Integration of Problem Based Learning (PBL) and Engineering is Elementary (EiE) to improve students’ creativity

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Abstract. This study aims to measure and analyze the creativity of high school students on Magnetic Induction topic through the application of Problem Based Learning (PBL) which are integrated with the Engineering is Elementary (EiE) approach. This quasi-experimental control group design formed research was conducted on students of Darul Imarah 1 Public High School. By using random sampling, grade twelve 2 was chosen as an experimental class and grade twelve 3 was chosen as control class. Student’s creativity was obtained through student’s answers to the Torrance Test of Creative Thinking (TTCT) creativity instrument for three aspects of creativity (elaboration, originality, and fluency). The result of t-test analysis of student’s creativity in the experimental class showed significant differences between both classes. The creativity of the experimental class students was found to be better than the control class for all three aspects of creativity. The result of this study has provided an evidence of empirical results that the models and approaches could increase student’s creativity, so active student learning approaches such as the PBL model have deserved to be used in teaching and learning process and are considered to be carried out in the High School Curriculum.

1. Introduction

Creativity in education is an important aspect that must be considered, but from all observations and also research shows that learning activities that are generally still teacher centered (teacher centered) are not able to increase student creativity [1]. One of the latest efforts and innovations in the world of education to develop student’s active and creative learning is the implementation of learning that is based on problems or often referred to as Problem Based Learning (PBL). This is inseparable from the characteristics of the PBL model which is one model that focuses on developing thinking skills, problem solving, and skills in independent learning [2]. Besides PBL, it is also a model of learning approach that actively promotes students in learning through research, integrating theory, and applying knowledge and skills to real solutions to solving everyday problems [3].

The implementation of the PBL model in the teaching and learning process is also in line with the goals of 21st century education in general, namely education that leads to human development that is able to think critically and creatively and is able to apply it in solving problems [4]. In the context of science (Physics) education as well, [5] has suggested that we need to foster students’ skills in thinking
about solving problems and making conclusions based on scientific facts and explanations. So that the PBL learning model should be used as a model in the process of teaching and learning Physics at school.

The implementation of the PBL model as one of the pedagogical models in the teaching and learning process will certainly show maximum results if implemented through active student learning approaches. One of the appropriate active learning implemented with PBL is the Engineering is Elementary (EiE) approach [6,7]. This is also in line with the K-13 curriculum philosophy, where the EiE approach generally applies an appropriate engineering design process to be carried out in the process of teaching and active learning such as the PBL model [8]. Besides that from the results of several studies, the EiE approach as one of the active learning approaches shows a positive influence on increasing students' various abilities, especially in improving student creativity [9].

Therefore the implementation of the PBL and EiE models in the teaching and learning process of physics is considered appropriate, given that physics learning prioritizes models and approaches that emphasize student process skills and are characterized by active learning such as the PBL model and EiE approaches [7,10,11]. Integration between the PBL model and the EiE approach is possible because both have learning characteristics that are in line.

Based on various advantages of the characteristics of the PBL model and the EiE approach to improve student's abilities, this study attempts to integrate the PBL and EiE models into the teaching and learning process of physics to improve student’s abilities, especially aspects of creativity. So that this integration is expected to be used as a guide by the teacher for the implementation of active learning through the application of the PBL model along with the EiE approach. Besides this study also tried to provide empirical evidence of the implementation of the PBL model and the EiE approach to increasing student creativity in physics learning especially Magnetic Induction topic.

2. Literature review
PBL is one learning model that presents contextual problems as a basis for learning to stimulate learning students, where the learning process is centered on students and teachers only as facilitators [12]. PBL learning is a learning model that challenges students to "learn how to learn", work in groups to find solutions to real-world problems. This problem is used to bind students to increase curiosity in the intended learning. In other words, the PBL learning model is designed so that students get important knowledge that makes students proficient in solving problems, and has their own learning model and participate in groups [8].

