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Developing creativity through STEM education

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Abstract. The problem faced in classroom learning was rarely a learning activity that was able to improve creative thinking skills consistently. Therefore, one of the alternatives to the learning activity that could be used as a tool for improving the basic skills needed in this century in Science, Technology, Engineering, and Mathematics (STEM) education. This study aimed to describe the effectiveness of the STEM learning model in improving the creative thinking skills of students. It was a quasi-experimental research with Posttest-Only Design with Nonequivalent Groups. Based on data analysis, there was an effect of STEM education on students' creative thinking skills. Based on the research results obtained from students' creativity varies between low and moderate and the answers to the creativity tests given show lower results than expected. STEM can be recommended as an alternative and approach in learning biology, especially in improving students' creative thinking abilities. Creative thinking is important to everyone, because to proof of the truth of the formulation of an assessment can be encouraged by way of thinking.

1. Introduction

The development of science and technology in the 21st century is unstoppable. There is no boundary between countries in terms of communication and cooperation so that all disciplines must anticipate this situation. The education environment needs to be changed to improve the basic skills needed to anticipate the 21st century [1]. One of the basic skills to deal with the 21st century is creative thinking, which is the ability needed someone to think creatively in solving a problem.

Creative thinking is reflective thinking that is full of considerations in making decisions about what is believed and done [2]. There are five key ideas, namely: practical, reflective, reasonable, belief, some indicators of creative thinking skills include: looking for statements, questions, and reasons clearly; understand the information well by choosing reliable sources; pay attention to the overall situation and conditions; be strong with the main idea; maintain authenticity and fundamentals; look for alternatives and behave, systematically open-minded, and orderly; take a position accompanied by sufficient evidence, and look for as many explanations as possible. Creative thinking is also called logical thinking and analytical thinking [3]. Some indicators of creative thinking skills include: determining the credibility of a source; distinguish between relevant or valid from irrelevant or valid ones and between facts from valuation; identify and evaluate assumptions, biases, and points of view; and evaluate evidence to support recognition. Besides, there are differences in creative thinking skills between male and female students [4].



Traditional teaching couldn't improve students' creative thinking skills. Therefore, an alternative is needed to improve students' creative thinking skills. One alternative learning activity that can be used as a means of improving the basic skills needed in this century is STEM education. On the other hand, Promoting STEM education to pre-service biology teacher is important because the majority of in-service teachers had never heard about STEM education [5]. STEM is integration learning to help the success of the 21st century. In general, the objectives and benefits of the STEM learning model are expected, among others: to develop creative and creative thinking skills, logical, innovative and productive; instill a cooperation spirit in solving problems; introduce the perspective of the world of work and prepare it; utilizing technology to create and communicate innovative solutions; media to develop the ability to find and solve problems; media to realize 21st-century skills by connecting experience into the learning process through increasing the capacity and skills of students; and standard technology literacy.

STEM combines several learning approaches that include Science, Technology, Engineering and Mathematics. The combination of these four aspects is a harmonious combination to deal with problems that occur in everyday life. Skills in solving problems in the real world are very useful for individual and social development [6]. This learning approach can lead to active and integrated learning situations because of the interrelation between the four aspects needed together to solve the problem presented. Students can unite abstract concepts from every aspect based on the solutions provided. Learning activities using the STEM approach directly provide student experience to be able to combine every aspect at once. Stages of learning that integrate all four aspects facilitate understanding of learning material. A special feature in STEM learning is to explore students' abilities in understanding concepts and knowledge in a problem. STEM education effects on pre-service physics teachers' motivation in planning and implementing STEM activities [7]. For example in learning biology, STEM conditions students in learning to use technology in experimental activities to prove a science concept. The experimental data are processed mathematically to get a conclusion. This research is important because there is not much learning training related to STEM [8], and the skills studied in this study are the basic skills that every young generation must have in facing the 21st century.

