The effect of science, technology, engineering, and mathematics (STEM) on students’ creative thinking skills

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Abstract. Students’ creative thinking skills at Senior High School 4 Banda Aceh are still low. This is not in accordance with the Indonesian curriculum, K-13, where students must be more innovative and creative in learning than the teacher. STEM is one approach that is in line with K-13 to improve students’ creative thinking skills. The purpose of this study was to determine the effect of STEM on students' creative thinking skills on the topic of momentum and impulse. The research method used is a quantitative method with a pretest posttest control group design. The populations in this study were all students of 10th year at senior High School 4 Banda Aceh. The sample uses two randomly selected classes. The research instrument was a written test and the data were analyzed using t-test and N-gain. Results of creative thinking skills that arithmetic > t table (5.75 > 1.67) and N-gain 0.63 included in the medium category. The Result showed that there was a significant effect on creative thinking skills students use STEM learning.

1. Introduction
Knowledge, thinking skills, and student learning results in Indonesia are still very low. The results of the PISA data show that the averaged value of knowledge in Indonesia is ranked 9th lowest in the world with the average of 403. Education in Indonesia is still lacking in improving students’ thinking skills and scientific concepts, as evidenced in 2012 Indonesia is ranked 64th of 65 countries [1]. Based on while observations that researchers have done at Senior High School 4 Banda Aceh through interviews with physics teachers, there are still some students whose learning results are still below the minimum score criteria (KKM), this shows that students’ thinking skills and creativity are still low, the low learning results and students' thinking skills are in stark contrast to the demands of Indonesia Curriculum 2013 (K-13) which requires students to be more innovative and creative in learning, there are already many approaches and learning models that can improve student learning outcomes and creativity such as STEM.

STEM was first introduced by the NSF (National Science Foundation) in the United States in the 1990s. STEM is combinations of four major branches of sciences are science, technology, engineering, and mathematics [2]. STEM education is an approach in learning where in its application
can combine two or more components of the branch of science or between one component of STEM with other sciences [3], STEM education aims to combine the skills of students called 4C namely: creativity, critical thinking, collaboration (collaboration), and communication (communication) [4]. STEM Education expects students to be able to develop their skills in the real world and are able to solve problems encountered in daily life. Students’ abilities that are expected after STEM integrated learning are: (1) able to identify problems and gain new knowledge, (2) understand the characteristics of stem disciplines as an investigation, design and analysis process, (3) understand how stem disciplines demonstrate the intellectual and cultural conditions of the world, and (4) are involved in issues concerning stem [5]. Students will be better at solving problems, becoming innovators, inventors, more independent, logical thinkers, and technologically skilled with integrated learning STEM [6]. STEM education can help the next generation of students to solve real-world problems by applying concepts that are interdisciplinary as well as the capacity for critical thinking, collaboration, and creativity [7].

The integration of STEM education in teaching can be done at all levels of education from elementary schools to universities [8], STEM education is an alternative to make learning more relevant for students in discussions, discoveries, experiences, and to increase knowledge [9], STEM can help students to solve real-world problems by applying the concept of interdisciplinary and also the capacity of critical thinking and collaboration [7], previous STEM research shows that students become more understanding about the relevance of scientific knowledge they learn in class with everyday life [8] so that students are more creative in solving problems, STEM is suitable for creativity because in the engineering process this is a process of creativity training [10].

Creativity is often described as the ability to think differently, sensitive to a problem, the ability to solve problems, and find unusual solutions for a period [11], analyzing and solving problems are important steps of the creative thinking process so that if there is no problem solving, then there is no creative thinking [12]. Creative thinking has the characteristics, there are generating unique ideas, produce ideas that are usually not thought out, imaginative, able to produce ideas in a fixed time, the tendency to see problems directly from various perspectives [13], based on the introduction to the problem, this research aims to determine the effect of STEM on students’ creative thinking skills (KBK) in topic momentum and impulses.

2. Methods
This study uses a quantitative method with a pretest-posttest control group design, which is a research design using experimental and control classes. Experimental classes get grade ten one as sample and grade ten-two class as a control class. In the experimental class evaluated using STEMS learning and conventional classes using the lecture method. The hypothesis of this study is about the significant influence on student learning outcomes and creative learning after STEM learning. Samples were taken as many as two class’s determined using random sampling. The object of this study is the results of creative thinking skills (KBK) of 10th year students in Senior High School 4 Banda Aceh. Before using the instrument, it is first validated by the relevant lecturer, then tested on students with a reliability score of 0.79 and classified as high. Statistical tests to improve creative thinking skills (KBK) using normalized gain (N-gain). Hypothesis testing uses parametric t-test samples.

3. Results and Discussion
The results of data analysis are in Table 1.

| Classes   | Score of pretest | Score of posttest | Information          |
|-----------|------------------|-------------------|----------------------|
|           | $x^2_{count}$    | $x^2_{table}$     | $x^2_{count}$        | $x^2_{table}$ | Normally distributed |
| Experiment| 16.98            | 43.8              | 11.31                | 43.80         | Normally distributed |
| Control   | 14.60            | 43.8              | 10.06                | 43.80         | Normally distributed |
Analysis of the experimental and control class data pretest values obtained from the experimental class $x^2_{\text{count}} < x^2_{\text{table}}$ that is equal to 16.98 <43.8 and pretest control 14.60 <43.8. In the experimental class posttest, 11.31 <43.8 and the control posttest were obtained 10.06 <43.8, so it can be concluded that the pretest and posttest normality test scores of the experimental class and the control class were normally distributed.

