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Implementation of PjBL-STEM to Improve Students' Creative Thinking Skills On Static Fluid Topic

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ABSTRACT
This research aims to investigate the influence of Project-Based Learning (PjBL)- Science, Technology, Engineering, and Mathematics (STEM) on Students' Creative Thinking Skills. The research method was quasi-experiment using a nonequivalent control group design. Samples were taken using purposive sampling technique from two of 11th-grade science classes as an experimental and a control groups. This study used a test instrument of creative thinking skills. Research data were analyzed using SPSS and Microsoft Excel software. Hypothetical test results were assessed using independent sample t-test, obtained sig value (2-tailed) = 0.01 indicating sig value < 0.05. According to statistical analysis, there is a significant difference between the control class and the experiment class. The n-gain value was obtained with a score of 0.59 (a medium category). This result shows that the application of PJBL-STEM can improve students' creative thinking skills in the static fluid topic (Pascal law).

INTRODUCTION

Education today should be able to produce human resources (HR) that have 21st-century skills [1] [2]. The 21st-century skills consist of four components, namely: (1) Critical Thinking and Problem-Solving ability, (2) Communication ability, (3) Collaboration (cooperation with others), and (4) Creativity and Innovation [3]. One component of 21st-century skills that students should have is creative thinking. Creative thinking is an individual ability to create or produce something new, whether it is an idea or a product which still related to a product that ever existed [4]. Creative thinking is a form of self-expression that is showed uniquely [5]. There are four indicators of creative thinking skills: (1) Fluency, (2) Flexibility, (3) Originality, and (4) Elaboration [6].

Based on field studies, physics learning in the classroom is still dominated by a teacher-centred approach, where teachers become the only learning resource. Accordingly, students are less active in the learning process, and it is resulting in low creative thinking skills. Creative thinking skills can be improved through various training efforts [7]. One of the efforts in improving creative thinking skills is to implement innovative learning models or approaches. Some learning models can facilitate learners to be active in the learning process, such as Inquiry-Based Learning models integrated mind map [8], Problem Based Learning (PBL) assisted multimedia [9], Guided Discovery models [10], project-based learning models [11] [12], or constructivism approaches [13].

Project-based learning (PjBL) is one of the learning approaches for students to construct knowledge in groups with scientific methods [14]. In PjBL, students can define their own learning process in groups, conduct research and create creative project projects that can explore their knowledge [15]. Currently, Science learning must combine science and technology and other disciplines. This can be done through the integration of Science, Technology, Engineering, and Mathematics (STEM) in learning. STEM approaches to learning are expected to produce meaningful learning for students through the mathematical integration of knowledge, concepts, and skills [16]. The PjBL-STEM relationship can be used as an innovative learning approach, and wherein PjBL students are required to create a project or create a tool, while STEM is a component that has a connection between across disciplines. STEM integration in the PjBL model results in five learning syntax, namely: (1) Reflection, (2) Research, (3) Discovery, (4) Application, and (5) Communication [17].

Based on previous research, PjBL-STEM has some significant impact in science learning, for example: to improve science literacy [18], improve problem-solving skills [19] [20], improve mastery of student concepts and learning activities [21], or to improve metacognitive skills [22].

The application of STEM integrated PJBL models is suitable for teaching the static fluid topic that addresses Pascal's law [23]. The Core Competency (KI) and Basic Competency (KD) on static fluid themes are applying the static fluid laws in daily life (in KI 3.3), and designing and conducting experiments utilizing static fluid properties, as well as presenting the results of experiments and their utilization (in KI 3.4). Based on KI 3.3 and KD 3.4, it appears that students are required to design and conduct experiments, which can be facilitated through an integrated STEM PJBL model. Pascal's law is the fundamental law of the concept of static fluid, which addresses fluid pressure in enclosed spaces [24]. There are many Pascal's law applications, for example on hydraulic jacks, hydraulic brakes, excavators, and so on.

