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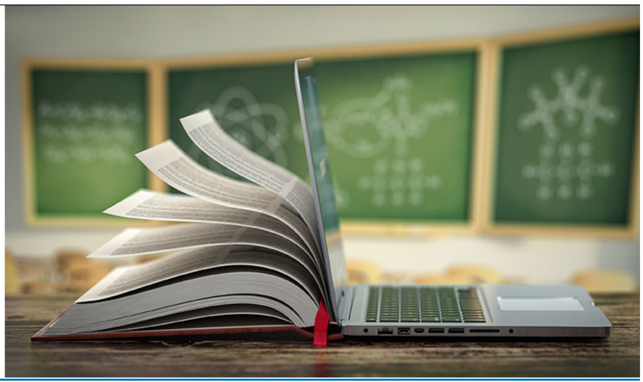

STEM-E: Fostering mathematical creative thinking ability in the 21st Century

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Abstract. Creative thinking is important in improving the formation and discovery of learning ideas in the 21st century. This study aims to determine differences in the ability of students' mathematical creative thinking in learning STEM and Ethnomathematics (STEM-E). This research employed the experimental design with a simple random sampling technique to determine the sample. The population of this study was 300 junior high school students in Lampung Province, Indonesia. The data collecting technique used was a test instrument tested to see the improvement of mathematical creative thinking. Hypothetical testing used was one-way ANOVA with a significance level of 5%. We found that the average score of the class that applied the STEM-E learning model was 74.71, which is higher, compared to the STEM class with the average score of 72.10, and the control class with the average score of 67.88. It can be concluded that the STEM-E model can be used as an alternative solution for learning in the industrial era 4.0.

Key words: *creative thinking; ethnomathematics; STEM*

1. Introduction

The concept of thinking that emphasizes the relationship between mathematics and real-life phenomena in the 21st-century is creative thinking [1]–[3]. Creative thinking can provide insight into ideas to make logical conclusions that lead to new ideas in the learning classroom [4]–[6]. As a learner, it is important to find a good creative thinking strategy to produce good academic output related to the field of mathematics and science [7]–[9]. Creative thinking skills is an important aspect for the students to solve problems and find ideas for solving the problem to the different perspectives [10]–[13]. Creative thinking can provide a great opportunity for students to exploit their knowledge in learning mathematics [14]–[16]. Also, they are provided an opportunity to explore their abilities [17]–[20], critical aspect particularly relevant to the analysis-synthesis component of the design process [21], and to see the relationship between the knowledge they obtain and their daily lives [22]–[25]. The process of exploring this ability will arouse curiosity and reflect on the knowledge that has been built [26]–[30].

However, Indonesian students' creative thinking abilities are still far from good compared to the creative thinking abilities of international students. This is evidenced by the percentage data comparison of creative thinking of Indonesian students and the international students in terms of the cognitive process domain in PISA 2018.

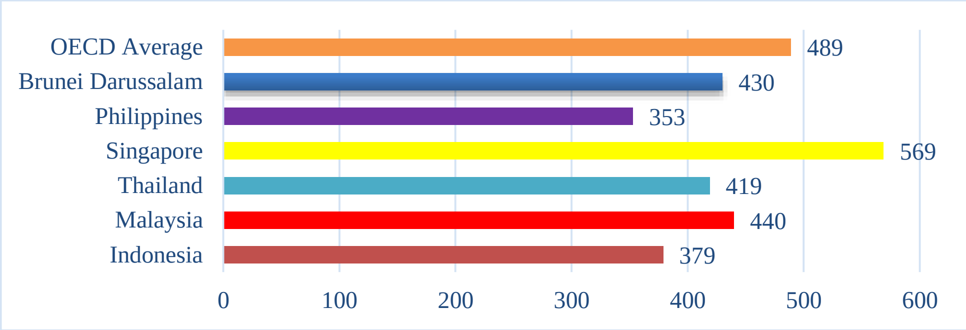

Figure 1. Graphic of Southeast Asian Nations Mathematics Ability.

Figure 1 shows that Singapore is the country with the highest score of 569 and the Philippines is the country with the lowest score of 353. Indonesia only scored 379 that is below the international average of 489. Based on this, it is suspected that the learning system has not been fully effective in building students' technical ideas.

The solution to phenomenon problems and to foster the creative thinking is to prepare educational provisions [4], [31]. One of them is STEM learning [32]–[34]. STEM is popular at the world level that is effective to be applied as integrative thematic learning [35]–[37]. This learning combines 4 main areas in education, namely science, technology, mathematics, and engineering [38], [39]. STEM is an important issue in industrial era 4.0 and educational trends [40]–[43] and is internationally recognized to be able to advance the skills needed by the 21st-century society [44]–[46].