**Table 2. Analysis of Homogeneity**

| Variant | $F_{\text{count}}$ | $F_{\text{table}}$ | Information |
|---------|------------------|------------------|-------------|
| Pretest | 1.27             | 1.82             | Homogeneous |
| Posttest| 1.76             | 1.82             | Homogeneous |

The table shows that $F_{\text{count}} < F_{\text{table}}$ is 1.27 <1.82 and the posttest is 1.76 <1.82, so it can be concluded that the pretest and posttest of the experimental class and the control class are homogeneous.

**Table 3. Analysis of t-test**

| Groups     | Average | $t_{\text{count}}$ | $t_{\text{table}}$ | Interpretation | Conclusion |
|------------|---------|--------------------|--------------------|----------------|------------|
| Experiment | 79.90   | 5.75               | 1.67               | $t_{\text{count}} > t_{\text{table}}$ | Really different |
| Control    | 63.00   | 1.67               | 1.67               | $t_{\text{count}} > t_{\text{table}}$ | Really different |

The table shows that $t_{\text{count}}$ is 5.75 and $t_{\text{table}}$ is 1.67, so it can be concluded that $t_{\text{count}} > t_{\text{table}}$ is 5.75 > 1.67. The data obtained shows that there is a significant effect on students' creative thinking skills by applying STEM in the experimental class compared to conventional models in the control class.

**Table 4. Analysis of N-gain**

| Classes   | N-gain | Category |
|-----------|--------|----------|
| Experiment| 0.63   | Medium   |
| Control   | 0.33   | Medium   |

**Table 5. Analysis for t-test of N-gain**

| Groups     | Average | $t_{\text{count}}$ | $t_{\text{table}}$ | Interpretation | Conclusion |
|------------|---------|--------------------|--------------------|----------------|------------|
| Experiment | 63.00   | 7.03               | 1.67               | $t_{\text{count}} > t_{\text{table}}$ | Really different |
| Control    | 33.00   | 1.67               | 1.67               | $t_{\text{count}} > t_{\text{table}}$ | Really different |

Data shows that the results of the analysis of the N-gain for t-test experimental class and control class $t_{\text{count}} > t_{\text{table}}$ are 7.03 > 1.67. This shows that there is a significant difference between student creative thinking skills in the experimental class and the control class.

**Table 6. Creative skills data analysis for each indicator for class of experiment**

| Question number | Indicators | Pretest | Posttest | N-gain | N-gain category |
|-----------------|------------|---------|----------|--------|-----------------|
| KBK 1: 2,6,7,8,10 | Fluency (Ask lots of questions) | 46.18 | 79.71 | 0.62 | Medium |
| KBK 2: 1,5,9 | Flexibility (Providing various interpretations of story pictures or problems) | 43.63 | 77.94 | 0.60 | Medium |
| KBK 3: 4 | Originality (Questioning old ways and trying to think of new ways) | 41.17 | 85.29 | 0.73 | High |
| KBK 4: 3 | Elaboration (Look for answers or problem solving by taking steps in detail) | 47.06 | 81.62 | 0.66 | Medium |
Table 7. Creative skills data analysis for each indicator for class of control

| Question number | Indicators | Pretest | Posttest | N-gain | N-gain category |
|-----------------|------------|---------|----------|--------|----------------|
| KBK 1: 2,6,7,8,10 | Fluency (Ask lots of questions) | 50.29 | 63.53 | 0.26 | Medium |
| KBK 2: 1,5,9 | Flexibility (Providing various interpretations of story pictures or problems) | 47.06 | 62.99 | 0.30 | Medium |
| KBK 3: 4 | Originality (Questioning old ways and trying to think of new ways) | 38.97 | 61.03 | 0.36 | High |
| KBK 4: 3 | Elaboration (Look for answers or problem solving by taking steps in detail) | 37.50 | 63.24 | 0.41 | Medium |

Based on the results of the study there is an influence on students’ creative thinking skills after STEM learning, before STEM learning was done there were still many students whose grades were below KKM, but after STEM learning was done, students' creative thinking skills improved, this is because students are directly involved in the learning process the teachers only act as facilitators, so students become more active and creative in learning.

Increased students' creative thinking skills can be seen in the average values of posttest students which is increasing compared to the average values of pretest, the difference in creative thinking skills between the experimental class and the control class is also evidenced by the results of the t-test that there are significant differences like the data in the table above, learning by using STEM the results are better than the lecture method.

The results of the analysis indicators of students’ creative thinking skills improved after STEM learning, as seen in table 6 and table 7. Students in the experimental class can dominate the four STEM indicators compared to the control class. The difference can be seen in the average value and N-gain. This is caused by students directly involved with the four indicators; fluency, flexibility, originality elaboration.

The results of the data analysis above show that learning using STEM is better in improving student learning outcomes and creative thinking skills, STEM is problem-centered learning, inquiry-based learning, design-based learning, and cooperative learning [15] so students can connect momentum learning and impulses with the technological design that has developed at this time. Student learning outcomes in STEM learning improve because students can connect learning by identifying information scientifically and applying it in everyday life.

The results of previous studies on learning with the STEM approach show a positive influence on learning outcomes and students’ creative thinking skills. Student achievement and interest in learning in science learning increases by using an entrepreneurial-based STEM approach [8]. 90% of students get results above the KKM [16]. Integrating the STEM approach in learning media shows satisfactory results on the validity and reliability of the instruments used [17]. STEM-based teaching materials can improve students’ command of concepts in the learning process [18].

4. Conclusions
There is a significant influence on students’ creative thinking skills in momentum and impulses topics, creative thinking skills of students through STEM learning obtained N-gain KBK 1 of 0.62 medium criteria, KBK 2 of 0.60 medium criteria, KBK 3 of 0.73 high criteria and KBK 4 of 0.66 medium criteria.
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