The Effectiveness of Inquiry Learning with Brainstorming on Students’ Creative Thinking Skills in Mastering Scientific Method

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*Abstract*— This research aims to observe the effectiveness of the guided inquiry learning model combined with brainstorming to increase divergent and creative thinking ability of students at class XI Natural Science in mastering the scientific method in Biology. This is a quasi-experimental research with non-equivalent pretest posttest control group design. The population used in this research consisted of (1) research population i.e. all students of class XI Natural Science in State High School Banguntapan 2 and (2) target population, i.e. all senior high school students of class XI IPA SMA in other places and in different times with some similar characteristics to research population used for generalization. 2 classes were taken as the sample by cluster sampling technique from the classes randomly formed without any particular consideration. Both the experimental class and the control class consisted of 32 students. The data collection of divergent thinking ability and the creative thinking ability in mastering the scientific method was carried out using the description tests. Data were analyzed using the independent sample t-test. The results of this research indicated that the guided inquiry learning model combined with brainstorming was effective to increase (1) divergent thinking ability and (2) creative thinking ability of Senior High School students at Class XI Natural Science in mastering the scientific method in Biology. It was proven through the results of independent sample t-test with a significance level (p-value) of 0,000 for the two dependent variables.

Keywords—biology, brainstorming, creativity, inquiry, scientific methods

# Introduction

Towards the beginning of the third decade of the 21st century, there are many unresolved global-scale problems. These problems include the 22 global issues released by the United Nations in 2019, which range from shrinking non-renewable natural resources, climate change, incurable diseases, food scarcity, and environmental pollution, all of which are still waiting to be resolved [1]. Hence, scientists have a pivotal role both in creating inventions to overcome these problems and in developing science and technology to facilitate and ease human life in the future. On the other hand, the rapid growth of globalization requires every country in the world to produce skillful and professional human resources to compete at the international level. Moreover, the industrial revolution 4.0, which allows the replacement of human labor with engine power, leads to an prediction that in 2030, 75 million to 375 million workers (3%-14% of the global workforce) will lose their jobs and have to look for new businesses for a livelihood [2]. The abovementioned problems challenge the global community in general and the millennial generation in Indonesia in particular to take an immediate measurement for the national development.

The aforementioned modern challenges come up with two urges: (1) the need for future generations with skillful viability and competency in their prospective fields to make them irreplaceable by machines or artificial intelligence, by mainly concerning on creativity and innovation [3], and (2) the needs to produce prospective experts, scientists, or researchers who will play a role in research and discovery to solve existing problems or develop products that can improve the welfare of human life. On this basis, it is noteworthy that education is one of the important keys to answer these challenges, since it is one of the factors that determines the quality of human resources.

In terms of Biology education, it is possible to develop those two demands consecutively by way of honing students’ creative thinking skills through research activities integrated in the learning process. Such research may take the form of observation or experimentation, which is adjusted to students’ development level. This integrated research and learning process aims to obtain facts and concepts in Biology. This is deemed as an ideal learning method in Biology considering that Biology is not only treated as a mere product (facts, concepts, theories, laws), but also as a process of discovery (science as inquiry), which is based on scientific methods. The implementation of scientific method is inseparable from creative thinking skills. Creative thinking skill is an important aspect to foster sensitivity to existing problems, encourage the formulation of new ideas, build a new model, look for the right answer or solution of a problem, and find the failure factors in a study [4]. This is reinforced by the demands on the latest curriculum applied in Indonesia (The 2013 curriculum) that focuses on developing students’ creative thinking skills and their mastery of methods in accordance with scientific principles (scientific method).

However, many surveys reveal that the currently applied curriculum cannot generate the ideal conditions as required above. International surveys such as PISA - which measures procedural knowledge as a basis for scientific investigation, shows an average score of Indonesians students in the field of science that is of 403, which is still below the average of 493, the same as other 39 countries. In addition, TIMSS ― which measures the ability of students in conducting scientific research, indicates the score acquisition of Indonesian students’ for scientific skills with 397, which is still below the TIMSS scale center point of 500. Surveys at the local level also corroborated findings regarding the lack of student creativity in mastering scientific methods.

Some key factors to trigger the low level of student achievement is the ineffective learning process in the classroom [5]. Given the abovementioned problems, the researcher seeks to find solutions by trying out learning designs that may increase students’ creative thinking skills in mastering scientific methods. In this context, creative thinking is defined in two forms of abilities. The first one is the ability to practice divergent thinking as an indicator of creative potential [6-7]. The second one is a cognitive ability to create that is in line with the taxonomy of Bloom as revised by Anderson & Krathwohl (2001). On this basis, this research aims to test a learning design that is combined from guided inquiry learning models and brainstorming techniques. The syntax of the guided inquiry learning model is identical to the steps in the scientific method, while the brainstorming technique encourages students’ creative ideas. The combination of guided inquiry learning models with brainstorming is expected to improve students’ creative thinking skills in mastering scientific methods. The design is compared with the discovery learning model commonly used by teachers at schools based on the results of initial observations. This learning design particularly addressed the Biological material of the digestive system. This material is selected because it is closely related to daily life so that it is expected that students will have more opportunities to come up with research ideas from the material.