STEM can be combined with ethnomathematics to provide students more comprehensive learning experience [47]–[49]. Because we believe that STEM with ethnomathematics can provide opportunities to learn mathematical concepts [50], [51]. The main point of mathematical thinking and culture refers to ethnomathematics. This means that both of mathematical thinking and culture can be developed uniquely toward methods and sophisticated explications to understand and to transform their own realities [52]. Ethnomathematics represents the way that various cultural groups mathematize their own reality because it is described as the techniques developed by students from diverse cultures and are used to explain, understand, and manage social, cultural, and environments [26], [53], especially in the connected and well-known areas of mathematical creative thinking. In addition, creative thinking developed through the integration of mathematics and culture is characterized by logical, rational, imaginative accompaniment with aesthetic sense, and can facilitate teaching and learning activities to be interesting and not monotonous [54]–[57]. Hence, teaching through the technological advances [58], [59], the process of curriculum delivery, and understanding of various disciplinary/interdisciplinary can be facilitated [60]–[62].

Based on previous research, STEM can improve mathematical thinking ability [63]–[65] using ethnomathematics as a means to improve student mathematical achievements [51], [66], [67]. In other words, students can learn to be involved in the process of analyzing problem spaces, generating ideas, and developing a better understanding of the relationship between variables and thinking concepts [68]–[70], provide an increase in higher-order thinking [71], and provide good techniques for teachers [72]. STEM learning can improve literacy in science, mathematics, technology, and engineering [73], train causal reasoning [74], improve creative thinking skills [75]–[78], can increase achievement and interest in learning [79]–[81], and increase motivation and provide experience in the engineering process [82]–[85]. Based on previous research, the novelty of this research lies in the integration of ethnomathematics in STEM learning to improve creative thinking.

Thus, the purpose of this study is to compare two learning models, namely STEM and STEM-Ethnomathematics (STEM-E) learning towards students' creative thinking. Through STEM-E, students are expected to be motivated to explore and foster their love for learning. With the advancement of technology, STEM-E will become the standard informing students' understanding, knowledge, skills, abilities, and learning processes.

2. Research Method

This research is quasi-experimental. The respondents in this study were 300 junior high school students in Lampung Province, Indonesia, academic year 2019/2020. To determine the experimental class and control class, the simple random sampling technique with no replacement method was used. It means that each element of the population has an equal opportunity to be elected as the members of the sample. Two of the classes were randomly selected as an experimental group and other for the control group. There were 32 students in the experimental group 1, 30 students in the experimental group 2, while 32 students in the control group.

After selecting the control and experimental groups, the students were matched according to their first term mathematics scores [86]. The study was carried out for a total 20 hours. During the process of preparing activities and post-test questions, Indonesian junior high school curriculum was considered and 3 activities were prepared. In the experimental group 1 dynamic oriented activity was used by using the STEM and Ethnomathematics (STEM-E) learning model. In the experimental group 2 were used by using the STEM learning model. In the control group, the normal teaching sequence in the curriculum was followed.

The data collection technique used was an essay test to measure creative thinking. The indicators of creative thinking include Fluency, Flexibility, Elaboration and Originality [87] as shown in figure 2.

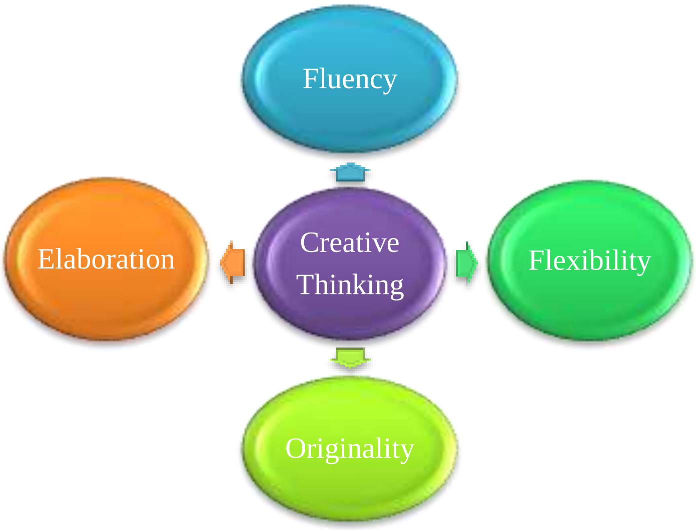

Figure 2. Creative Thinking Indicators.

The STEM-E learning steps were carried out using the steps shown in figure 3.

