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The Effectiveness of Inquiry Based Learning Model to Improve Science Process Skills and Scientific Creativity of Junior High School Students

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Abstract

The purpose of this study was to identify and describe the improvement of students' scientific process skills and scientific creativity. This type of research is quantitative descriptive research with thirty students of Class VII of the junior high school Negeri 12 with the main subjects of temperature and heat. The results showed that the improvement of science process skills with an average n-gain of 0.57 was in the medium category and the n-gain average of scientific creativity was 0.51 in the moderate category. The paired sample T-test shows that after using inquiry-based learning there is an increase in science process skills and scientific creativity with each sig value. <0.05. The Product Moment correlation test also shows that the correlation between the variable science process skills and scientific creativity is 0.69 which means an increase in science process skills as well as an effect on the increase in scientific creativity. Students who are able to do tasks related to science process skills will also be able to do scientific creativity tasks, especially those related to temperature and heat material.

Keywords: Effectiveness, Inquiry, Learning model, Improve science process skills, Scientific creativity.

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Ethical: This study follows all ethical practices during writing.

Contents

Contribution of this paper to the literature
This study contributes to existing literature by identifying the improvement of students' scientific process skills and scientific creativity.

1. Introduction

The characteristics of the 21st century are marked by the increasingly interconnected world of science. In the context of the use of information and communication technology in the world of education, it has been proven by the narrowing and melting of the "space and time" factors which have been the determining aspects of the speed and success of science by mankind (BSNP, 2010). In the context of science education, 21st century skills offer several new ways from the framework considered approaches in science learning and some new ideas for enriching student inquiry with cross-disciplinary learning models. Likewise, science, with its rich characteristics of critical and creative thinking, applied technology, and collaborative work with high standards for communication and personal responsibility, contributes to meeting the skills needs of the 21st century in all disciplines (Windschitl, 2009). In the 21st century skills map, the relationship between the 21st century and skills is rooted in terms of inquiry, process knowledge, experimental design, and elements of scientific thinking habits, as mentioned in the Project American Association for the Advancement of Science 2061 Benchmarks for Science Literacy, the Atlas of Science Literacy, and the National Science Education Standards, as well as extrapolating from scientific research practices as they change in the 21st Century.

Science process skills can be classified into basic process skills and integrated process skills, even though the components are the same and some are different. Basic process skills consist of observing, classifying / classifying, measuring, communicating, interpreting data, predicting, using tools, conducting experiments, and concluding. While the types of integrated science process skills include formulating problems, identifying variables, describing relationships between variables, controlling variables, defining variables operationally, obtaining and presenting data, analyzing data, formulating hypotheses, designing research, and conducting investigations / experiments. Science learning for class VII SMP trains basic process skills, and begins to practice integrated process skills (Kemendikbud, 2014).

The established inquiry learning model to improve learning outcomes and science process skills does not specifically develop creative thinking skills. The steps of the inquiry learning model (Arends, 2012; National Research Council, 2012) do not explicitly show hypothesis submission, but the phase encourages students to collect data to test the hypothesis. Given that the model was developed for grade VII junior high school students, it is deemed necessary that a separate hypothesis testing phase. Before testing the hypothesis, it should also be introduced and explained about the variables that support the hypothesis. The second phase of the inquiry learning model (National Research Council, 2012) is combined to formulate problems and test hypotheses and solve problems.

Various basic skills that are important in science lessons to generate creative thinking are that students must be able to choose concepts, gather information, and generate ideas. Learning activities should include investigative or investigative activities that allow students to carry out the process of seeking new information while learning science. These activities will raise and develop students' creativity to solve problems in learning science. These activities include developing ideas, connecting different ideas, and formulating ideas to solve certain problems. Creativity activities are applied in various learning activities, including in classrooms, online learning and laboratory practice (Mumford, Meideros, & Partlow, 2012).

Fasko (2001) stated that creative thinking skills can be developed through learning. Several relevant studies support the achievement of creative thinking through learning. Anna and Lau (2010); Koray and Köksal (2009) concluded that academic achievement and creative thinking can be improved through the selection of learning models. Meanwhile, Wynder (2008); Hamza and Griffith (2006); Baker, Rudd, and Pomerey (2001) concluded that it is necessary to design curriculum and classroom learning to increase student creativity.