Application of the PBL model when the teaching and learning process in the classroom is carried out following five phases of learning and teacher behaviour [2,8]. The five learning phases consist of: student orientation to the problem; organize students; guiding independent and group investigations; develop and present the work; and analyze and evaluate the problem solving process. More detailed each phase in the teaching and learning process in the classroom can be carried out as follows [2,8,12].

Phase of student’s orientation to the problems; in this phase students are given a problem and asked to think about the solution. The problem given is a contextual problem and requires complex thinking so it does not have an absolute correct answer. In addition, in this phase, students must understand what is the purpose of the learning that will be carried out. Phase organizes of students; besides developing problem solving skills, PBL learning also encourages students to collaborate through this phase of organizing students. Considering that to solve a problem, students need to collaborate and discuss between groups so that groups compiled by teachers should pay attention to heterogeneous students so that communication that occurs between group members is more effective for. Phase helps independent and group investigations; although each problem situation requires different investigation techniques, but generally involves identical characters, namely data collection and experimentation, hypothesizing and explanation, and providing solutions. In this phase the teacher must encourage students to collect data and carry out experiments (mental and actual) until they truly understand the dimensions of the problem situation.

Phase develops and presents works; the investigation phase is followed by creating products or works and showing them off. Artifacts are more than written reports, but can be a video (showing the problem
situation and proposed solution), a model (physical manifestation of a problem situation and its solution), a computer program, and a multimedia presentation. Of course the sophistication of artifacts is greatly influenced by the level of thinking of students. Then students exhibit their work and the teacher acts as an exhibition organizer. The phase analyzes and evaluates the problem solving process; This phase is the last stage in PBL, where this phase is intended to help students analyze and evaluate the problem solving process, investigative skills, and intellectuals that they use. During this phase the teacher asks students to reconstruct the thoughts and activities that have been carried out during the process of learning activities, such as when students first begin to get a clear understanding of the problem situation?, when students begin to feel confident in a particular solution?, why do students adopt the final solution of students?, and what they will do differently at other times.

Meanwhile Engineering is Elementary (EiE) is also one of the learning approaches that adopts and implements engineering design process steps in the teaching and learning process in the class which consists of ask steps, imagine, plan, create, and improve [9,10,13]. In more detail they also gave an overview of student activities for each step of the engineering design process. Ask steps; students study or think of one problem related to the science concepts that occur in their daily lives. If students cannot find problems related to science concepts, the teacher can help by giving a problem or a scientific phenomenon in the form of a story. After students understand the problem, at the step of imagining (imagine), students think or imagine how to solve the problem based on the knowledge of the physical concepts they learned. So from the completion they have thought, students choose the best for the next designed (plan) together with group members and discuss how the solution can be applied in the form of real products. In order to make it easier for students to find ideas or designs for how the solution can be applied as a product, students can draw it first in the form of a sketch. The next step of the engineering design process is to apply or create, where students are asked to produce a product according to what has been planned and in accordance with the sketch of the drawing that has been made before. Then the final step is to improve, in this step students are asked to present the products they have produced so they can assess the advantages and disadvantages of the product. The five steps of the engineering design basically do not have a standard sequence but are in the form of a cycle, so that if after the last step the product is produced it cannot solve the problem given, the student can repeat it from the first step.

The five PBL phases and the five steps of EiE described above in the research are arranged in the form of a Learning Implementation Plan (LIP) as a teacher's guide to implementing the teaching and learning process in the classroom. Integration between the PBL model and the EiE approach is very likely to be carried out in the learning process because both are based on a problem that must be solved by students [12,14-16].

3. Method
Research with quasi experiment type was carried out at Darul Imarah 1 Public High School, Aceh Besar in the Odd Year 2017/2018. Two classes of grade twelve that have the same Physics average score are selected as sample then given a different learning model and approach. Through random sampling the class grade twelve 2 was selected which numbered 26 students carried out the PBL model and EiE approach to this research. Meanwhile, grade twelve 3 which numbered 26 students carried out conventional learning, namely learning that combined lecture and discussion methods.

