A Biology Students' Scientific Creativity Based on Gender Differences in The Introductory Physics Learning

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Abstract. Everyone has the potential to be creative though with different characteristics and levels. Scientific creativity involves a number of thought processes, imagination, action, emotions, and other factors, such as science process skills, culture, age, and gender. Gender differences in scientific creativity have been a topic of great interest to scientists of various disciplines for many decades. However, it is also controversial because the results of scientific creativity research based on gender differences are so diverse that they sometimes seem contradictory and cause confusion. This study aims to describe the differences of biology students' scientific creativity on the Introductory Physics learning in a biological context based on gender and the types of their scientific creativity. The research participants are Introductory Physics students at Biology and Biology Education study programs from two universities in Semarang, Indonesia, with 37 students of university A and 26 students of university B (an experimental class) and 29 students of university B (a control class). The experimental class applied Introductory Physics to learn using Scientific Creative Problem Solving (Sci-CPS). The number of participants based on gender are 11 males and 52 females, all of them aged between 18 and 20 years old. Based on the results of the data analysis and discussion, it can be concluded that the scientific creativity of male students is higher than females after participating in Introductory Physics learning with the Sci-CPS. However, the scientific creativity of male and female students is not significantly different. It means that gender does not have a significant influence on students' scientific creativity. Meanwhile, based on the aspect of scientific creativity, it can be seen that male students are better at flexibility, originality, elaboration, and evaluation, whereas female students are better at fluency.

Keywords: scientific creativity, gender, introductory physics, biology students

1. Introduction

Creativity is one of the skills needed by students to compete in the 21st century. The development of science and technology today cannot be separated from the contribution of creativity to encouraging the growth of innovation. Creativity is defined as a process that leads to the production of new or original products and useful or effective products (Runco & Jaeger, 2012). The creativity product is not always in the form of objects, but can be in the form of ideas and performances, for example music, drama, or theories in science. Creativity can also be interpreted as the result of a combination of novelty or originality and value or utility (Glăveanu, 2018). Therefore, creativity has two criteria, namely novelty or originality and value or usefulness. These criteria represent several types of emphasis and represent very different dynamics of creativity. Novelty and originality are often associated with the creative process in art, whereas special value and usefulness are for science-based invention and creativity (Glăveanu, 2018). Guilford (1967) states that creative people have more divergent thinking than convergent thinking. Convergent thinking is individual ways of thinking about things with the view that there is only one right answer. It is different from divergent thinking, namely the individual's ability to find various alternative answers to a problem.

Creativity can be found in many fields, but it is unique in accordance with their respective fields. Kaufman (2006) specifically state that creativity is highly relevant to art and science because they both use universal language that transcends different sub-disciplines, making it interesting to study. Creativity in science is different from creativity in the arts and languages. Creativity in science is often called scientific creativity. Moravcsik (1981) defines scientific creativity as an effort to realize the goals of science through various forms of conception of new ideas that contribute to science itself, formulation of new scientific theories, and setting up new experiments to investigate natural laws. In other words, scientific creativity is creativity that is limited by scientific nature.

Scientific creativity is defined as the ability to generate new ideas or products that are relevant to the context and have scientific uses or interests (Ayas & Sak, 2014). According to this definition, any scientific idea that is highly original but does not fit its context or is completely useless cannot be considered creative. Any scientific idea that can be accepted as creative needs to exhibit a certain degree of originality and usefulness. The level of originality and usability determines the level of creativity of ideas. Scientific creativity can also be defined as any thought or behavior in science that is new and useful. Science is a creative field of work with creative products in the form of theories, research designs, hypotheses, methodologies, data analysis, interpretation, and communication or publication of results (Feist, 2011). Scientific creativity is also defined as creativity that unites the uniqueness and aesthetic aspects of various fields of different disciplines (Demir, 2015).

2. Scientific Creativity in Learning Physics

According to the definitions, scientific creativity is a part of creativity in general. Because of its unique, Hu and Adey (2002) have defined the structure of scientific creativity so that it is not biased by creativity in other fields. The structure of scientific creativity is as follows:

a. scientific creativity differs from creativity in art and language. It relates to creative science experiments, creative science problem discovery, and solutions;
b. scientific creativity is an ability that includes intellectual factors;
c. scientific creativity depends on scientific knowledge and scientific process skills;
d. creativity and analytical intelligence are two different factors for a single function that comes from mental abilities.