Inquiry-based learning is considered to be the most widely used to encourage creativity in science education (Johnson, 2000; Kind & Kind, 2007; Meador, 2003). Craft (2003);Meador (2003) and Shahrin, Toh, Ho, and Wong (2002) consider that involving students in an open inquiry approach and scientific process training will be able to help students build new concepts, and develop creative thinking skills and creative attitudes. Scientific research is an important element in increasing creativity (Starko, 2010). The phases of the inquiry-based learning model guide the activities of teachers and students in creative activities in learning, especially during the implementation of experiments or investigations. The teachers' and students' activities are called the creative process as shown in Table 1.

Table-1. Creative process in inquiry-based learning model syntax.

No	The Inquiry-Based Model Phase	Creative Process
1	Phase 1: Orientation	1. Motivation by teachers (Apperception)
2	Phase 2: Problem Definition	1. Information gathering 2. Organizing information 3. Determine the problem
3	Phase 3: Submission of Hypotheses	1. Responding to problems 2. Combining concepts 3. The emergence of new ideas
4	Phase 4: Hypothesis Testing	1. Selection of new ideas 2. Investigation 3. Brainstorming
5	Phase 5: Evaluation and Follow Up	1. Communicate the results 2. Assessment of results 3. Monitoring of results 4. Further investigation

Torrance (Hu & Adey, 2010) views thinking fluency, flexibility, and originality as central features of creativity. Fluency means the number of original ideas generated. Flexibility is the ability to 'change tack' or 'change task', not being bound by a predetermined approach after the approach is no longer efficient. Originality is interpreted statistically: a rare answer, which only occurs occasionally in a certain population, is seen as original. Scientific creativity is the ability to find and solve new problems, and the ability to formulate hypotheses usually involves some addition to our initial knowledge (Pekmez, Aktamis, & Taskin, 2009). If students are involved with investigative work, they will be more creative in determining variables, methods and tools, and so on Aktamis and Omer (2008).

The characteristics of scientific creativity can be summarized as follows: remaining sensitive to any problem, the ability to generate new technologically accepted ideas, the ability to be curious, understand the world around it, the ability to solve problems, seek solutions, design experiments, imagination , identify difficulties, formulate predictions or hypotheses, and so on Aktamis and Omer (2008). The measurement of scientific creativity in this research focuses on creative thinking and scientific processes. In this study, students' scientific creativity can be assessed using a holistic approach; ask questions related to the use of their scientific process skills. The creativity component of investigative work can be measured by checking students' skills in asking appropriate questions and determining variables, planning experiments and trying different methods. The researcher believes that the items in this test have included both components, namely scientific creativity and the scientific process as shown in Table 2.

Table-2. The Relationship between science process skills and scientific creativity

Aspects of Science Process Skills	Aspects of scientific creativity
Asking questions - defining the problem	Finding problems, curiosity
Hypothesis formulation, variable determination	Looking for solutions, understanding the world around, taking advantage of previous experiences.
Fair test planning	Design experiments using existing knowledge
Measuring, collecting data, presenting data	Test whether the method used or the hypothesis is correct or not, determine new methods when needed.
Evaluation, formulate conclusions	Producing new scientific and technological ideas

2. Research Methods

This research study is a quantitative descriptive educational development research study. Previously, the implementation of learning had developed science learning tools. The tools developed are learning models based on creative-inquiry processes, syllabus, lesson plans, student study sheets in the form of concept summaries, student activity sheets, science process skills and scientific creativity tests adapted from "A scientific creativity test for secondary school students "(Hu & Adey, 2010).

The research sample was a class of students at junior high school Negeri 12 Pematangsiantar consisting of 30 people / odd semester classes for the 2018/2019 academic year with the subject matter of Temperature and its change and heat and transfer. The consideration of choosing junior high school Negeri 12 Pematangsiantar students is that under the school's A accreditation and one of the schools that has implemented the 2013 curriculum. The school is also willing to make learning innovations especially related to learning models that can develop higher-order thinking in accordance with the demands of the century education paradigm 21. The research design used the one-group pretest-posttest design (Fraenkel, Wallen, & Helen, 2003).

