21 software. The degree of freedom df = $(n_1 + n_2) - 2 = 65$ at a significance level of 5% was obtained whereby t-table = 1.99. $H_0$ was rejected and $H_1$ was accepted if the value of t counts $\geq$ t table and significance value < 0.05. The result of t-test is presented in Table 3.

Based on Table 3, the result of the hypothesis test calculation obtained by t count is 2.44 and the significance value is of 0.017. Thus, the result of the t-test shows that t count > t table (2.44 > 1.99) and the significance value reaches 0.017 (<0.05). Hence, it is concluded that $H_0$ is rejected and $H_1$ is accepted. There is a significant difference between students' ability to think logically in the experimental class and in the control class. In other words, there is an effect of generative learning model application on students' logical-thinking ability.

**Table 3**. The Result of t-Test

| | T-test for Equality of Means | | |
|---|---|---|---|
| | t | df | Sig. (2-tailed) |
| Equal variances assumed | 2.44 | 65 | .017 |
| Equal variances not assumed | 2.46 | 55.8 | .017 |

Regarding these results, a study shows that the use of generative learning strategy is a promising approach to improve students' metacognitive calibration skills (Pilegard & Fiorella, 2016). This ability will direct students to improve their ability to think logically (Pezzuti *et al.*, 2014). As known, metacognitive is the ability of students to control their cognitive domain. Generative learning model encourages students to make an understanding of the material using their own language and then relate it to the knowledge they have (Fiorella *et al.*, 2015). This is able to facilitate students to develop their logical-thinking abilities (Pezzuti *et al.*, 2014).

The suitability of the generative learning model syntax to facilitate the development of students' logical-thinking abilities is explained in Table 4.

Based on Table 4, the syntax of generative learning model is convenient in order to develop students' logical-thinking ability. The activities of students design and carry out experiments will develop their ordering ability, while the activities of students observe and compare image, make a question, and processing information and data will develop their comparing ability. Then, the activities of students make a hypothesis, design experiments, processing information and data will develop their contrasting ability. The activities of students make a reason that occur in a phenome-

**Table 4**. The Suitability of the Generative Model to Facilitate the Development of Students' Logical-Thinking Abilities

| Syntax of Generative Learning Model | Indicators of Logical-Thinking Ability (LTA) | | | | | Students' Activities |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Selecting | | √ | | | | Observe and compare images |
| Attention | | √ | | | | Make a question |
| Sensory Input | | | √ | | | Make a hypothesis |
| Generating Links | √ | | √ | | | Design and carry out experiments |
| Constructing meanings | | √ | √ | | | Processing information and data obtained |
| Evaluating of constructions | | | | √ | | Reasoning relationships that occur in a phenomenon |
| Subsumption | | | | | √ | Make conclusions |
| Motivation | | | | | √ | Reflect on the benefits of learning |

* √ : the indicator of logical-thinking ability is developed * Indicators of LTA: 1 (ordering), 2 (comparing), 3 (contrasting), 4 (evaluating), 5 (selecting)

**Table 5**. Achievement of Students' Logical Thinking Ability Indicators

| Indicators of Logical-Thinking | Pretest | | | | Posttest | | | |
|---|---|---|---|---|---|---|---|---|
| | Exp. | Category | Cont. | Category | Exp. | Category | Cont. | Category |
| Ordering | 57.35 | Moderate | 53.03 | Moderate | 83.82 | High | 79.54 | High |
| Comparing | 34.80 | Low | 35.86 | Low | 65.69 | Moderate | 65.12 | Moderate |
| Contrasting | 61.76 | Moderate | 60.60 | Moderate | 79.41 | High | 64.39 | Moderate |
| Evaluating | 44.12 | Moderate | 57.58 | Moderate | 60.29 | Moderate | 57.58 | Moderate |
| Selecting | 46.32 | Moderate | 42.42 | Moderate | 72.79 | Moderate | 65.15 | Moderate |
| Average | 48.87 | Moderate | 49.90 | Moderate | 72.40 | Moderate | 66.36 | Moderate |

non will develop their evaluating ability, while the activities of students make a conclusions and reflect the benefits of learning will develop their selecting ability.

Students will be trained repeatedly to be able to draw the right conclusion in natural science learning with generative model, so that they can improve their ability to think logically. Dunlosky *et al.*, (2013) and Papadopoulos *et al.*, (2017) states that that kind of learning process will encourage student participation in the process of making summaries, providing logical explanations, and proving based on the data obtained. The achievement of students' logical thinking abilities in each indicators is presented in Table 5.

Based on Table 5, the results of the students' pretest showed that the achievement of each indicator of the ability to think logically is relatively moderate to low. The comparing-indicators in the ability to think logically included in the low category in the experimental class and in the control class require special attention. Learning science is then done with the aim to encourage students to improve their logical thinking abilities, especially the ability to compare the characteristics of a variable using a sufficient understanding of the material of the excretory system. These objectives are able to be actualized through the application of Generative Learning Model (Wittrock, 2016).

Based on the results of the posttest, it is known that there is an increase in the average value of the ability to think logically in the experimental class and in the control class. The results of the students' posttest showed that the achievement of each indicator of the ability to think logically is relatively moderate to high. The achievement of each indicator in the ability to think logically tends to be high and increase in the comparing-indicator.

These results indicate that the generative learning model is more suitable to be applied in natural learning process to improve students' logical-thinking abilities compared to the conventional learning model. The schools and teachers can use the generative learning model in order to encourage students' logical-thinking abilities.

## CONCLUSION

Based on the analysis and description of the study results, it can be concluded that the ability to think logically between the students in the experimental class applying generative learning model and the students in the control class is significantly different. The average of students' logical-thinking abilities applying the generative learning model is higher than that of the control class. The results of the analysis can be used by the schools and teachers for evaluating the quality of natural science learning in order to encourage students' logical-thinking abilities.

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