Divergent and Creative Thinking Skills of XI Graders of Senior High School in Bantul District in Mastering Scientific Methods in Biology

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Abstract. This study aimed to determine the level of divergent and creative thinking skills of XI graders in mastering scientific methods in biology and their differences based on gender and levels of most desirable school. This research was a descriptive study using the survey method conducted between March and April 2018. The population in this study were all students of grade XI of senior high schools in Bantul District. Sampling was carried out through stratified sampling to obtain 259 respondents from 3 senior high schools in Bantul District. The independent variable in this study was the levels of most desirable school and gender, while the dependent variable involved students’ divergent and creative thinking skills in mastering scientific methods. Data was collected using questionnaire and test. The results showed that; (1) the average score of divergent thinking skills was classified as medium (17.00), while the average score of creative thinking skills was low (41.07), (2) the results of one-way ANOVA indicated that there was no significant difference in the mean scores of divergent and creative thinking skills based on the levels of most desirable school, (3) female students have better divergent and creative thinking skills in mastering scientific methods than male students.

Keywords: Biology, creative thinking, divergent thinking, scientific method

1. Introduction

Towards the beginning of the second decade of the 21st century, there have been radical changes in many aspects of human life by the incessant rapid growth of technology that will continue to grow in the future. Scientists are increasingly required to discover and invent a solution to global problems such as environmental damage, global warming, declining non-renewable resources, and uncured diseases. They are also demanded to create an innovation to further facilitate human life. On one hand, the inundating wave of globalization has been eroding inter-national barriers. The ASEAN Economic Community (AEC) is an example of the ever widening flow of trade in goods and services and the professional labor market, such as doctors, lawyers, accountants, teachers and so on in the region of Asia. This is a wake-up call for worldwide countries- especially the developing countries - to enhance quality human resources capable of competing globally. One factor that determines the quality of
human resources is how a country manages its education system. Therefore, P21 (Partnership for 21st Century Skills) develops a learning framework to be applied by all stakeholders in the field of education throughout the world. This aims to produce an output with a set of knowledge and skills required to face global challenges. One of the key competencies in 21st century skills is creativity and the ability to innovate. Creative individuals will be able to solve problems in new ways, create new technologies or upgrade existing technologies, or even discover new branches of knowledge [1].

In terms of Biology education, it is necessary to follow up the abovementioned challenges by way of designing a learning process to generate creative scientists. This is commonly applied by developing students’ creative thinking skills and their ability to master the scientific method. This is so because Biological science is not only limited to familiar and memorable concepts, but also to a process of identification and problem solving (science as inquiry) that involves significant creative and critical thinking [2]. The ability to think creatively is highly needed in the scientific procedures performed by scientists such as: developing sensitivity to existing problems, encouraging the formulation of new ideas, building a new model, finding answers or the right solution of a problem, and finding the factor of failure in an investigation [3].

On this basis, it is important to study how students develop creative thinking skills in Indonesia to master the scientific method. This is attributed to the fact that one of the 2013 Curriculum demand - the latest curriculum - is using methods in accordance with scientific principles, commonly referred to as the scientific method. In this light, creativity development is one of the goals of national education. Thus, a study of the profile of students’ creative thinking skills and mastery of scientific methods will be useful in the context of assessment for learning.

As an organized system to systematically study certain aspects of nature, science has scientific method as its essence [4]. In a broad sense, the scientific method refers to the steps of scientists’ regular work guided by curiosity to learn the order and relationships between the phenomena they investigate. In a more formal sense, the scientific method refers to the steps of systematic research as the development of the method formulated by Francis Bacon (1561–1626) [5-6]. The steps of the scientific method starts from formulating the problem, designing research, formulating hypotheses, collecting data through experiments or observations to testing hypotheses, analyzing results, making conclusions, to reporting the research finding [7].

Creative thinking is defined as the ability to formulate an idea or product that is new, amazing, and valuable in many ways [8]. The idea can also be derived from combining old ideas with new ways. A simple way to do this is to add, replace, or reduce the old product to generate something new [9]. Creative thinking skill is a prerequisite for every creative process and its output [10]. There have been many formulations on creative thinking skills by several experts. According to Treffinger, Young, Selby, & Shepardson, there are five indicators of creative thinking which covers (1) fluency, the ability to formulate a variety of ideas, ways, suggestions, questions, and alternative answers smoothly within the allotted time, (2) flexibility, the ability to formulate a variety of ideas, answers, or questions, derived from a variety of different points of view by changing the way of thinking or approach used, (3) originality, the ability to express answers to a question or ideas that are unusual, unique, and rarely thought by most people, (4) elaboration, the ability to develop or enrich existing ideas or products, and (5) metaphorical thinking, the ability to make analogies or comparisons in order to construct a relationship [11]. Creative thinking is related to the ability to think divergently initiated by the ability to express ideas openly until ideas emerge that are rarely thought by many people. If the idea is really new and has never existed before, it is referred to as innovation. Furthermore, the divergent thinking process will end with the most appropriate and logical decision making based on the convergent thinking process [12].