2.1. Research Instruments

2.1.1. Instrument for Assessment of Science Process Skills

The instrument used to measure science process skills was in the form of a 6-point essay. The test questions tested on students showed indicators of science process skills in the form of: formulating hypotheses, naming variables, controlling variables (controlling variables), making operational definitions (making operational definitions), conducting experiments (experimenting), interpretation (interpreting), designing investigations, application of concepts (applying concepts).

2.1.2. Scientific Creativity Assessment Instruments

An assessment instrument that can measure students' creative thinking skills (scientific creativity) is an essay question instrument that demands creative answers. The instrument is equipped with an assessment rubric in accordance with the creative thinking component according to the expert. The components of creative thinking that can be applied in this research are the adaptation of the Scientific Structure Creativity Model (SSCM). The reason for changing or modifying the questions or assignments is that each item is adapted to the material that students have learned. The use of this test is considered efficient because it can explain the relationship between science process skills and scientific creative thinking (scientific creativity), as shown in Table 3.

Table-3. Tests for measuring scientific creativity.

Original test items	Item used	Science Process Skills	Scientific Creativity
1) Please write down as many as possible scientific uses as you can for a piece of glass. *For example, make a test tube.*	1) List as many scientific uses as you possibly can for a piece of wire. The grain is the same as the original	• Problem solving skills	*Unusual Uses* • Ability to generate new ideas that are technologically accepted • Being sensitive to Difficulties and Problems • *Fluency, flexibility, originality*
2) If you can take a spaceship to travel in the outer space	2) The item used is the same as the original	• Asking question	*Problem finding*

Original test items	Item used	Science Process Skills	Scientific Creativity
and go to a planet, what scientific questions do you want to research? Please list as many as you can. *For example, are there any living things on the planet?*		• Defining the problem	• Finding problems, • Curiosity
3) Please think up as many possible improvements as you can to a regular bicycle, making it more interesting, more useful and more beautiful. *For example, make the tires reflective, so they can be seen in the dark.*	3) Please think about and write down as many improvements you can make to make a rice cooker more attractive, more useful and more beautiful.	• Hypothesis Formulation • Design of experiments	*Product improvement* • The ability to generate new technologically accepted ideas • *Fluency, flexibility, originality*
4) Suppose there was no gravity, describe what the world would be like? *For example, human beings would be floating.*	4) What would happen if the boiling heat of water was the same as the melting heat of aluminum	• Hypothesis Formulation • Estimation • Explanation of results • Ability to solve problems	*Creative imagination* • Scientific Imagination • Ability to ask questions • Understand the world around • *Fluency, flexibility, originality*
5) Please use as many possible methods as you can to divide a square into four equal pieces (same shape).*Draw it on the answer sheet.*	5) There are two types of metal, how do you test which metal is better for conducting heat? Please write down as many of the methods as you found and the simple instruments, principles and procedures you used.	• Ability to solve problems	*Creative experiment ability* • The ability to solve problems • Ability to ask questions • Trying earnestly to find solutions • Imagine designing experiments • Identifier of difficulties • Formulation of predictions • Be productive • *Fluency, flexibility, originality*
6) There are two kinds of napkins. How can you test which is better? Please write down as many possible methods as you can and the instruments, principles and simple procedure.	6) Design a water heater without using fire and electricity. Paint a picture; show the name and function of each part.	• Hypothesis Formulation • Design of experiments	*Product design* • Trying earnestly to find solutions • Design of experiments • Imagination

Pekmez et al. (2009).

Task scores 1 to 4 are the sum of the fluency score, flexibility score, and originality score with the scoring procedure in Table 4.

Table-4. Scoring procedure for scientific creativity skills.

Criteria	Description
Fluency	The fluency score is obtained simply by counting all of the separate responses given by the subjects, regardless of the quality.
Flexibility	The flexibility score for each task is obtained by counting the number of approaches or areas used in the answer.
Originality	The originality score is developed from a tabulation of the frequency of all of the responses obtained. Frequencies and percentages of each response are computed. If the probability of a response is smaller than 5%, we give it 2 points; If the probability is from 5 to 10%, we give it 1 point; If the probability of a response is greater than 10%, we give it 0 points.