# METHODS

## Research Design

This is a quasi-experimental research with a non-equivalent pretest posttest control group design. Quasi-experiments were chosen because it was not possible for the researchers to form an artificial control group and experimental group. In addition, not all confounding variables could be fully controlled. This research was conducted at SMA Negeri 2 Banguntapan from January to February 2019. This high school was selected based on the results of preliminary research in Bantul Regency revealing that the school had the lowest score of creative thinking skills in the mastery of scientific method.

The population used in this study consisted of: (1) all students of XI grades of Science of SMA Negeri 2 Banguntapan as the research population, and (2) all students of class XI grades of Science of SMA (high schools) in other places and at different times but with different characteristics similar to the research population for generalization as the target population [8] The sample was taken from XI 3 grades of science and XI 4 grades of science, each consisting of 32 students. The sampling was done by cluster sampling technique*.*

## Data Collection and Analysis

Data were collected through the test techniques to measure divergent thinking skills and the students’ creative thinking skills in the mastery of the scientific method. Tests were given to students twice, in the form of pretest and post-test. Divergent tests were arranged in the form of non-objective description to allow various alternatives of right answers. In total, the test items amounted to 10 items. Each item presented a case and asked the students to provide two correct alternative answers. For example, the question presented a case about a student who will conduct a research on the relationship between people's lifestyle and the digestive system diseases. The test takers were asked to mention two independent variables that they could examine. Each item was scored by the politomous scaling. Three categories were made since each item asked for 2 correct answers, namely category-1 with a score of 0 if all answers were wrong, category-2 with a score of 1 if only one answer was correct, and category-3 with a score of 2 if all answers were correct. Thus, the ideal maximum score (the highest score) for divergent thinking is 20. Meanwhile, creative thinking tests were prepared by following creative indicators according to Anderson & Krathwohl (2001). The test items were in the form of descriptions, amounting to 5 items in total. Each item presented a problem regarding the human digestive system that has never been taught before at school and is not found in any textbooks. Then, students were asked to formulate hypotheses and design research procedures in accordance with the given problem to obtain new facts or concepts as a product [9]. The maximum score for creative thinking skill is 70.

 The test instrument used in this study was considered valid by experts (expert judgment) of 2 philosophical doctors (Ph.D) in the field of Biology education and 1 doctor (Ph.D) in the field of Biology. It also has passed the empirical validity test through the calculation of the sensitivity index (S). The sensitivity index value (S) is calculated per item using the following formula (1):

(1)

where *ΣSA* is the total score of all students for one item after learning, *ΣSB* is the total score of all students for one item after learning, *Maxscore* is the maximum score for that item, *Minscore* is the minimum score for that item, and N is the number of students working on that item at the pretest and post-test [10]. Empirical validity calculation results show that all divergent and creative test items have a sensitivity index value of (S)> 0.3 or are considered valid for use [11-12]. Details of the S value for each item and its interpretation can be seen in table I.

The instrument has also passed the reliability test using the calculation of the Kappa coefficient (K) and the coefficient of agreement (Po) [13]. The Kappa coefficient was calculated by the estimated method by first calculating the *z-score* (*|z|*) using the following formula (2):

(2)

where c is the cut-off score of the test, *M* is the average score of the test takers, and *S* is the standard deviation. Afterwards, the reliability coefficient (*r*) was calculated by the following formula (3):

(3)

where *k* is the number of items, *ΣSI2* is the total number of item score variants, and *ST2* is the total variant. Given the value of |z| and r, the magnitude of the Kappa coefficient (K) and the approval coefficient (Po) can be calculated from the estimated table created by Subkoviak (1985). The results is shown in table II. A test is classified as reliable if the value of the agreement coefficient (Po) ≥ 0.86 and the value of the coefficient Kappa is (K) ≥ 0.60.