Scientific creativity is formed through a systematic process. Mansfield and Buse (1981, in Liang, 2002) showed five stages of scientific creativity, namely (1) correct and careful selection of problems; (2) expansion of efforts to solve problems; (3) use of experimental, methodological, and cognitive skills; (4) change the decision according to the hypothesis; and (5) verification and elaboration of experiments that need to be repeated.

Scientific creativity can be investigated through five basic cognitive and computational concepts. The five concepts include: (1) motivation to conduct scientific research; (2) the ability to formulate research problems correctly according to their scientific field; (3) the ability to generate a comprehensive research field for solving scientific problems; (4) the ability to apply a set of heuristics to reduce the research field; and (5) patient and tenacious in-depth search to solve scientific problems according to the field of search that is limited. This concept explains that a creative scientist knows how to formulate research problems correctly, produces a broad field of research for certain problems, and is able to formulate the necessary research methodology. In modern scientific research, access to extensive and systematic knowledge is necessary to formulate scientific problems correctly, to create a comprehensive search field, and to reduce the search field to find solutions within acceptable time and resource constraints. The formulation of the correct search problem requires mastery of the conceptual structure of the field of science involved.

Along with the needs of the world of work in the 21st century, science is seen as one of the important fields in the development of creativity (Curriculum Development Council, 2002; Ikromovna, 2022). Therefore, creativity needs to be applied in science learning at the elementary, secondary, and tertiary levels of education. In the early 1980s, McComark and Yager had proposed a taxonomy of science education covering the areas of imagination and innovation. Based on this taxonomy, Gilbert (1992, in Daud et al, 2012) suggests six questions in learning design, namely integration, imagination, brainstorming, organizing, making analogies and metaphors, and conceptualizing. These six questions have been proven to be able to encourage students to develop their scientific creativity through various learning methods. This is in line with the opinion of Sternberg (2003) who suggests that in creative science learning, students need to be encouraged to create, discover, explore, and imagine in order to process the information they get.

There are five types of scientific creativity learning activities that can be applied, namely discovery, understanding, presentation, application, and transformation of scientific knowledge. Discovery activities in learning can be done through independent research or engaging in divergent thinking training. Students are encouraged to develop interesting and diverse sciences, perform classifications, ask scientific research questions, formulate hypotheses, plan experiments and measurement methods, use equipment, and draw conclusions from empirical data (Cheng, 2011). Scientific creativity can also be generated through scientific knowledge in various methods. For example, knowledge, concepts and principles of science are presented through role-playing, demonstration, and observation methods with student activity sheets (Dwikoranto et al, 2020). In addition, to foster creative knowledge, teachers create situations where students have the opportunity to find new ways to explain scientific phenomena, make predictions, solve problems, and state what is not known. As for the transformation of scientific knowledge, students are given the opportunity to propose changes based on their knowledge by asking questions and criticizing various scientific disciplines and knowledge in textbooks, as an alternative to developing new methods to integrate them with creativity in learning. Previously, Cheng (2004) had also presented a comprehensive strategy for creating creative learning in physics. This is then followed by a comprehensive model in the physics curriculum (Cheng, 2006).

3. Scientific Creativity and Gender

Everyone has the potential to be creative though with different characteristics and levels. Scientific creativity involves a number of thought processes, imagination, action, and emotions. In addition to these factors, creativity also involves other variables, such as science process skills, culture, age, and gender. Gender differences in scientific creativity have been a topic of great interest to scientists of various disciplines during the last five decades. However, this topic is also controversial because the results of scientific creativity research based on gender differences are so diverse that they sometimes seem contradictory and cause confusion.

Some research has found equality of creativity between male and female (Runco & Okuda, 1988; Runco & Smith, 1992; Lee, 2002; Harris, 2004; Charyton, 2005). Meanwhile, other studies showed that females' scientific creativity is better than males' (Shin et al., 2002) or vice versa, males' scientific creativity is better than females' (Conti et al., 2001; Okere & Ndeke, 2012; Yuan Z et al., 2017). The advantages of males to females is due to the fact that males are more non-conformist, so they are closer to innovation, while women are usually oriented towards additional creativity, so they are closer to adaptation (Gilson & Madjar, 2011; Wittich & Antonakis, 2011). Karwowski et al. (2016) stated that the greater male variability in creativity was observed since the age of 4 years old, and tends to increase with age, especially in the case of original thinking, whereas the female scores are more diverse in terms of adaptive thinking. This study aims to describe the differences of biology students' scientific creativity on the Introductory Physics learning in a biological context based on gender and the types of their scientific creativity.