Creativity data obtained from the results of student answers to the Torrance Test of Creative Thinking (TTCT) instrument which includes three indicators of creativity, namely: elaboration, originality, and fluency [17-19]. Students are given the task of designing images of energy-efficient fans on the test sheets provided. Then the results of the student answers were assessed for the three indicators of creativity through the assessment rubric as shown in table 1.
Table 1. Scoring student creativity tests.

| Indicators | Score | Information |
|------------|-------|-------------|
|             | 0     | a. Only one line is needed to make one picture  
|             |       | b. Several times the picture is the same  
|             |       | c. No additional ideas added  
|             |       | d. There are additional ideas added, but are outside the previous answer area  
| Elaboration | 1     | a. There are only two lines needed to make one picture  
|             |       | b. Once the picture is the same  
|             |       | c. No additional ideas added  
|             |       | d. There are additional ideas added, but are outside the previous answer area  
|             | 2     | a. More than two lines are needed to make one picture  
|             |       | b. Once the picture is the same  
|             |       | c. More than two additional ideas added  
|             |       | d. There are additional ideas added, but are outside the previous answer area  
|             | 3     | a. More than two lines are needed to make one picture  
|             |       | b. There are no similar images  
|             |       | c. More than two additional ideas added  
|             |       | d. There are additional ideas that are added and are in the previous answer area  
| Originality | 0     | a. There are no unique or unusual ideas at all  
|             |       | b. There is no image of the initial stimulus for the combination, resulting in an original bonus score  
|             | 1     | a. There is one unique or unusual idea  
|             |       | b. There is no image of the initial stimulus to do a combination, resulting in an original bonus score  
|             | 2     | a. There are two to three unique or unusual ideas  
|             |       | b. There is one image of the initial stimulus for the combination, resulting in an original bonus score  
|             | 3     | a. There are more than three unique or unusual ideas  
|             |       | b. There are more than one initial stimulation image for combination, resulting in original bonus score  
| Fluency | 0     | a. There is no title & no stimulus  
|         |       | b. Repeat the same image  
|         |       | c. Draw quickly and carelessly  
|         |       | d. Simple image & Incomplete image  
|         |       | e. The image is not well organized  
|         | 1     | a. There is a title & no stimulus  
|         |       | b. There is no repetition of the same image  
|         |       | c. Draw quickly and carelessly  
|         |       | d. Detailed picture but incomplete picture  
|         |       | e. The image is not well organized  
|         | 2     | a. There is a title & stimulation  
|         |       | b. There is no repetition of the same image  
|         |       | c. Draw quickly and carelessly  
|         |       | d. Detailed picture & complete  
|         |       | e. The image is not well organized  
|         | 3     | a. There is a title & stimulation  
|         |       | b. There is no repetition of the same image  
|         |       | c. Draw carefully and thoroughly  
|         |       | d. Detailed picture & complete  
|         |       | e. Well organized image  

[17-19]
So after the experiment, the creativity data obtained in the form of creativity scores were then analyzed using the independent sample t-test through the SPSS program. This analysis was carried out to answer the research problem, namely whether there are significant differences between the experimental classes that implement the PBL & EiE model with the control class implementing conventional learning.

4. Result and discussion
The research at Darul Imaarah 1 Public High School, Aceh Besar Regency was carried out from October 23 to November 30, 2017. Implementation of teaching in both classes of research samples, both for teaching classes PBL & EiE models and conventional teaching classes held for 3 (three) meeting times. After the experimental class and the control class carry out the teaching and learning process of Physics by using the model and their respective approaches then given a creativity test using the Torrance Test of Creative Thinking (TTCT).