1. Empirical Validity Calculation of The Research Instruments

| Item Number | Divergent Thinking Test | Creative Thinking Test |
| --- | --- | --- |
| Sensitivity Index Valuea | Sensitivity Level | Sensitivity Index Valuea | Sensitivity Level |
| 12345678910 | 0.70.60.80.60.60.90.70.50.70.5 | HighModerateHighModerateHighVery HighHighModerateHighModerate | 0.70.80.80.80.8 | HighHighHighHighHigh |

1. The test item is declared valid if the sensitivity index value is ≥ 0.3
2. Empirical Reliability Calculation of The Research Instruments

| **Types of Instrument** | |z| | r | Po | K |
| --- | --- | --- | --- | --- |
| Divergent TestCreative Test | 0.820.89 | 1.111.25 | 0.900.90 | 0.690.68 |

Data were analyzed using descriptive and inferential statistics. Inferential analysis mainly uses independent sample t-tests of both pretest and post-test. The aim of the pretest is to find out the differences in the initial abilities of students, whereas the post-test aims to see the effectiveness of the model being tested.

# Results

The research reveals the following results:

## Divergent Thinking Ability in Mastering Scientific Methods in Biology

First, the pretest score of students’ divergent thinking skills in both the control class and the experimental class is shown in table III.

1. Descriptive Analysis Results of Divergent Thinking Skill Pretest

| Measured Aspects | Divergent Thinking Skill Pretest |
| --- | --- |
| Control Class | Experiment Class |
| MeanMaximum ScoreMinimum ScoreStandard Deviation | 3.136.000.001.86 | 3.287.000.001.76 |

From table III it is known that the difference between the means score of divergent pretest between the control class and the experimental class is 0.15. In other words, there is no significant difference between the mean of the two classes. The conclusion is confirmed using an independent sample t-test. Previously, a prerequisite test for parametric analysis was conducted. The following result shown in table IV.

1. Indpendent Sample t-Test Calculations for Divergent Pretest and Its Prerequisites

| **Test Types** | Analysis Options | Sig. |
| --- | --- | --- |
| Normality TestHomogeneity of Variance TestDifference of 2 Mean Test | Kolmogorov-SmirnovLevene’s testIndependent sample t-test | 0.2000.6510.732 |

Table IV above indicates that the divergent pretest data are normally distributed and have a homogeneous variant so that they meet parametric requirements. Meanwhile, the results of the independent t-test showed the value of Sig.> Α (0.050), which is equal to 0.732. This means that there is no statistically significant difference in divergent thinking skills between the experimental class and the control class. On this basis, the confounding variable in the form of different initial abilities that can affect student performance when treated has been eliminated.

Second, the post-test result of students’ divergent thinking skills in both the control class and the experimental class is presented in table V. Post-test was done after the two classes learned with the model tested. In the experimental class, the material about the digestive system was delivered with guided inquiry learning model combined with brainstorming, while the control class was provided with digestive system learning material using discovery learning models*.*

1. Descriptive Analysis Results of Divergent Thinking Skill Posttest

| Measured Aspects | Divergent Thinking Skill Posttest |
| --- | --- |
| Control Class | Experiment Class |
| MeanMaximum ScoreMinimum ScoreStandard Deviation | 5.8410.002.002.19 | 16.0918.0013.001.44 |

The divergent posttest data were tested further with an independent sample t-test using the SPSS 16.0 application. When making the Group Variable, the control class was classified as group 1 and the experimental class was treated as group 2. The test results are presented in table VI.

1. The Independent Sample t-Test for Divergent Thinkins Skill Posttest

| **Test** | t | df | Sig. (2-tailed) | Mean Difference |
| --- | --- | --- | --- | --- |
| Divergent | -22.123 | 62 | 0.000 | -10.25000 |

Table VI above indicates that the dependent t-test for the divergent posttest resulted in Sig. (2-tailed) of 0,000 <α (0.050). This means that there is a statistically significant difference in the average ability of divergent thinking between the control group and the treatment group. The average difference is shown by the mean different value of -10.25000. The negative mean difference pinpoints that the experimental class (group 2) has a greater average final ability than group 1 (control class). In other words, the guided inquiry learning model combined with the brainstorming given to the experimental class is more effective in increasing students’ divergent thinking skills in mastering the scientific method.

## Creative Thinkins Skill in Mastering Scientific Methods in Biology

*First*, the pretest result of students’ creative thinking skills in both the control class and the experimental class is presented in table VII.

1. Descriptive Analysis Results of Creative Thinking Skill Pretest

| Measured Aspects | Creative Thinking Skill Pretest |
| --- | --- |
| Control Class | Experiment Class |
| MeanMaximum ScoreMinimum ScoreStandard Deviation | 3.348.000.002.2 | 4.289.000.002.39 |

Table VII highlights that the mean difference of the creative thinking skill pretest scores between the control class and the experimental class is 0.94. In other words, there is no significant difference between the mean of the two classes. The conclusion is in line with the previous analysis that is confirmed using an independent sample t-test. The results are shown in table VIII.