4. Method

Participants

This is quantitative research with true experimental design. The research participants are Introductory Physics students at Biology and Biology Education study programs from two universities in Semarang, Indonesia. The sample of research are 37 students of university A and 26 students of university B as an experimental class and 29 students of university B as a control class. The experimental class applied Introductory Physics learning using the Scientific Creative Problem Solving (Sci-CPS) with a syntax that includes extraction (extracting problems and ideas), design (hypothesizing and planning), invention (inventing solutions), and termination (taking conclusions and follow up). The number of participants based on gender are 11 males and 52 females, all of them aged between 18 and 20 years old.

Instruments

The students' scientific creativity was obtained from pretest and posttest scores of the Introductory Physics Scientific Creativity Test (IPSC Test). The IPSC test was developed from the Scientific

Creativity and Scientific Process Skills' Test (SCSPS) and the Test for Creative Thinking-Static Fluid (TCT-SF) by Hanni et al. (2018). It is a static fluid essay test with nine questions.

The IPSC test was validated by experts. The test scoring was obtained from the sum of fluency, flexibility, originality, elaboration, and evaluation. Fluency is scored by the number of respondents' answers, regardless of their quality. Flexibility is scored by the number of approaches or fields used in answering questions. Originality is scored by the tabulation of the frequency of answers. Elaboration is scored by the number of ideas or objects that can be explained in detail correctly. Evaluation is scored by the percentage of conformity of the standards/criteria set and the number of ways to meet these criteria. Content validity for the IPSC test uses the Aiken index (V), which is classified accroding to the following category, i.e. $0 \leq V \leq 0.4$ (less valid), $0.4 < V \leq 0.8$ (quite valid), and $0.8 < V \leq 1.0$ (very valid) (Aiken, 1985). The reliability of the IPSC test uses the Alpha Cronbach formula with the category of reliability, i.e. $\alpha \geq 0.9$ (excellent), $0.9 > \alpha \geq 0.8$ (good), $0.8 > \alpha \geq 0.7$ (accepted), $0.7 > \alpha \geq 0.6$ (doubtful), $0.6 > \alpha \geq 0.5$ (poor), and $0.5 > \alpha$ (rejected) (Cronbach, 1951)

Data Analysis

The IPSC test scores were analyzed by paired sample t-test to compare the pretest and posttest mean score in the experimental class and by independent sample t-test to compare posttest mean scores of the experimental class and the control class. Before being analyzed, the IPSC pretest and posttest scores were analyzed by normality tests and homogeneity tests of variance.

The paired sample t-test aims to examine whether there is a difference in the mean score of students' scientific creativity before and after attending the Introductory Physics learning in a biological context.

$$H_0: \mu_1 = \mu_2$$
$$H_1: \mu_1 \neq \mu_2$$

with μ_1 = average pretest score and μ_2 = average posttest score. The mean difference test for two hypotheses using this formula.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{{s_1}^2}{n_1} + \frac{{s_2}^2}{n_2} - 2r\left(\frac{s_1}{n_1}\right)\left(\frac{s_2}{n_2}\right)}} \qquad (1)$$

The independent sample t-test aims to determine the effect of the Sci-CPS learning model on students' scientific creativity abilities. This test was carried out on the results of the posttest of the experimental class and the control class.

$$H_0: \mu_1 \leq \mu_2$$
$$H_1: \mu_1 > \mu_2$$

with μ_1 = average posttest score of experimental class and μ_2 = average posttest score of control class. The mean difference test for two hypotheses using this formula.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad (2)$$

with

$$s = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}} \quad (3)$$

Statistical analysis was performed with IBM SPSS Statistics Version 24 software.

5. Results and Discussion

The average posttest score of male students' is 40.45, whereas the female students is 38.88. The average posttest score of male students was slightly higher than the female students. The difference of the average posttest scores of male and female students can be calculated by the homogeneity of the variance test. The results of the homogeneity test can be seen in Table 1.

Table 1: Homogenity Test of Average Posttest Score

Average_Posttest

Levene Statistic	df1	df2	Sig.
.241	1	61	.625

Table 1 shows the Levene Statistics number of 0.241 with a significance (Sig.) of 0.625 > 0.05, so it can be concluded that the variance of the two groups is the same or homogeneous. The comparison of average posttest scores between male and female students used one-way ANOVA, which is the results are shown in Table 2.

Table 4: ANOVA One Path Experiment Class

Average_Posttest

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	22.378	1	22.378	.584	.448
Within Groups	2338.035	61	38.328		
Total	2360.413	62			

Table 2 shows the F_{count} is 0.584 with a significant level (Sig.) of 0.448. Because the value of Sig. > 0.05, it can be concluded that the scientific creativity of the male and female students is not significantly different. In other words, gender does not have a significant effect on students' scientific creativity.