This study aims to determine the level of divergent and creative thinking skills of 11th grade high school students in mastering the scientific method in biology and their differences as viewed based on gender and the popularity of their school. Divergent and creative thinking ability in mastering the scientific method refers to the divergent and creative mindset that underlies the students’ ability to
perform scientific procedures. High school students are selected as the research subject to reflect the quality of the entire education system they have completed since elementary school.

2. Methods

2.1 Research design

This is a descriptive research conducted by way of a survey method. The research was conducted between March and April 2018. It involved all students of class XI SMA (high school) in Bantul Regency as the research population. Sampling was derived by way of stratified sampling by taking into account the school achievement as indicated by the National Examination (high, medium, low). Of each school, the researcher took 3 classes randomly to get 259 students.

2.2 Data collection and analysis

Data were collected using two types of instruments, namely tests and questionnaires. Test instruments were used to measure students' divergent and creative thinking skills in mastering the scientific method, while the questionnaires were used to obtain information about the characteristics of students and schools.

The mastery test of the scientific method of divergent patterns in high school for biology subjects developed by Cahyani (2017) who had achieved the trial stage with a sample of 954 students was selected as the research instrument. The instrument has passed the validity covering content validity with expert judgment and construct validity using confirmatory factor analysis (CFA).

The test was arranged in the form of a non-objective description with a total of 24 items. Description test items were made with a divergent pattern, thus opening up opportunities for different alternatives to correct answers between testies. Divergent scoring for each item followed polotomous 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 48.

The creative thinking ability was scored based on the followings: (a) Score of 0: when students had a wrong answer or did not answer every 2 questions, (b) Score of 1: if there was only 1 correct answer and answered by >40% of students, (c) Score of 2: if there was only 1 correct answer (provided by ≥ 20 - 40% of students) or if there were 2 correct answers (first and second answers answered by > 40% of students), (d) Score of 3: if there was 1 correct answer (provided by <20% of students) or if there were 2 correct answers (where the first was provided by 20 - 40% of students & the second was answered by > 40% of students), (e) Score of 4: if there were 2 correct answers where the first and second answers were provided by ≥ 20 - 40% of students or if of the 2 correct answers, the first answer was provided by <20% of students and the second answer was provided by > 40% of students, (f) Score of 5: if there were 2 correct answers (first answer was provided by <20% of students and the second answer was provided by ≥ 20 - 40% of students), and (g) Score of 6: if both questions were answered correctly by <20% of students. Thus, the ideal maximum score for creative thinking is 144.

The measured scientific method include three types of skills: (1) skills in designing investigations, (2) skills in carrying out investigations, and (3) skills in reporting the results of investigations. Indicators of each skill is as presented in table 1.

| Table 1. Indicators of mastery of each of scientific method aspect |
|----------------------|---------------------------------------------------------------|
| **Scientific Method Aspect** | **Indicators**                                                   |
| **Designing Investigation** | 1. Establishing independent variables as treatment factors in the investigation |
|                     | 2. Identifying the relationship between the independent variable and the dependent variable in an investigation |
|                     | 3. Highlighting the importance of investigations               |
4. Formulating the objectives of the investigation
5. Identifying random variables in an investigation
6. Establishing the research hypothesis in an investigation
7. Designing the sample size needed in an investigation
8. Designing the type of data collect in an investigation
9. Designing data analysis techniques resulted from investigations

Performing Investigation
1. Giving treatment (treatment)
2. Controlling variables
3. Observing responses

Reporting Investigation Result
1. Presenting research findings in a diagram, table, or graph
2. Presenting research conclusion
3. Presenting research analysis
4. Verifying the research finding
5. Drawing conclusion based on the observation and data generalization or statistic analysis
6. Presenting findings, analysis, and conclusion in a written research report
7. Presenting research finding, analysis, and conclusion orally

The research data were processed by Microsoft Excel 2007. After that, the data were analyzed with descriptive statistics to present an overview of the mean, standard deviation, maximum score, and minimum score of divergent and creative thinking ability in mastering the scientific method. Then, both divergent and creative scores were interpreted based on the categorization shown in table 2.