Before the results of the creativity test of the experimental class and the control class were compared using the free sample t-test (independent t-test), the normality test and homogeneity test were first carried out. The normality test from the results of the answers to the creativity test of the experimental class students and the control class shows normal results as shown in table 2.

Table 2. Results of the normality test of student creativity.

| Class      | L_count | L_table | Decision |
|------------|---------|---------|----------|
| Experiment | 0.127   | 0.184   | Normal   |
| Control    | 0.183   | 0.184   | Normal   |

In table 2 shows that the results of the normality test of creativity data of experimental class students and the control class get a smaller value than \( L_{table} = 0.184 \) at a significant level \( \alpha = 0.05 \). Thus it can be concluded that the data on creativity learning in the experimental class and the control class were normally distributed. Meanwhile to determine whether the creativity data of the experimental class students and the homogeneous control class, the F-test homogeneity test was carried out. The results of the F-test homogeneity of the creativity data of the experimental class and control class as shown in table 3.

Table 3. Homogeneity test results for student creativity.

| Data source                                    | F_count | F_table | Decision |
|------------------------------------------------|---------|---------|----------|
| Creativity score for experimental class and control class | 1.804   | 1.984   | Homogen  |

In table 3 shows that the results of the F-test variance of data on learning creativity of the experimental class students and the control class were smaller than the value of \( F_{table} = 1.984 \) at a significant level \( \alpha = 0.05 \). So it can be concluded that the data variance of the two classes was homogeneous. Before the results of the creativity test of the experimental class and the control class compared to each creativity indicator were first described as a whole the average and the standard deviation value of the creativity tests of the students of the two classes. The mean and standard deviation value of the creativity test of the experimental class students and the control class as shown in table 4.
Table 4. Average score of student creativity.

| Class          | Experiment | Control |
|----------------|------------|---------|
| Mean           | 1.40       | 0.95    |
| Standard deviation (SD) | 0.41       | 0.46    |

Based on Table 4, it can be seen that the average score of creativity in students of the experimental class was 1.40 with a standard deviation of 0.41, while for the control class it was 0.95 with a standard deviation of 0.46. This shows that overall the creativity of the experimental class students was better than the creativity of the control class students. Likewise, when viewed on average for each indicator of creativity (elaboration, originality, & fluency), the creativity of the experimental class students was better than the creativity of the control class students, as shown in figure 1.

Figure 1. Average of each student creativity indicator in experimental class and control class.

Then to determine whether the average creativity of the experimental class students and the control class for each indicator as shown in Figure 1 is significantly different or the t-test analysis was carried out. The results of the t-test analysis for each indicator of creativity between the experimental class students and the control class can be seen as in table 5.

Table 5. Average results and t-tests of student learning creativity for each indicator.

| No | Creativity indicator | Experiment class | Control class | t<sub>count</sub> | t<sub>table</sub> | Conclusion                |
|----|----------------------|------------------|---------------|-----------------|-----------------|---------------------------|
| 1  | Elaboration          | 1.46             | 1.00          | 2.379           |                 | significantly different   |
| 2  | Originality          | 1.65             | 1.07          | 2.698           | 2.064           | significantly different   |
| 3  | Fluency              | 1.96             | 1.19          | 3.922           |                 | significantly different   |

Based on the results of data analysis as shown in table 5, it can be seen that the average creativity for the experimental class in the elaboration indicator was 1.46, originality 1.65, and fluency 1.96. As for the control class on the elaboration indicator 1.00, originality 1.07, and fluency 1.19. Based on the average value it can be said that the average learning creativity of students in the experimental class was higher than the control class.
Based on the results of the t-test analysis to see differences in the average creativity between the experimental class students and the control class showed that there were significant differences. Where the values are calculated for each indicator of creativity, elaboration 2.379; originality 2.698; and fluency 3.922 was greater than t-table 2.064. This shows that there was a significant difference between the creativity of the experimental class students and the control class for all indicators of student creativity, where the creativity of the experimental class students was better.