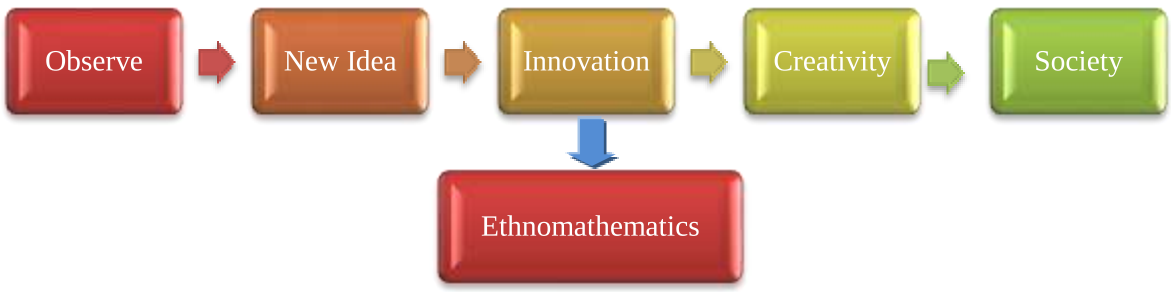

Figure 3. The STEM-E Learning Steps.

The prerequisite tests were conducted using the normality test with Kolmogorov Smirnov and Homogeneity test with Levene's Statistics used by SPSS. The hypothetical testing was performed using one-way ANOVA.

3. Results and Discussion

Based on data analysis, the researchers combined the research data in the form of data on the creative thinking abilities in the experimental class and the control class. The data collected were in the form of pretest and posttest results, both from the experimental class and the control class. The highest value (X_{max}) and the lowest value (X_{min}) in all three classes were sought as well as the central tendency including the mean ($\bar{x}$), median (Me), and mode (Mo). Here is the summary of pretest and posttest data.

Table 1. Description of the Results of Pretest and Posttest on Students Creative Thinking Abilities.

Class	Pre-test				Post-test			
	x_{max}	x_{min}	$\bar{x}$	S	x_{max}	x_{min}	$\bar{x}$	S
Experiment 1	65.43	60.20	65.63	10.057	87.50	63.00	74.71	4.77
Experiment 2	56.80	50.40	55.48	7.748	85.50	62.00	72.10	4.92
Control	55.38	40.30	54.44	10.12	73.20	58.00	67.88	5.23

Based on table 2, it is known that the results of the pretest and posttest of each class were different. Based on the data, in the pretest, the highest value was obtained by experimental class 1 which applied the STEM-E and the lowest value was obtained by the control class which applied the learning regularly used at the school. Based on the average score of the classes, the highest average score was obtained by the control class and the lowest value was obtained by experimental class 2 and the control class. Based on the data, the highest posttest score was obtained by the experimental class 1 and the lowest score was obtained by the control class. The following is the graphic of the pretest and posttest score on creative thinking abilities:

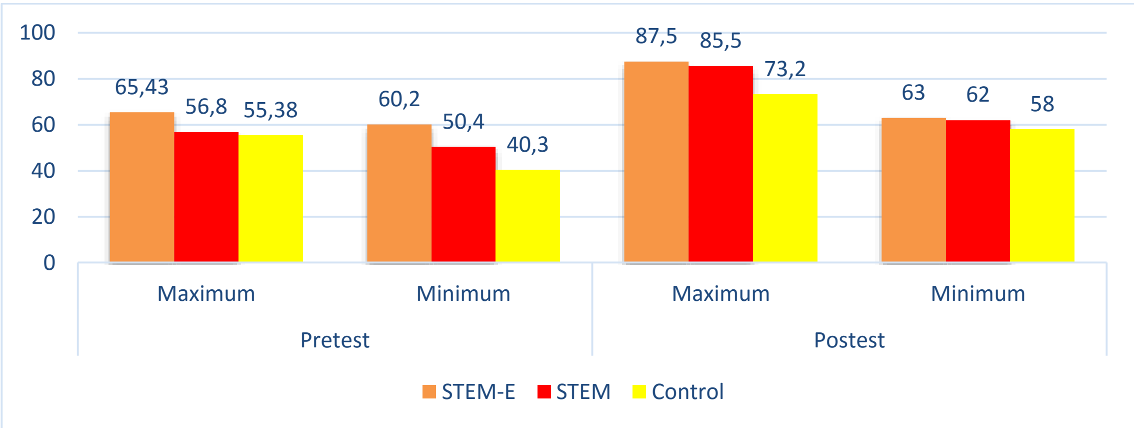

Figure 4. Graphic of Pretest and Posttest Scores on Creative Thinking.

Figure 4 illustrates the results of the highest and lowest scores of the pretest and posttest of the three classes. These data indicate that there is a significant increase in students' creative thinking abilities after the implementation of STEM-E in the experimental class 1, STEM model in the experimental class 2, and school's model in the control class.