Based on the above description, the research was selected with the theme "Implementation of PJBL-STEM To Improve Students' Creative Thinking Skills in Static Fluid Topic (Pascal's Law)". The formulation of the research questions are (1) whether the application of PJBL- STEM can improve students' creative thinking skills in static fluid materials (Pascal's law), (2) How to analyze students' creative thinking skills using PjBL-STEM and Direct instruction models on static fluid material (Pascal's law), (3) How is the student's creative thinking ability for each indicator.

METHOD

The study used a pretest-posttest nonequivalent control group design. In this design, there were two groups that each group is not randomly selected, but has been specified in advance. The population in this study is 11th grade upper secondary school student from Madrasah Aliyah Negeri in Lebak district, and the sample used is 2 sample classes with each class of 30 people. Samples were taken using purposive sampling technique, which is divided into two classes. The first group was an experimental class group treated with the PjBL-STEM model, and the second group was a control class group not treated. The design of the research can be seen in table 1 [25].

Table 1. Pretest-Posttest Research Design nonequivalent control group design

Group	Pretest	Treatment	Posttest
Experiment Class	O_1	X	O_2
Control Class	O_3		O_4

Description :
X = PjBL-STEM

In the PjBL-STEM model, there is a learning syntax as in table 2.

Table 2. PjBL-STEM Syntax

PjBL-STEM Syntax	Activities in the classroom
Reflection	*Learning motivation* The teacher gives questions regarding the concept of Pascal's legal application to explore the student's early understanding. Example question: How does hydraulic brake work in the car's braking process? How to lift a vehicle with the hydraulic pump when tires leak?
Research	*Group sharing and searching for resources to answer motivational questions.* Teachers divide students into groups, of which each group consists of 4-5 students
Discovery	*Provide a project related to the material.* An example of a workable project related to Pascal's law material is pascal maze. This tool integrates pascal's law knowledge in the form of a game. Pascal mazes can be triangular, square, or other shapes 
Application	*Create and test products* Students create and test the products, namely pascal mazes. 
Communication	*Students present in front of the class* 

A research instrument is required to investigate the impact of PjBL-STEM in improving creative thinking skills. The research instrument used in this study was five items essay questionnaires which consist of four indicators of creative thinking skills. Furthermore, the research instruments were validated by expert judgement and using the calculation of content validity ratio (CVR) and content validity index (CVI). The results of the validity test showed the instruments were valid, with a score of 0.42 (medium) [13]. The indicators of creative thinking skills were shown in table 3 [14].

Table 3. Creative Thinking Skills Indicators

No	Indicators	Sub-indicator	Question number
1	Fluency	Have many answers and ideas in solving a problem. - Students are expected to have various alternative answers related to the problem of building in areas with mushy soil structures by applying the concept of pressure.	1
2	Flexibility	Have different ideas and answers to others in solving a problem. - Students are expected to have various answers related to the different problems of hydrostatic pressure experienced by people swimming in freshwater pools by swimming in the sea. So divers at sea must be equipped with special equipment.	4
3	Originality	Produce a different way of thinking according to his own thinking - Students are expected to have an original idea in the form of utilizing objects around the environment to create science projects from pascal law application, where the project can also be used for gaming facilities. - In addition, students are also expected to have a various original idea about the structure of a dam, in order to withstand the large hydrostatic pressure of water.	2, 5
4	Elaboration	Generate a broader idea of a problem so that it can solve the problem in detail. - Students are expected to have detailed answers to solve a given problem, related to how the brakes work to stop a large-time car in an easy style, associated with Pascal's law application. - Or how to lift a car with a large mass when the car has a tire bomb or will be washed, in a small style. Associated with the broad form of lever pipe and lifting pipe.	3

