Development of creative thinking skills through STEM-based instruction in senior high school student

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Abstract. Creative thinking is one of the abilities in the 21st Century that must be mastered by students. The difficulty of developing students' creative thinking is because teachers in the school do not make a collaboration between technology and science in learning. The purpose of this study is to develop creative thinking through the application of Science Technology Engineering and Mathematics (STEM) based learning. This research was conducted at 1 Kerinci Public High School. the sample include 90 Students divided into three classes namely Experiment Class 1 (EC 1) are given STEM-based learning, experiment Class 2 (EC 2) given Science Engineering Mathematics Learning (SEM) and Control Class (CC) given conventional learning. The method used is a quasi-experiment with pre-post control design. The instrument used was 12 essay questions validated by 7 experts. The results were analysis using Anava mixed method with the General Linear Model. The results show that STEM-based learning improves creative thinking skills by 0.663 or 66.3% in the medium category, this shows that STEM-based learning is effective in developing students' creative thinking, STEM-based learning also provides experience to students in collaborating between technological science, engineering and mathematics in optimizing learning.

1. Introduction

The development of information technology enables the implementation of unlimited distance and time education. Teaching materials, learning resources and assessment techniques can be developed online and initiate leaving the traditional learning system. However, the development of this technology has not been fully supported by human resources capable of adopting advanced technology. Resources are needed that have creativity and innovation to take advantage of the development of information technology especially for the advancement of education. This challenge must be overcome for the generations who want to compete in the 21st century. One of the competencies that must be possessed to compete in the 21st century is creative thinking skills. Creative thinking is also the foundation of world progress and development [1]. People who have a high level of creativity are able to find solutions to the problems they face. Creative Thinking is one of the 21st Century skills that students ought to master [2]. The government has understood this need by always developing a curriculum that follows the demands of development and market needs. One of them is by improving the existing curriculum into the 2013 curriculum by prioritizing scientific skills and activities that trigger creative thinking. However, based on surveys conducted in SMA N 1 Kerinci, learning in schools still does not lead students to think creatively, many teachers do not use technology, and based learning asks students to
conduct investigative activities in learning that encourage students to learn and student learning resources become limited [3]. To improve the ability to think creatively on students, the teacher must create a creative environment and learning. One of the lessons learned is to collaborate the science of engineering technology and mathematics (STEM) in learning [4], [5]. SMA N 1 Kerinci is a suitable school for implementing STEM-based learning, this is related to school policies that allow students to bring smartphones.

STEM-based learning provides opportunities for students to collaborate their knowledge in building understanding. Where students can use technological science engineering and mathematics to solve everyday life problems. The application of STEM in the teaching and learning process can be applied with various learning models [6]. One model that can be combined with the application of STEM is inquiry [7], this is because the inquiry learning model combined with STEM is in accordance with the characteristics of high school students who use technology a lot in solving laziness in everyday life [8]. Besides learning using the inquiry model provides opportunities for students to improve their creative thinking skills [9].

Especially in physics learning, giving meaningful learning experiences to students through inquiry activities can foster student learning motivation [10-11]. Physics learning is closely related to experiment activities which require students to be able to cooperate in solving problems, conducting investigations, using tools, collecting data, analysis data, expressing opinions in drawing conclusions so that these activities can encourage students to think creatively [12].

Creative Thinking is an ability that allows students to apply their imagination to produce ideas, questions and hypotheses, experiment with alternatives, and to evaluate themselves and the ideas of their peers, with the end result in the form of products [13-14]. Creative thinking can also be interpreted as a mental process that gives birth to an intelligent mind, reasoning that uses imagination extends, modifies, or changes symbols, images, ideas, patterns, conditions, or elements in the world around us as a result of creative thinking in the form products, devices, processes or methods. In developing the ability to think creatively students need self-motivating abilities which are part of emotional intelligence [15].

The development of creative thinking skills can be done by applying the 4 steps that must be passed including preparation, exploration, incubation, and verification [16-17]. At the preparation stage begins with searching for information, this can use the facilities that are provided by the library, website, communicate with people around, or collect data and other materials that support. The next step is Exploration at this stage what must be done is analyzing, designing, seeing one with a different perspective and try to connect ideas and draw conclusions. After doing this, one can leave the task for a moment, this stage is called the Incubation stage, this aims to employ the subconscious to the problem and help us see the problem with a different perspective. The final stage of the development of Creative Thinking is verification where someone tries to understand why and why it can determine whether the solution to the problem obtained can be improved by different problems that require complex solutions.

Increasing the ability to think creatively can be seen from the indicators of creative thinking. Measurement of creative thinking in this study will focus on 4 aspects, namely as follows Fluency includes the ability to express various kinds of ideas and always provide many ways or suggestions for doing many things. Flexibility (flexibility) includes the ability to produce ideas, answers or questions that are varied, originality includes the ability to provide unique responses that are different from others, elaboration includes the ability to enrich and develop ideas and detail the details of an object [14,18-20].