The average pretest and posttest scores of male and female students in the experimental class can be described based on the aspects of scientific creativity as shown in Figure 1. Based on Figure 1, it is known that the average posttest score of male students is higher than the average posttest score of female students in almost all aspects, except fluency.

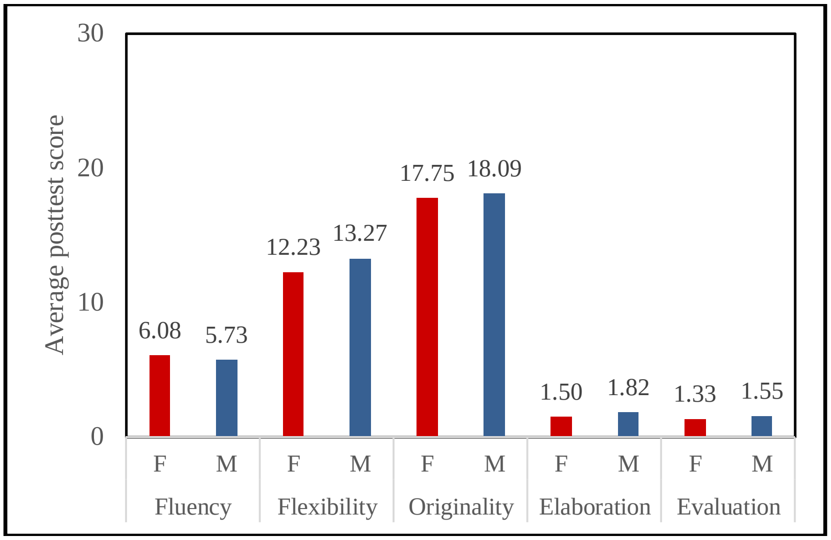

Figure 1. Average posttest score based on the aspect of scientific creativity

The average posttest score of male students was higher than the average posttest score for female students. However, based on the homogeneity test, the variance between the two groups was homogeneous. This is reinforced by the results of the one-way ANOVA test, which shows that the scientific creativity of male and female students is not significantly different. In other words, gender does not have a significant effect on students' scientific creativity. This is in accordance with the results of previous studies which stated that creativity between males and females did not differ significantly (Kaufman, 2006; Kaufman et al., 2010; Mori, 2014; Gunawan et al., 2017; Fadllan et al., 2018). The absence of significant differences between males and females in scientific creativity provides equal opportunities for everyone to develop their scientific creativity. It also provides opportunities for educational practitioners and researchers to develop strategies or learning models that can encourage increased scientific creativity.

Although the results of this study do not show the effect of gender on students' scientific creativity, several other studies have stated that males are more creative than females (Karwowski et al., 2016; Zhang et al., 2018; He, 2018; He, 2021) or females are more creative than males (Vergara et al., 2018). This shows that the assessment of creativity based on gender is controversial but very interesting to research (Pinker, 2009). The difference in the results of this study occurs because creativity is influenced by many factors, including intellectual intelligence, academic achievement, socio-economic status, attitudes towards science and problem solving, school and home environment

(Raj & Saxena, 2016; Ulger & Mosunbul, 2016; Sidek et al., 2020). However, none of these factors confirms the effect of gender differences on creativity.

According to students' scientific creativity score based on its aspects, it is known that male students are superior in aspects of flexibility, originality, elaboration and evaluation, whereas female students are superior in fluency. Handayani & Novianto in Aziz (2008) state that Javanese females are better educated to solve practical problems at home. On the other hand, males are taught to be oriented outside the home, develop more imagination in work, but tend to be abstract, so that they lack flexibility and originality in thinking. The superiority of male students in the evaluation aspect is likely because they are educated to make decisions quickly about solving problems. One of them can be seen in the determination of the leader of a group that is dominated by males.

Other research has highlighted the possible contribution of socio-cultural factors (Cheung & Lau, 2010) or the interaction of biological/evolutionary and socio-cultural factors (Wood & Eagly, 2002) to creativity. From a socio-cultural perspective, Gray et al. (2019) stated that adult male variability is generally more heterogeneous. It can be attributed to practices or social policies that target improving the quality of male-female performance in general. In line with this argument, other studies have shown that men tend to have higher levels of self-efficacy than women in math and science-analytic creativity, which affects creative outcomes (Kaufman, 2006; Karwowski et al., 2015) and problem solving (Hughes et al., 2013), whereas women show higher levels of creativity self-efficacy than men in arts and languages (Kaufman, 2006; Hughes et al., 2013; Karwowski et al., 2015).