1. Independent Sample t-Test Calculations for Creative Thinking Skill Pretest and Its Prerequities

| **Test Types** | Analisis Options | Sig. |
| --- | --- | --- |
| Normality TestHomogeneity of Variances Test Difference of 2 Mean Test | Kolmogorov-SmirnovLevene’s testIndependent sample t-test | 0.1210.7880.109 |

Table VIII above indicates that the creative thinking pretest data are normally distributed and have homogeneous variants that meet parametric requirements. Meanwhile, the independent t-test resulted in the value of Sig.> Α (0.050), which is equal to 0.732. In other words, there is no statistically significant difference in students’ creative thinking skills between the experimental class and the control class.

Second, the posttest result of students’ creative thinking skills in both the control class and the experimental class is set out in table IX.

1. Descriptive Analyis of Creative Thinking Skill Posttest

| Measured Aspects | Creative Thinking Skill Posttest |
| --- | --- |
| Control Class | Experiment Class |
| MeanMaximum ScoreMinimum ScoreStandard Deviation | 37.4448.0017.007.13 | 58.4468.0038.007.04 |

The creative thinking skill post-test data were further tested with an independent sample t-test using the SPSS 16.0 application. Based on Grouping Variables, the control class was made as group 1 and the experimental class was made as group 2. The results are presented in table X.

1. The Independent Sample t-Test for Creative Thinking Skill Posttest

| **Test** | t | df | Sig. (2-tailed) | Mean Difference |
| --- | --- | --- | --- | --- |
| Creative | -11.853 | 62 | 0.000 | -21.00000 |

The independent t-test for creative thinking skill post tests resulted in Sig. (2-tailed) of 0.000 <α (0.050). In other words, there is a statistically significant difference in the average creative thinking skills between the control group and the experimental group. The average difference is shown by the mean different value of -21.00000. As explained earlier, the negative mean different values indicate that the experimental learning model given to the experimental class is more effective in improving students’ creative thinking skills in the mastery of the scientific method than that provided to the control group.

# Discussion

Based on the theoretical review, there is significant differences in the divergent thinking skill in the mastery of the scientific method between the experimental group and the control group. This is so because students of the experimental class are better trained to express ideas related to scientific research openly, either through brainstorming activities at the beginning of the learning process to formulate problems or through discussion and group work to design, conduct research, and communicate results. Divergent thinking skill will grow through social and associational processes that are present in a group discussion. Each individual is encouraged to share any ideas popping up in mind to find possible solutions to the problems discussed [14]. Next, convergent thinking skill will be used to take the most appropriate measurement as a decision that is accounted for by the group.

Meanwhile, the discovery learning model in the control class is not accompanied by stimulation using brainstorming. As a result, only a few students asked questions at the beginning of the learning process. Practical activities in the control class also contrast with inquiry activities in the experimental class. In practicum, divergent thinking skill is not well developed because the procedure of activities has been presented on a ready-to-use worksheet. Students are not facilitated to involve in discussions when designing and conducting a new research, even in a simple level. This results in the lack mastery of the steps in designing scientific research.

The significant difference of students’ creative thinking skill between the experimental class and the control class in the mastery of the scientific method is because the guided inquiry learning model trains students to find facts or concepts by collecting data through a study they designed. Students were asked to work in group to discuss and collaborate to design work steps, tools and materials, determine the sample of respondents, collect data, analyze data, then disseminate their research. In the presentation session, students in one group learn from what is conveyed by the other groups. The group conducting observational research will learn about the procedures and concepts obtained by other groups conducting experimental research, and vice versa. As a result, when the posttest asked the students to design an inquiry that they have done, they can make an analogy to the design of an inquiry they have done while learning in class.

This result is in contrast to learning process in the control class where students are not well trained to design and conduct research to build knowledge. Instead, students are directed to find concepts through practical activities where tools, materials, and procedures are available. In this line, their practicum tend to direct them more on the attempt to prove something than making a discovery.

# Conclusions and Recommendations

Based on the research, it is conclusive that the guided inquiry learning model combined with brainstorming is proven to be efficient in improving the divergent and creative thinking skills of class XI high school students in mastering scientific methods. The combination of guided inquiry learning models with brainstorming is more effective than discovery learning models commonly used by teachers in various regions in Indonesia.

Based on the given conclusions, it is possible to make the following recommendations. First, the guided inquiry learning model combined with brainstorming can be used as an alternative learning opportunity to improve divergent and creative thinking skills in the mastery of scientific methods. Second, the results of this study can be used as a reference for research that emphasizes on other biological concepts related to everyday problems such as: excretion system, respiratory system, circulatory system, and motion system, by reviewing other variables.

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