Source: Hu and Adey (2010).

The score of task six is the sum of the flexibility score and the originality score. The flexibility score has a maximum of 9 points for one correct method (instrument: 3 points; principle, 3 points; procedure, 3 points). The originality score was computed as before: if the occurrence of the method generally was less than 5%, it got 4 points; if the probability was between 5–10%, it got 2 points; if the probability was larger than 10%, it got 0 point. We used a different scoring system in this task because it was more difficult for students to design an original method in testing the napkins than to get an original answer in task 1 to 4 (Hu & Adey, 2010).

2.2 Data Analysis

The data obtained were in the form of pretest and posttest scores of students' scientific process skills and creative thinking. Each indicator of scientific process skills and scientific creativity was analyzed with n-gain. N-gain shows the magnitude of the increase in science process skills and scientific creativity of students before and after inquiry-based learning. The originality indicator is in a separate discussion, because the scoring method is different from the scoring method for fluency and flexibility indicators.

$$n_{gain} = \frac{(Sf - Si)}{(S\max - Si)} x100\% \qquad \text{(Hake, 1999)}$$

with :

n_{gain} : normalized gain.
Sf : score of posttest.
Si : score of pretest.
Smax : maximal score.

The results of the normalization-gain calculation are then converted to n-gain <0.3 for the low category; 0.7> n-gain> 0.3 in moderate category and n-gain> 0.7; high category (Hake, 1999). Based on the data from the results of the scientific creativity test, a quantitative descriptive analysis was carried out of the students' scores. Analysis of students' scientific creativity was carried out by giving students' scores in answering creativity questions. Students' scientific creativity after being given treatment using a creative-inquiry process-based model, the inferential statistical analysis was carried out as follows:

1) Normality Test

The normality test aims to determine that the data obtained is normally distributed or not. The normality test was carried out for pretest and posttest data on students' science process skills and scientific creativity using the One Sample Kolmogorov-Smirnov Test with a significance level of $\alpha = 0.05$ (2-tailed).

2) Test for Increasing Science Process Skills and Scientific Creativity of Students

The pretest and posttest difference test was performed using the inferential parametric statistical paired T test with a significance level of $\alpha = 0.05$ (2-tailed).

3) Product Moment correlation test to determine the relationship between science process skills and scientific creativity.

3. Results and Discussion

3.1. Normalized Gain

Normalized-gain students' science process skills on each indicator can be seen in Table 5 as follows:

Table-5. Normalized gain of science process skills for each indicator.

No	Problem Indicators	Average of Score		N-gain	Description
		O_1	O_2		
1	Formulate a hypothesis	14	57.25	0.50	Moderate
2	Identifying variables	11	47.50	0.41	Moderate
3	conducting experiment	35	78.00	0.66	Moderate
4	Record observations	25	74.25	0.66	Moderate
5	Analyze data	11	65.75	0.62	Moderate
6	Formulate conclusions	8	77.00	0.59	Moderate
Average		17.33	60.62	0.57	Moderate

Note: O_1 = Pretest O_2 = Posttest.

Normalized-gain scientific creativity on each indicator can be seen in Table 6 as follows:

Table-6. Normalized gain of scientific creativity for each indicator.

No	Test indicator	Average of score		Average of value		N-Gain	Description
		O_1	O_2	O_1	O_2		
1	Unusual use	4	7	45	81	0,65	Moderate
2	Problem Finding	4	9	43	85	0,75	High
3	Product Improvement	3	5	37	53	0,25	Low
4	Creative imagination	3	8	30	80	0,78	High
5	Science Experiment	0	3	0	39	0,29	Low
6	Product Design	0	3	3	33	0,31	Low
Average		2.33	5.83	26.33	61.83	0.51	2.33

Note: O_1 = Pretest O_2 = Posttest.

3.2. Inferential Statistical Test

3.2.1 Normality Test

The pretest and posttest data normality test of scientific creativity using the One Sample Kolmogorov-Smirnov Test with a significance level of $\alpha = 0.05$ (2-tailed) is shown in Table 7.