2. Methods

The research was a quasi-experimental method with Posttest-Only Design. Students in the experimental class are taught with the STEM approach. On the other hand, students who are used as control classes are taught with traditional learning. Traditional learning is interpreted the same as traditional learning where teacher-centered learning [9]. Traditional learning begins with the teacher delivering the concept, then the teacher explains the procedures needed to find a solution, and continues with the students practicing the procedures that the teacher has presented with additional problems [10]. In this learning, the teacher is more active in the teaching and learning activities, but then, students are passive objects in receiving lessons [11]. A final test was given to the both of two sample classes to measure students' creative thinking skills.

All students of the study program of biology education of the University of Khairun were population in this study. The research sample was a second-semester student. The numbers of students involved in this study were 76 students. A general biology initial ability test was given to the sample class. The test is used as a reference for the feasibility of both classes to be compared. The instruments in this study were the Initial and Final Creative Thinking Test. This research consists of 4 meetings plus 2 meetings for tests on elementary biology courses.

Data from research on creative thinking skills the students were analyzed using SPSS (Statistical Product and Service Solution). Before testing, there will be a detection of outliers and testing of normality and assumptions homogeneity of variance research data, namely data about students' creative thinking skills. Outliers are detected using raw scores. Data that have a raw score around an absolute value of three should be suspected of being an outlier. Because data that are normally distributed about 99% should lie in three standard deviations from the average [12]. Therefore, data that has a standard score of around three will be specifically considered.

The assumption of normality is a requirement of most inferential statistical procedures. SPSS provides two normality test formulas, namely the Lilliefors normality test (Kolmogorov-Smirnov) and the Shapiro-Wilk Normality Test. A variance homogeneity test will also be carried out, both of which will be used to perform the type of test to be used next, namely parametric test or nonparametric test.

3. Result and Discussion

This study of creative thinking was in elementary biology courses. The description of students' creative thinking abilities in the sample class can be seen based on the average value and standard deviation. The sample group consisted of the experimental class and the control class and the level of creative thinking ability consisted of three levels, namely high, medium, and low. Table 1 shows a description of students' creative thinking abilities.

Table 1. Students' creative thinking ability

Treatment	PCTS Level	Mean	SD	N
STEM	High	22.50	1.732	12
	Moderate	18.21	1.477	14
	Low	13.33	2.741	12
Traditional	High	17.92	4.981	12
	Moderate	17.07	1.141	14
	Low	12.25	3.334	12

Note. PCTS = Prior Creative Thinking Skill

The ability of students' creative thinking skills in the STEM class is divided into three levels: high, medium, and low with an average of three consecutive levels being 22.50, 18.21, and 13.00. While, the standards deviations of three consecutive levels are 1.732, 1.477, and 2.741, respectively. In traditional classes, the average creative thinking ability of students from a high, medium, and low levels are 17.92, 17.07, and 12.25. The standard deviations at all three levels from top to low are 4.981, 1.141, and 3.334. The combined average of the two classes, namely STEM class and traditional class is 18.03 and the standard deviation is 4.188. The range of the value of creative thinking skills in this study is 0 to 30. Therefore, the average creative thinking ability of students from both STEM and traditional classes is included in the medium criteria.

The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to find out whether the data came from normally distributed populations. Data on students' creative thinking abilities both from STEM and traditional classes have $p > 0.05$ based on the Kolmogorov-Smirnov test. As for the Shapiro-Wilk test, p values > 0.05 for STEM classes and p values > 0.05 for traditional classes. The homogeneity test of variance between STEM classes and traditional classes shows a value of $p > 0.05$. Furthermore, the three levels of students' creative thinking abilities were also tested by normality tests. P values > 0.05 were obtained for data on creative thinking abilities at high levels and p values < 0.05 for data at medium and low levels for the Kolmogorov-Smirnov test. On the other hand, in the Shapiro-Wilk test, p values > 0.05 for the upper level and $p < 0.05$ in the medium and low level of creative thinking abilities. In addition, the variance homogeneity test showed $p < 0.05$ for all three levels of students' creative thinking abilities. Based on this, it can be concluded that the data of students' creative thinking abilities come from a normally distributed population based on a test-based learning approach, and the data of students' creative thinking skills do not originate from the population of normal distribution based on the level of students' previous creative thinking skills.

Statistical tests to determine the effect of the STEM education approach on students' creative thinking abilities using the two-way ANOVA test. Test results using SPSS are shown in Table 2.