Based on the problems described above in this study will apply STEM learning to physics subjects using the inkuri model. Where students will be given the opportunity to develop scientific knowledge by utilizing the ability to use technology, the ability of engineering and mathematics in solving science problems in everyday life to develop the ability to think creatively. The objectives of this study in detail are:

1. To find out the implementation of STEM-based learning that is applied in SMA N 1 Kerinci?
2. To find out the effect of STEM-based learning on increasing creative thinking?
2. Methods

The method used was quasi experiment where there were three groups given treatment different from the experimental class 1 given STEM-based learning, experimental class 2 given SEM learning, and the control class was given conventional learning which was usually done in school. Design the research used was pre-post control design. In the first stage students in each group were given a pre-test to learn the students' initial abilities. Furthermore, a different treatment was set by the next group to be given a post test to determine the increase in creative ability of thinking skills after being given treatment. The research design used in this study can be seen in table 1.

| Group  | Pre-test | Treatment | Post-test |
|--------|----------|-----------|-----------|
| CE1    | T1       | X1        | T2        |
| CE2    | T1       | X2        | T2        |
| CC     | T1       | C         | T2        |

CE1 : Class Experiment 1 (STEM)
CE2 : Class Experiment 2 (SEM)
CC : Class Control (Conventional)
X1 : Treatment with STEM-based learning.
X2 : Treatment with STM-based learning.
C : Conventional Method.
T1 : Pre-test
T2 : Post-test

The study was conducted at SMA N 1 Kerinci with a sample of 90 students of class X randomly selected, and divided into 3 groups. The instrument used to measure creative thinking ability is 12 essay questions that are adjusted to Newton's legal material using four indicators of creative thinking, namely fluency, flexibility, originality, and elaboration. The instrument used was first validated by seven validators, the results were analyzed by calculating the CVR score the results of the analysis are shown All validators consider that all items of creative thinking are ready to be used in research with several improvements, including the use of images, writing formulas and the simplicity of sentences, where CVR scores = 1. Then analysis the value of content validity index (CVI) the average value of CVR is equal to 1. After the instrument is declared valid by the validator, then the instrument is tested first in class XI students who have received Newton's legal material using a sample of 96 people to see the empirical validity and reliability of the questions before use. The trial results are analysis using the QUEST program. Infit mean square shows that the items used in accordance with the rasch model, it is intended that the distribution of data is in the interval 0.77-1.30. for infit t all items are in the range of -2.0 to +2.0 this shows all items valid and ready for use in the research.

The increase in creative thinking ability was measured based on the results of the pre-test and post-test, the data analysis using the Anava Mixed Design test with the General Linear Model in which two analysis were combined, namely within subject test (pre vs. post) and between subject test (CE1, CE2, CC). the purpose of selecting this technique is to determine the effect of STEM learning with the Inquiry Model on increasing the ability to think creatively.

3. Results and Discussion

3.1. The Implementation of STEM-Based Learning applied in SMA N1 Kerinci

The implementation of learning is done by using two observers who are assessed based on the prepared lesson plan. STEM-based learning using the Inquiry Model has five steps. namely, 1. Orientasi, where students are given an understanding before the implementation of learning in school, students are given material and some research questions. At the meeting in class students are asked to discuss to strengthen understanding of the questions given. 2. Organizing, at this stage students in groups try to find trial and
error about Newton's law with guidance from the teacher. 3. students observe the results of experiments, data collection and analyze the results of experiments. 4. Test the hypothesis, students try to find answers to the research questions that have been given by the teacher based on the results of the experiment with the discussion method. 5. Make conclusions, at this stage the educator is asked to verify the experiment activities carried out, report the results of the experiment and present the results of the experiment. The implementation of STEM learning that is applied follows figure 1.

Figure 1. percentage of implementation

The first meeting of students is given learning in the material of Newton's Law I, on the Orientasi step, only a portion of students do online learning so that the learning material, video learning and research problems are not understood by students so that at this step the teacher gives a direct explanation in class so the learning time to do the trial was not maximal, this happened because online learning and the use of technology in learning were new for students of SMA 1 Kerinci. The second meeting and three students were given the material of Newton's Second Law, at the second meeting many students had difficulty in finding an experimental design that was suitable for conducting motion experiments on flat fields, how to collect data and analyze data. So, learning time in discussing experimental results is not optimal. At the third meeting students are getting used to STEM learning, students actively ask questions on online learning so that at face-to-face meetings students become proactive. At the fourth meeting the students were given the Newton 3 Law material, students were familiar with the learning pattern so that students could complete experiments on Newton's Third Law before the learning time ended, to maximize learning at the meeting of the four teachers giving a review of Newton's Law I and II discussed earlier.