Table 2. Score Categorization of divergent and creative variable

| Score Type       | Score Range | Description |
|------------------|-------------|-------------|
| Divergent Score  | 0 - 16      | Low         |
|                  | 17 - 32     | Medium      |
|                  | 33 - 48     | High        |
| Creative Score   | 0 - 48      | Low         |
|                  | 49 - 96     | Medium      |
|                  | 97 - 144    | High        |

In addition, inferential statistical analysis was also used which includes the Kolmogorov-Smirnov test to determine the normality of the data, Levene test to determine the homogeneity of the data, and a one-way variance test to compare the average divergent and creative thinking skills of students in three high schools with different achievement in the National Examination. Inferential statistical analysis was done using the SPSS 16.0 program.

3. Results and Discussion
3.1. Results
The results of descriptive analysis of students' creative and divergent thinking skills in mastering the scientific method are shown in table 3.
Table 3. Results of descriptive analysis scores of creative and divergent thinking in mastering the scientific method

| Data Group               | Ideal Maximum Score | Average | Standard Deviation | Maximum Score | Minimum Score |
|--------------------------|---------------------|---------|--------------------|---------------|---------------|
| Divergent Thinking Ability | 48                  | 17.00   | 5.26               | 33            | 4             |
| Creative Thinking Ability         | 144                | 41.07   | 12.78              | 75            | 8             |

Table 3 highlights that the average divergent thinking ability of students is medium (17<32). The average creative thinking ability is still relatively low (41.07<48). The maximum score for divergent thinking is 33 or only 68.75% of the ideal maximum score. Meanwhile, the maximum score for creative thinking is 75 or only 52.08% of the ideal maximum score. From these data, in general, it is clearly seen that the divergent and creative thinking skills of class XI students in Bantul Regency are still far from ideal.

Then, the data was re-analyzed using an independent sample T-test to see differences in the average divergent and creative scores based on gender. The results of the analysis is presented in table 4.

Table 4. Independent sample T-test analysis with α = 5%

| Gender    | Divergent Thinking Ability | Creative Thinking Ability |
|-----------|----------------------------|---------------------------|
|           | N  | Average | Standard Deviation | Sig. (2-tailed) | Average Score of Creative Thinking | Standard Deviation | Sig. (2-tailed) |
| Male      | 76 | 16.76   | 5.28               | 0.00           | 34.32                          | 12.23               | 0.00            |
| Female    | 183| 20.58   | 4.84               | 0.00           | 43.88                          | 11.96               | 0.00            |

From table 4, it is prominent that female students have higher divergent and creative thinking skills than male students. This can be seen from the average score of divergent thinking skill of male students which are lower than that of female students (16.76 <20.58). Similarly, the average score of creative thinking skill of male students is lower than that of female students (34.32 <43.88). Based on the Sig. (2-tailed) the average divergent and creative thinking ability of female and male students is different (H0 is rejected and H1 is accepted because the value of 2-tailed Sig is 0.00 <α).

Table 5. Results of normality and homogeneity test of divergent and creative data with α = 5%

| Data Group       | Normality Test (Kolmogorov-Smirnov) | Homogeneity Test (Levene’s Test) |
|------------------|-------------------------------------|----------------------------------|
|                  | N | Asymp. Sig. (2-tailed) | Sig.              |
| Divergent Thinking Skill | 259| 0.120 | 0.761    |
| Creative Thinking Skill    | 259| 0.331 | 0.908    |

Furthermore, the data were further analyzed to compare the average divergent and creative thinking abilities of students in the three high schools in terms of differences in the results of the National
Examination. Previously, normality and homogeneity tests were conducted using SPSS 16.0, the results of which were presented in table 5. As is clearly observable from table 5, the divergent and creative data were normally distributed and homogeneous. This is indicated by the value of Sig. which is greater than the value of α (0.05). Based on the results of the prerequisite test, it possible to continue to parametric statistical analysis of One-Way ANOVA. Analysis with One-Way ANOVA is tabulated in table 6.

Table 6. Result of One-Way Anova average score for divergent and creative thinking skill of students in 3 high schools based on their achievement in the National Exam classified into high, medium, and low

| Data Group                  | Sig. Value (Between Groups) |
|-----------------------------|-----------------------------|
| Divergent Thinking Skill    | 0.737                       |
| Creative Thinking Skill     | 0.393                       |

Based on the ANOVA test, it is known that the Sig. for divergent and creative thinking skills is greater than α (0.05). This means that there is no significant difference between the average divergent and creative thinking abilities of students in schools with high, medium, or low National Exam scores.