Table 2. Tests of effects of between-subjects

Dependent Variable: CTS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	825.407 ^a	5	165.081	20.779	0.000
Intercept	21543.471	1	21543.471	2711.727	0.000
Level	683.181	2	341.591	42.997	0.000
Approach	97.376	1	97.376	12.257	0.001
Level * Approach	49.384	2	24.692	3.108	0.051
Error	556.119	70	7.945		
Total	23142.000	76			
Corrected Total	1381.526	75			

a. R Squared = 0.597 (Adjusted R Squared = 0.569)

The two-way ANOVA test results in Table 2 show that the value of $p < 0.05$ is both a factor in the level of students' creative thinking abilities and learning approaches. Based on this, it can be concluded that the level of students' creative thinking abilities divided into high, medium, and low levels affect the students' creative thinking abilities. The STEM learning approach also influences students' creative thinking abilities. On the other hand, we can also see that the value of $p > 0.05$ for the interaction between the level of students' creative thinking abilities and learning approaches which means that there is no interaction of the two factors on students' creative thinking abilities.

Creativity is the ability to create something new that sometimes requires careful preparation and sometimes creativity comes without preparation [13]. Creative thinking in the learning process requires preparation through various training activities that are presented in a task or problem-solving. Resolving a problem can be done through observation, reflection on experience, reasoning, or communicating. The ability of activities in thinking is a combination of various scientific disciplines that are not independent. A student must combine concepts, analysis, synthesis, or evaluate activities or problems that are used as media to develop creative thinking. The students' abilities shown in this study were categorized as medium criteria. This can be seen in students' responses in making short explanations, developing basic skills, in concluding, and determining the appropriate strategy in solving problems.

There are four characteristics of creativity examined in this study, namely fluency, flexibility, originality, and elaboration [14]. There are three questions to explore students' creative thinking skills. One of the three questions is: One disadvantage of paper chromatography is that the results of the analysis are less accurate. Explain alternatives or solutions to minimize these shortcomings! Exploring students' fluency to solve this question is with analysing who students in generating many ideas, solving with lots of answers, and who they thinking of more than one answer. There are some indicators to describe students' characteristics of flexibility, namely generating answers from different points of view, looking for many alternatives or different directions, and able to change the way of approach or way of thinking. The originality of students' answers includes being able to show new and unique expressions. Indicators of students' elaboration are being able to enrich and develop an idea or product and add a solution which more interesting.

This study shows that STEM education learning approach influences students' creative thinking abilities. In addition, the level of students' initial ability also influences students' creative thinking abilities. However, the interaction between the learning approach and the initial level of influence does not affect students' creative thinking abilities. This shows that the STEM education approach has an effective influence if compared to traditional learning in learning biology. Also seen are positive student attitudes towards the subject matter with active student participation.

4. Conclusion

Creative thinking skills can show the ability to identify a task or problem that requires a solution, reason, assumption through a hypothesis, test assumptions, and make conclusions in the form of arguments to

be communicated to other parties. Creative thinking generally uses inductive reasoning. A conclusion based on inductive reasoning comes from a problem solving through scientific stages that begin with understanding the problem, formulating a hypothesis, to drawing a conclusion based on an analysis of the results.

One way to explore biology ideas by students is to think creatively, so creative thinking is an important tool to be developed by students through teacher assistance. The atmosphere of learning as a means of increasing the ability to think creatively about biology can be designed through good learning planning to enable students to think something new about a task or problem that is used in learning activities. Some creative thinking skills include identifying main ideas of arguments, evaluating sources of information, evaluating evidence, and evaluating claims. Improving students' creative thinking is one indicator of the success of learning managed by the teacher. However, the creative thinking of students who have been trained in class can be developed in the real world.

The STEM education learning approach and the student's initial ability level in this study affect the students' creative thinking abilities. In addition, there is no interaction between the two factors. Therefore, STEM can be recommended as an alternative and approach in learning biology, especially in improving students' creative thinking abilities. Creative thinking is important to everyone, because to proof of the truth of the formulation of an assessment can be encouraged by way of thinking.

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