Table 2. Normality Test Results.

	Teaching Methods	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Value	STEM	.158	30	.055	.948	30	.080
	STEM-Ethnomathematics	.142	32	.109	.957	32	.430
	Control	.141	32	.082	.926	32	.209

Table 3. Variance Homogeneity Test Results.

F	df_1	df_2	Sig.
.619	5	93	.686

Based on table 2 and table 3, it is known that the data are normally distributed with a significant level of α = 0.05 so that it can be continued at the homogeneity of variance test stage. Furthermore, homogeneous variance with a significance level of 0.05 was obtained sig value of 0.686, it is clear that sig value of 0.686 > 0.05. Therefore, we can apply the inferential test of the difference of means among the three groups using a one-way ANOVA test. The results of the one-way ANOVA test is presented in table 4 with $H_0: \mu_{STEM} = \mu_{STEM\_E} = \mu_{Control}$.

Table 4. Hypothetical Test Results.

Variances	JK	Dk	RK	$F_{observed}$	$F_{critical}$	Result
Model (A)	13573.23	3	6886.74	59.03	3.15	H_0 is rejected
Error (G)	10223.72	91	116.67			
Total (T)	23707.21	94				

Based on Table 4, the results of the one-way ANOVA show that there is an improvement of creative thinking abilities through the STEM-E model. It can be seen that in the F test the value of $F_{observed}$ count was 59.03. As the conclusion from the hypothesis test based on the analysis of variance if $F_{observed} \geq F_{critical}$ then H_0 will be rejected. Because 59.03 ≥ 3.15, then we can say that H_0 is rejected, which mean that there is significant differences of the means among the three groups test scores. The post-test results showed that the STEM-E learning model has a better effect on students' creative thinking abilities compared to the STEM learning model and the non-STEM learning model. This is in line with previous study that STEM with ethnomathematics has influence on teaching and learning [48]. This shows that the use of STEM-E is appropriate to improve students' creative thinking abilities. Based on Table 2, the average score of the class that applied the STEM-E model is higher than the STEM model and other models. So, it can be concluded that the STEM-E model is better than the STEM and other models. Judging from difference steps, it can be seen that STEM-E was implemented by mathematics and culture. The students can be guided to solve everyday problems by using technology and combining mathematical thinking patterns and techniques that will bring up new ideas.

Based on the rules of students' mathematical creative thinking ability through the STEM-E model the process begins by observing the questions given by the teacher and gathering facts from various sources, new idea and innovation conduct to ethnomathematics. The facts gathered here are in the form of arguments from some students which are then discussed to find solutions to the problems given [47]. The level of mathematical creative thinking ability in STEM-E models is increased through the stage of creativity and society [48], [88], [89]. On the other hand, in STEM model, the goal is achieved through the stage where the teacher provides initial treatment to students as an introduction that will trigger the emergence of students' creative thinking abilities [65], [90], [91]. Furthermore, in STEM model, students will be observed problems by routine problems which are then given treatment by the teacher.

STEM-E learning can increase sensitivity to real-world problems and make students able to provide various answers or solutions with justification for various phenomena contained in the environment of everyday life related to creative thinking abilities. STEM learning without ethnomathematics will make the process of finding problems slower because of the limited culture innovation given by teacher. This has led to the improvement of creative thinking abilities through STEM-E learning better.

Based on the steps to improve creative thinking through STEM-E learning there are stages of forming ideas and creativity using ethnomathematics conten, namely analyzing the questions given by the teacher and gathering facts from other students, then discussed to find solutions to the problems given. Creative thinking in STEM learning can also be improved through the stage of forming new ideas, creativity without ethnomathematics content. As an achievement of improving students' creative thinking in learning STEM-E refers more to the stage of the use of ethnomathematics content which gives new experiences to students in learning.

STEM-E learning is better in influencing students' creative thinking than STEM learning and normal school curriculum learning. This is based on the STEM-E learning steps. There is an approaching stage by giving new ideas, creativities, and innovations to students in accordance with the students' abilities, as a result of learning mathematics in class can provide optimal results [68], [79], [81], [83], [92]–[94].

Judging from the differences in these steps, it appears that STEM-E learning provides intensive treatment for students to the effect of increasing students' creative thinking, where students can implement new ideas and find various solutions to a problem.

4. Conclusions and Suggestions

Based on the analysis of research, it can be concluded that the creative thinking abilities through STEM-E learning are better than STEM learning and another learning model. STEM-E learning becomes innovative learning that can be applied to optimize students' creative thinking in the industrial revolution era 4.0.

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