3.2. The effect of STEM-based learning on improving creative thinking skills

Improvement of students 'creative thinking skills can be seen from the desirability of students' pretest and posttest. Measurement of creative thinking skills is done by giving essay questions that are in accordance with creative thinking indicators, namely fluency, flexibility, originality and elaboration. Descriptive and posttest descriptive results follow Table 2.

| Creative thinking skills | CE1 pre | CE1 post | CE2 pre | CE2 post | CC pre | CC post |
|--------------------------|---------|----------|---------|----------|--------|---------|
| Fluency                  | 50.63   | 81.87    | 49.37   | 71.87    | 54.63  | 69.38   |
| Flexibility              | 43.13   | 78.75    | 47.50   | 74.37    | 47.50  | 66.25   |
| Originality              | 44.38   | 80.00    | 42.50   | 76.25    | 37.50  | 66.25   |
| Elaboration              | 45.63   | 79.38    | 42.50   | 70.00    | 39.38  | 62.50   |
| Average                  | 45.94   | 80.00    | 45.47   | 73.12    | 42.50  | 66.09   |
| Normality                | 0.159   | 0.130    | 0.262   | 0.430    | 0.238  | 0.097   |
| Homogeneity              | Pre-test = 0.742 | Post-test = 0.166 |
The descriptive results of pretest and posttest showed that the increase in students' creative thinking skills increased after being given treatment. This means that the treatment given has an influence on the ability to think creatively. Further analysis using anova mixed design with a general linear model to determine the increase and effect size of the treatment given. To find out the amount of improvement given each treatment given to students is done by looking at the effect size score. Results of analysis of bellows size effect table 3.

**Table 3. Analysis effect size**

| Class          | Hotelling’s trace | F     | Sig. | Partial Eta Squared |
|----------------|-------------------|-------|------|---------------------|
| Class Experiment 1 | 1.832E2*          | .000  |      | .663                |
| Class Experiment 2 | 1.208E2*          | .000  |      | .565                |
| Control Class    | 86.757*           | .000  |      | .483                |

STEM-based, SEM and conventional learning has a significant increase where (p <0.005) and learning that make the biggest contribution in increasing creative thinking are STEM-based learning of 0.663 in the "moderate" category. SEM learning contributed 0.565 with the category "moderate" and conventional learning contributed an increase of 0.483 in the "small" category. Thus it can be concluded that learning that is suitable for improving the ability to think creatively is STEM-based learning.

3.3. Finding

STEM-based learning with the inquiry model can theoretically be used to improve creative thinking skills, because its application is based on investigation and fits into the domain of physics (experimentation, experimentation, hypothesis and thinking in solving problems) [14,21]. STEM learning combined with the inquiry model provides opportunities for students to increase creative thinking skills [22]. In this study learning is designed based on the developmental steps of creative thinking with the use of STEM. Thus, each syntax that is applied interrelates between the steps of creative thinking and STEM so that the increase in creative thinking and the use of STEM can be integrated. The relationship between creative thinking steps and STEM follow table 4:

**Table 4. relationships between creative thinking and STEM**

| The Creativity Cycle | Investigation Activity at class room | STEM                        |
|----------------------|--------------------------------------|-----------------------------|
| Preparition          | Giving problems through online learning, discussion in problem solving planning. | Science and technology      |
| Exploration          | Designing experiments in solving problems, collecting data, analyzing data, making conclusions. | Science, Technology, Engineering, and mathematics. |
| Incubation           | Students recall what has been done and write sequentially what has been done during the experiment in solving the problem given. | Science                      |
| Verification         | Students make a report of the experiments conducted and present the results of the experiments in the class. | Science and Technology        |

STEM-based learning is creative and active learning that can build student motivation [4]. By collaborating the use of technology in learning such as blended learning can support the ability of science to energize students in solving problems [23]. Which is the basis in building students' creative thinking skills [15]. In implementing STEM learning it is necessary to pay attention to several aspects. Among the aspects of students' readiness in accepting STEM learning, this is because some students only excel in one aspect such as Science and are weak in the aspects of Engineering and Mathematics. Therefore,
the teacher needs to know the character, weaknesses and strengths of students in implementing STEM-based learning.

4. Conclusion

STEM learning combined with the inquiry model is suitable learning applied in increasing students' creative thinking abilities. This is because this learning directs students to go through the step of developing creative thinking, namely preparation, exploration, incubation and verification combined with experiment activities. The results of the study show that STEM-based learning contributes to improvement quite strongly towards creative thinking, this can be seen from the score of the effect size of 0.663. The implementation of STEM-based learning must pay attention to student characteristics and students' readiness to use technology. Further research is expected that researchers to design project-based STEM learning adapted to the stage of development of creative thinking where students are encouraged to innovate in solving everyday problems. So that learning can provide motivation to students in learning.

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