3.2. Discussion

On the basis of the study, it is indicated that there are differences in divergent and creative scores as seen from gender aspects. Female students show higher divergent and creative thinking skills than male students in mastering the scientific method of Biological aspects. Thus, the results of this study reinforce previous research which states that gender differences correlate with the achievement level of student, where female students show higher achievement than male students [13]. This finding is in accordance with the socio-cultural studies of Indonesian society since the seventies. In Indonesia, women have a comparative advantage in the field of education. They are more diligent, more careful, and more willing to listen well. Their more dominant emotional attitude than their physical ability has placed women in a very good position. Facts show that it is mostly women who occupy the top 10 rank in each school. This fact is valid from education at the primary level (elementary school) to university [14]. In contrast to various research results in other countries, men have more achievements in mathematics and science than women [15,16].

The study also highlights that there are no significant differences in creative thinking and divergent thinking skill between students who attended favorite schools with high National Examination scores; less favorite school with medium National Examination scores; and not favorite schools with low National Examination scores. This condition may be triggered by the high achievement of the National Examination derived from the drilling system for the material contained in the graduate competency standards. In other words, the high National Examination results do not represent the ability of students to master scientific methods or high-level thinking.

4. Conclusion

On the basis of the research, it is conclusive that the creative thinking skill of high school students in Bantul Regency in mastering the scientific method is still relatively low. The divergent thinking skill has reached the medium category although it is still far from ideal. It is also known that female students show higher divergent and creative thinking skills than the male students in mastering the scientific method of Biological aspects. Meanwhile, there is no significant difference in creative and divergent thinking skills when viewed from the aspect of school achievement in achieving the National Examination results.

References

[1] Trilling B and Fadel C 2009 21st Century Skills: Learning for Life in Our Time (San Fransisco: Jossey-Bass) pp 45-60
[2] Cambridge Assessment International Education 2018 Developing the Cambridge learner attributes (Cambridge: UCLES) p 68
[3] Hadzigeorgiou Y, Fokialis P and Kabouropoulu M 2012 Thinking about Creativity in Science Education Scientific Research 3(5) pp 603-611
[4] Goodstein D 2000 How Science Works: Reference Manual on Scientific Evidence (Retrieved on October 8 2018 from http://www.its.caltech.edu/~dg/HowScien.pdf)
[5] The Editors of Encyclopædia Britannica 1998 Baconian Method In Encyclopædia Britannica Online (Retrieved on October 7 2018 from https://www.britannica.com/science/Baconian-method)
[6] Eugenio E and Cortez R 2014 Knowledge is Power. Francis Bacon’s Theory of Ideology and Culture. Via Panorâmica: Revista Electrónica de Estudos Anglo-Americanos/An Anglo-American Studies Journal 3 pp 25-42
[7] Mc Giure S Y 2007 Using the Scientific Method to Improve Mentoring The Learning Assistance Review 12(2) pp 33-45
[8] Boden M A 2004 The Creative Mind: Myths and Mechanisms (New York: Routledge) p 1
[9] Lau J Y F 2011 An Introduction to Critical Thinking and Creativity: Think More, Think Better (Toronto: John Wiley & Sons) pp 216-223
[10] Kampylis P and Berki E 2014 Nurturing Creative Thinking (Brussels: International Academy of Education) p 6
[11] Treffinger D J, Young G C, Selby E C and Shepardson C 2002 Assessing Creativity: A Guide for Educators (Sarasota: The National Research Center on the Gifted and Talented) p 14
[12] Ritter S M and Ferguson S 2017 Happy creativity: Listening to happy music facilitates divergent thinking PLoS ONE 12(9) pp 1-14
[13] Gil R and Carvalho G 2016 Gender differences in academic achievement: The mediating role of personality Personality and Individual Differences 94 pp 54-58
[14] Nuryoto S 1998 Perbedaan Prestasi Akademik Antara Laki-Laki dan Perempuan: Studi di Wilayah Yogyakarta Jurnal Psikologi 2 pp 16-24 (Retrieved on October 9, 2018 from https://media.neliti.com/media/publications/127308-ID-perbedaan-prestasi-akademik-antara-laki.pdf)
[15] Hoff E V 2005 Imaginary companions, creativity, and self-image in middle childhood Creativity Research Journal 17(2/3) pp 167-180
[16] Abdu Raheem B O 2017 The Influence of Gender on Secondary School Students’ Academic Performance in South-West, Nigeria Journal of Social Sciences 31(1) pp 93-98