Promoting inquiry-based learning for science, technology, engineering, and math (STEM) to enhance students’ creative thinking skills

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Abstract. Creative thinking skills are one aspect of achievement expected in the 2013 curriculum. However, the result of evaluations conducted by PISA that student’s skills are still low. The present study was carried out to determine the application of inquiry-based learning for Science, Technology, Engineering, and Math (STEM) to enhance students’ creative thinking skills under temperature and heat material. To investigate the matter, a quasi experimental with the design of Nonequivalent control group design was employed. The participants were selected based on the purpose of the sample. To collect the data, test instruments were used among students’ creative thinking skills validated with 0.611 of reliability test results classified as high. The findings in this line of experimental class showed an average score of pretest 38.03 and posttest 83.17 with the acquisition of an N-gain value of 0.72 indicating the average score thus it was included high category. Besides, the control class disclosed the average score of pretest 37.20 and posttest 79.53 with the acquisition of N-gain value of 0.66 indicating the average score and thus it is included the average category. Based on the acquisition of the N-gain value, the t-test of the two classes was obtained, t_obs > t_table (2.118 > 2.045), and therefore it can be concluded that there were significant differences between the experimental class and the control class. Based on the results obtained in this line of study, it is therefore concluded that the application of inquiry-based learning for STEM could enhance students’ creative thinking skills under temperature and heat material.

1. Introduction
Throughout history knowledge and technology are growing rapidly and have been the driving force of change under the development of 21st century. And to be globally competitive today, students are required to master various essential life skills. Through education many beneficial lifelong learning skills can be developed such as thinking skills and problem solving skills [1]. The fundamental essence of education for world citizenship is to prepare students the right way of thinking, such as creative thinking skills [2]. Students must be empowered to use critical reflection and analysis to evaluate ideas and problems. Creative thinking skills are the ability of students to response problems based on existing information with various kinds of alternative answers, the answers show originality, flexibility, fluency and elaboration [3]. To
develop creative thinking skills the teacher shall have effective learning strategies in enhancing students’
creative thinking skills.

With regard to findings concerning creative thinking skills among students on one high school at Banda
Aceh conducted in November 2016, the researchers have found out several crucial issues. According to the
teacher of physics, students’ creative thinking skills are still low, especially in the matter of temperature and
heat, if there are changes in forms of questions in the same scope, students still relatively find it difficult to
work on such formulated questions. This can be figured out in their cognitive or daily test scores in the
previous lessons, which is fluid at 59.8, while KKM has been determined at 75. Students have experienced
difficulties because the strategies taught during learning are only to overcome problems that require math
calculations [4].

To address such issues, the effective learning strategy is mainly necessary because the creativity of
students depends on the teacher in understanding how creativity is developed [5]. Teachers are necessary to
utilize a learning approach that can train students’ creative thinking skills. One learning approach that can
be effectively used is the STEM learning approach [6]. STEM learning is an integration of learning science,
technology, engineering and mathematics which is recommended to help the success of 21st century skills
[6]. This has been proven by several researchers. The development of STEM education on student
worksheets can effectively train students' creative thinking skills [7]. And thus, its effectiveness is able to
train students' creative skills [8]. The STEM project-based learning approach is effective and can enhance
students' creative thinking [9]. Students’ creative thinking skills after the problem based learning model
approaching science, technology, engineering and mathematics in solubility and solubility products are
categorized in good criteria [10]. Furthermore, by applying the STEM approach, students' knowledge in
solving problems has demonstrated an increase in concrete and active learning for the development of
student competence [11]. STEM-based learning is able to improve students’ interest and provide experience
in the process of making techniques [12]. Student achievement and interest in science learning are getting
improved through the entrepreneurship-based STEM approach [13].

The application of STEM indirectly requires teachers and students to think creatively. Many previous
studies have explored STEM learning on the learning process and have received good results, yet the
inquiry-based learning model for STEM in measuring creative thinking skills is still limited. Therefore, this
study was carried out to examine the application of inquiry-based learning for Science, Technology,
Engineering, and Math (STEM) to enhance students’ creative thinking skills under temperature and heat
material.

2. Methods

2.1 Methods and research design
To address the issues in the current research, a quasi-experimental method referred to a method that controls
one of the variables is used. As well, the research design used was nonequivalent control group design. Two
groups are chosen as the research subjects, the experimental group and the control group.

2.2 Population and sample
This research chooses students of class XI one of the high schools at Banda Aceh 2018/2019 academic year,
there are 186 students divided into 6 classes. The participants were selected based on the purpose of the
sample, and in turns, students of class XI-MIA-5 and XI-MIA-4 are selected as samples in this research.
2.3 Data collection technique
Data collection is carried out in accordance with the design of the research technique. The types of instruments used in this study are creative thinking skills in the form of multiple choice questions adapted from the National Examination questions, SNMPTN, UMUGM, and SBMPTN. The instrument has been validated by an expert before delivered to the students. The validation results will be tested on the class that has studied the lesson concerning temperature and heat. The results of the trial analysis are obtained through reliability index of 0.611 with a high category.