6. Conclusion

Based on the results of the data analysis and discussion, it can be concluded that the scientific creativity of male students is higher than females after participating in Introductory Physics learning with the Sci-CPS. However, the scientific creativity of male and female students is not significantly different. It means that gender does not have a significant influence on students' scientific creativity. Meanwhile, based on the aspect of scientific creativity, it can be seen that male students are better at flexibility, originality, elaboration, and evaluation, whereas female students are better at fluency.

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Appendix 1

The Introductory Physics Scientific Creativity Test (IPSC Test)
(Adopted from Scientific Structure Creativity Model (SSCM) and Test for Creative Thinking-Static Fluid (TCT-SF)

Aspects	Questions and Time		Scoring Procedure
• Science konwledge (dimensions of product) • Fluency, flexibility, and originality (dimension of properties) • Thinking (process dimension)	1	a. Write down the scientific uses of a bottle of mineral water as much as possible! b. Write down the examples of the application of physics concepts in static fluids as much as possible!	The score is the sum of fluency (A), flexibility (B), and originality (C). A. Fluency score is obtained by counting the number of respondents' answers, regardless of their quality B. Flexibility score is obtained by calculating the number of approaches or areas/fields used in answering questions. C. Originality score is obtained from the tabulation of the frequencies of all the answers. The frequency and percentage of each answer were then calculated. • Score 2 if the answer probability < 5% • Score 1 if 5% < probability of answer < 10% • Score 0 if the answer probability > 10% Originality is very rarely generated by a group of populations.
• Science problems x fluency • Flexibility and originality x thinking and imagination	2	a. What scientific question would you like to research if you were to dive to the bottom of the ocean in a submarine? Write as much as you can! b. What scientific questions would you like to research when you are paragliding? Write as much as you can! c. What scientific question would you like to research if a person could walk on water without drowning? Write as much as you can!	
• Technical product x fluency • Flexibility and originality x thinking and imagination	3	a. Think of scientific ideas about what you would do to an infusion bottle to make it look more interesting and useful! Explain why the ideas are interesting! b. Think of scientific ideas about what you would do to a hydraulic machine in a car wash! Explain why the ideas are interesting! c. Think of scientific ideas about what you would do to an amphibious car! Explain why the ideas are interesting!	
• Science phenomena x fluency • Flexibility and originality x imagination	4	a. What would happen to living things in the ocean if there were no lifting force in the water? b. What would happen if there were no surface tension in the water? c. What impacts would occur if the density of oil is the same as the density of salt water and fresh water?	

		d. What impacts would occur if the compressive force on a liquid in an enclosed space were not transmitted equally in all directions?	
Science problem x flexibility and originality x thinking and imagination	5	a. Think of as many ways as you can to make an object float on the surface of the water! Draw it! b. Think of as many ways as you can to make paper airplanes fly well! Draw it!	The score is obtained by calculating the tabulation of all respondents' answers, then sorting certain answers for their rarity. • Score 3 if the answer probability < 5% • Score 2 if 5% < probability of answer < 10% • Score 1 if the answer probability > 10%
Phenomena x flexibility and originality x thinking	6	a. There are two infusion bottles, A and B. Bottle A contains crystalloids and bottle B contains colloids. How do you test to find out the greater density of the liquids? Write down as many ways as possible (simple tools, principles, and procedures.) b. There are two teak woods the same size. How do you test both? Which one has the better quality? Write down as many ways as possible can be done (tools, principles, and simple procedure)	The score is the sum of flexibility (A) and originality (B). A. Maximum score of flexibility is 9 for one correct method (3 for tools; 3 for principles; 3 for procedures). B. The originality score was developed from the tabulation of the frequencies of all the answers obtained • Score 4 if the answer probability < 5% • Score 2 if 5% < answer probability < 10% • Score 0 if the answer probability > 10%
Technical product x flexibility and originality x thinking and imagination	7	Design an advanced submarine like never before. Draw, name, and explain the function of each part of the submarine!	The score is determined by the function of the parts of the submarine, including: • for diving and surfacing • for motion control • for navigation systems, • for passengers activities in-cabin • for rescue • for other functions

Elaboration	8	Which parts of the submarine work in accordance with the principles of physics in static fluids?	The score is determined by the number of ideas/objects that can be explained in detail correctly
Evaluation	9	Does the submarine's design match your criteria? If not, please describe the part that doesn't meet the criteria and how to fix it?	The score is determined by the percentage of conformity of the standards/criteria and the number of ways to meet the criteria