From the results of the research data described above related to student creativity, it can be seen that the average creativity of the experimental class in the learning process applied by the PBL model through the EiE approach obtains higher creativity than the control class. This proves that through the PBL model with the EiE approach students can design technology product results by more systematically following the steps of EiE so that it will reduce errors in designing tools. Besides being accompanied by high interest and curiosity, students try to design images of technology products as they were often seen in daily life, even some students design technology products from their own thoughts. This was in accordance with [20] that today the EiE approach in learning is increasingly being applied because it can spur learning to be more useful, making students more motivated in learning so that it can spur the development of student creativity.

If reviewed for each indicator measured (elaboration, originality, fluency), the results of the study show that the experimental class students are more creative than the control class students, especially on the fluency indicator. The results of the t-test analysis show a significant difference between the creativity of the experimental class and the control class, where t-count was greater than t-table (2.379 > 2.064). Positive results for each indicator of creativity measured were certainly inseparable from implementing the PBL model through the EiE approach in the teaching and learning process in the classroom. The implementation of the PBL model in the teaching and learning process from the past is believed to be able to enhance student creativity in various indicators, including for the three indicators in this study [21]. The following was a discussion of the three indicators of creativity measured in this study.

The results of the t-test analysis showed that there were significant differences between the elaboration of the experimental class students and the control class students, where the average elaboration of the experimental class students was better than the control class with t-count greater than t-table (2.698 > 2.064). This positive result was certainly inseparable from PBL’s learning steps especially in the steps of developing and presenting the work. The step of developing and presenting the work was believed to be able to improve the ability of students to develop an idea or product and to detail its parts [22,23]. But even so the difference in average elaboration was lower when compared with the difference in the other two indicators of creativity (fluency and originality).

The average creativity for the originality of the experimental class students was higher than the originality in the control class students. The results of the t-test analysis show a significant difference between the originality of the experimental class and the control class, where t-count was greater than t-table (2.379 > 2.064). The PBL step which was believed to increase originality was at the step of organizing students to learn. Where in this step students were encouraged to learn collaboratively in developing problem solving skills [21,24]. Through work and group discussion, so students are able to produce new ideas that are unique in the steps of organizing the PBL model [24,25]. Besides that the originality indicator is also influenced by the imagine of the EiE strategy, where in this step students imagine problem solving according to their innovation [10,26].

Besides the indicators of elaboration and originality, the results of the analysis for fluency indicators also showed a significant difference between the experimental class and the control class, where the fluency of the experimental class students was better than the control class students. Fluency was an indicator of creativity that describes the ability of students to produce various ideas for solving problems given. The results of the t-test analysis show a significant difference between the fluency of the experimental class and the control class, where t-count was greater than t-table (2.922 > 2.064). This positive result was certainly inseparable from the implementation of PBL learning steps and EiE strategies in the process of teaching Physics. As in the third step PBL is the step of guiding the
investigation, where in this step students collect data and carry out experiments. Through this activity students can think of various problem solving ideas [2]. Likewise the step plan of the EiE approach which gives freedom to students to apply various ideas from the results of previous imagining steps [9,10].

Overall the results of the analysis of the three creativity indicators measured in this study (elaboration, originality, fluency) showed better results in the experimental class that carried out the STEM and EiE teaching and learning process than the control class that carried out conventional teaching. These results have provided one more empirical proof that the teaching and learning processes carried out in active and problem-based learning are able to enhance a variety of student abilities including creativity [9,21,22].

5. Conclusion
Based on the results of research that has been done, it can be concluded that students who carry out the learning process PBL model and EiE approach have higher creativity than students who carry out conventional learning. However, the application of the PBL model and EiE approach in this study was limited to measuring student creativity for the topic of Magnetic Induction. Therefore it was necessary to conduct further research or development efforts to apply the PBL and EiE models to other Physics topics.

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