2.4 Data analysis technique
The data analysis technique used in this study is a prerequisite test. In this regard, it consists of a test for normality and homogeneity. While for hypothesis testing uses the t test in order to test whether there is an increase in creative thinking skills using N-gain.

3. Results and discussion
The results of measurement and analysis of N-Gain per indicator data in the experimental class was presented in the following Figure 1. An analysis of each N-Gain data on each indicator of creative thinking skills was carried out to figure out how much improvement occurred in the experimental class through the application of inquiry-based learning model for STEM.

![Figure 1. Enhancing the average score of creative thinking skills for each indicator of experimental class.](image)

Figure 1 showed the difference in enhancing creative thinking skills with different categories of three indicators. It could be highlighted that the indicators have experienced an increase in the high category, it also demonstrated various interpretations towards a figure, story or problem (KBK 2) was 0.75, while the indicator questions the old ways and tries to think of new ways (KBK 3) has the lowest score of 0.47 classified in the average category. Overall, the inquiry-based learning model has a positive impact and most students experience significant increase. This shows that STEM is effective for creativity, because in the engineering process this is the process familiarly called as the training creativity [9].

Furthermore, the results of measurement and analysis of N-Gain data per indicator on students’ creative thinking skills in the control class are presented in the following Figure 2.
According to Figure 2, it can be seen that the indicators that experienced the highest increase were delivering questions (KBK 1) of 0.67 in the medium category. While indicators question the old ways and try to think of new ways (KBK 3) have the lowest score of 0.59 also in the average category. The direct instruction learning model can also enhance students' creative thinking skills. This shows that the implementation of direct instruction in students can improve students' creative thinking skills [14].

The results of different test average pretest scores on creative thinking skills in Table 1 disclosed that the initial ability of students in the experimental class and the control class were not significantly different. This demonstrated that the initial ability of the experimental class students and the control class is just similar. Furthermore, the increase in the final ability of students based on the posttest data has been analyzed through two different tests and showed a significant difference.

**Table 1.** Averaged difference of pretest and posttest scores of creative thinking skills

| Creative thinking skill | Classes   | Average score | Normality* | Homogeneity** | Significance*** |
|-------------------------|-----------|---------------|------------|---------------|----------------|
|                         |           |               |            |               |                |
| Pretest                 | Experiment| 38.03         | L_count< L_table (0.158)< (0.161) (normal) | F_count< F_table (0.177)< (4.004) (homogeneous) | T_count> T_table (0.394)< (2.045) (not significantly different) |
|                         | Control   | 37.20         | L_count< L_table (0.160)< (0.161) (normal) | F_count< F_table (0.056)< (0.081) (homogeneous) | T_count> T_table (1.67)< (2.045) (significantly different) |
| Posttest                | Experiment| 83.17         | L_count< L_table (0.154)< (0.161) (normal) | F_count< F_table (3.916)< (4.004) (homogeneous) | T_count> T_table (2.118)< (2.045) (significantly different) |
|                         | Control   | 79.53         | L_count< L_table (0.131)< (0.161) (normal) | F_count< F_table (0.177)< (0.161) (homogeneous) | T_count< T_table (0.154)< (0.161) (normal) |

Information:
*) = Lilliefors Test (normal, Lhit score< Ltab, = 0.05)
**) = Test F (homogeneous, Fhit score <Ftab, = 0.05)
***) = Test t (significant, thit<ttab, = 0.05)
Table 1 shows that the average score of the experimental class pretest is 38.03 and the mean score of the posttest is 83.17. While the mean score of the pretest in the control class is 37.20 and the mean score of posttest is 79.53. Differences in scores obtained on the results of both pretest and posttest on the creative thinking skills in the experimental class and the control class were influenced because of the treatment given to students. By applying the inquiry-based learning model for STEM can effectively enhance students’ creative thinking skills. The inquiry model can improve student understanding of concepts, as well as improve student learning activities [15]. Inquiry-based learning has been formed in a structured way [16]. This type of inquiry learning is used to teach certain concepts, facts or skills and teach students how to formulate problems themselves to be investigated. And therefore, the contribution of the inquiry-based learning model for STEM can improve students’ creative thinking skills. By creating such beneficially creative products and integrating STEM knowledge can influence the level of creativity of students [17]. Creative is influenced by STEM knowledge that can support students’ creativity by integrating knowledge, skills, and everyday problem solving skills. STEM is in the form of collaborative learning, direct experience, creativity, and practical application [18]. STEM is generally conducted in the middle class, where STEM content is interactive, interdependent, and adaptable are all centers of success [19].

4. Conclusion

By way of conclusion, the researchers would simply like to draw the attention once more to the fact that the application of the inquiry-based learning model for STEM can significantly enhance creative thinking skills under the temperature and heat subject seen from each indicator. This could be evidenced by the increase in the posttest average score of 83.17 creative thinking skills for the experimental class and 79.53 for the control class.

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