Table-7. Results of the pretest and posttest normality test for science process skills and scientific creativity.

No	Normality Test	N	Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
1	Science Process Skills	30	.641	.806
2	Scientific Creativity	30	.542	.931

Note:
Liliefors Significance Correlation.
*. This is a lower bound of the true significance.

The results of the normality test obtained pretest data with sig values of 0.806 and 0.931 (sig. ≥ 0.05), which means that the pretest and posttest data were normally distributed.

3.2.2. Student's Scientific Creativity Improvement Test

The test for increasing students 'scientific creativity used pretest and posttest data on students' scientific creativity using the Paired Samples Test with a significance level of $\alpha = 0.05$ (2-tailed) in Table 8.

Table-8. Results of paired sample t-test data for pretest and posttest of science process skills and scientific creativity.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest-Posttest Science Process Skills	-54.85833	5.23450	.95568	-56.81293	-52.90374	-57.402	29	.000
Pair 2	Pretest- Posttest Scientific Creativity	-38.79700	12.86162	2.34820	-43.59961	-33.99439	-16.522	29	.000

Note: *. Result of paired sample t-test Science Process Skills and Scientific Creativity-IBM SPSS Viewer.

The table above shows that the sig. <0.05, it means that there is a significant increase in students' scientific process skills and scientific creativity.

3.2.3. Correlation of Science Process Skills and Scientific Creativity

The relationship between the variable science process skills and scientific creativity is shown in Table 9.

Table-9. The correlation results of science process skills - scientific creativity.

		Science Process Skills	Scientific Creativity
Science Process Skills	Pearson Correlation	1	.697*
	Sig. (2-tailed)		.017
	N	30	30
Scientific Creativity	Pearson Correlation	.697*	1
	Sig. (2-tailed)	.017	
	N	30	30

Note: *. Correlation is significant at the 0.05 level (2-tailed).

Based on the results of the Product Moment correlation test Table 9, there is a significant positive correlation (0.697) between the variable scientific process skills and scientific creativity.

4. Conclusions and Suggestions

Task 1 aims to measure students' ability to generate new ideas that are technologically accepted. Based on the answers given by students the most different from other friends' answers that are useful for scientific activities in technology are making guitar strings, syringes, light bulbs and eel detectors. Question 2 aims to train to find problems and curiosity, and ask questions. For the answer to Task 2, the majority of the questions asked by the students, namely: is there life on Mars and is there water on Mars?

Task 3 is to measure the ability to generate new ideas received by technology for product improvement. The majority of students answered that the rice cooker was cleaned and made a cloth. A new and unusual response was to design energy-saving rice cookers and spoilage-resistant rice cookers. Students' answers varied but still had something in common with their peers. The majority of female students' answers were pasting dolls, toys and covers with colorful cloth.

Task 4 is a question to measure students' creative imagination. There were various responses given by the students, but the majority given by the aluminum students could not be used as a cooking utensil, experimental tool of musschenbroek. Task 5 measures creative experiment ability, only measuring experimental steps and determining variables in science process skills. The majority of students' responses to this question were the same, namely comparing the heat at the other two ends of the metal. In a standard procedure, many students were able to compare or distinguish metals with better conductivity by trying according to the procedure. There was a unique and practical answer from students, namely by creating a conductivity detector.

Task 6 is used for product design using existing imagination and knowledge to design a product, namely a water heater using sunlight. Here's an example of an answer that might be a creative idea. The answer given by students was a water heater using light or solar heat. The students added that the black water container was a good heat absorber.

The correlation between the variable percent science skills and scientific creativity is 0.697 indicating that there is a positive relationship between science process skills and scientific creativity. Scientific creativity is the ability to discover and solve new problems, and the ability to formulate hypotheses usually involves some addition to our previous knowledge. So it can be said that finding out science process skills will also show a component of students' scientific creativity.

Researchers need to introduce concepts to and train students with questions that generate new ideas for technology, ask questions, product improvement. Researchers must also consider students' abilities in understanding creative imagination, creative experiment ability, and product design. The purpose of understanding the indicators of science process skills is to make it easier for students to do creative thinking tests in accordance with the instructions for the learning model that has been developed.

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