Data analysis was conducted quantitatively to find out the improvement of creative thinking skills. The data were analyzed statistically to ensure normality and homogeneity. The normality of the data was tested using the Wilk Shapiro test, and the homogeneity was assessed using the Levene test with the score of $\alpha = 0.05$. Furthermore, the data was assessed with a parametric test. An independent t-test was used to ensure there is no difference in scores in the experiment class and control of students' creative thinking skills. A further analysis using N-Gain was conducted to test whether there is an increase in students' creative thinking [26]. The N-Gain formula used is

$$\langle g \rangle = \frac{X_{post} - X_{pre}}{X_{\max} - X_{pre}} \quad (1)$$

Description :

$\langle g \rangle =$ Gain value

$X_{post} =$ Posttest score

$X_{pre} =$ Pretest score

$X_{\max} =$ Maximum score

The criteria for n-gain value can be seen in the following table 3.

Table 3. N-gain value criteria

N-gain value	Criteria
$\langle g \rangle > 0,7$	High
$0,3 \leq \langle g \rangle \leq 0,7$	Medium
$\langle g \rangle < 0,3$	Low

RESULTS AND DISCUSSIONS

The teaching intervention in this PJBL-STEM was to engage the student´s project to create tools related to pascal law, as shown in table 2. The tool was made to resemble a game to make students more motivated and think creatively. The tools name was Pascal Maze, which applies pascal law in the form of a labyrinthine game, as shown in figure 1.

Fig 1. *Student Products, Square Pascal Maze (left) and Traingular pascal Maze (right)*

The N gain value was assessed using Ms. Excel software to find out the improvement of the creative thinking skills of students. Table 4 shows the recapitulation of pretest-posttest values in control classes and experiments.

Table 4. Pretest-Posttest values control class and experiment class

Description	Minimum	Maximum	Mean
Pre_Experiment	16	76	39.20
Post_Experiment	36	100	75.60
Pre_control	16	68	38.27
Post_control	20	92	59.73

Based on the analysis of the data, the result indicates that the creative thinking skills for the pretest scores on the experiment are higher than the control class, with a mean score of 39.20. The average score in the pretest on both control or experiment classes are relatively small because both classes have not obtained any intervention from PJBL-STEM or conventional learning. Unlike pretest scores, posttest scores obtain a reasonably high average in both control and experiment classes. However, in the experiment class, the average posttest score was more than the control class, with the score 75.60. The improvement of the students' creative thinking skills can be seen in table 5.

Table 5. N-Gain value creative thinking skills in Experiment Class and Control class

Description	Experiment Class	Control Class
N-Gain	0.59	0.33
N-Gain criteria	Medium	Medium
Number of students	30	30

The result of N Gain creative thinking skills in the control class was 0.33, while in the experiment class was 0.59. Based on these values, it can be interpreted that both classes have a moderate n gain value. However, in the experiment class, the N gain score is greater than the control class. This is in accordance with previous research that stated that the use of PjBL-STEM models is able to improve students' creative thinking skills [27] [28].

Research hypothesis testing was conducted to find out the differences in creative thinking skills in experiment classes and control classes. Hypothesis testing using an independent t-test. The test hypothesis used is Ho: There is no significant difference in the value of creative thinking skills test before and after learning; Ha : There is a significant difference in the value of creative thinking skills test before and after learning. The test hypothesis is: Ho ≥ 0.05; then Ho was accepted and Ha was rejected; Ho < 0.05; then Ho was rejected and Ha accepted. The independent t-test results are found in table 6.

Table 6. Independent t-test

		T	Df	Sig. (2-tailed)	t-test for Equality of Means: Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
Post-test experiment and control	Equal variances assumed	3.446	58	.001	15.867	4.604	6.651	25.083

Based on table 6, the sig value is known. (2-tailed) <0.05, which means Ho is rejected and Ha is accepted. This means that there is a significant (noticeable) difference between the experiment class and the control class. In class control, the PjBL-STEM model affects students' creative thinking skills [29]. STEM project-based learning helps students connect the knowledge gained with its application in real life. Integration between science, technology, engineering and mathematics (STEM) help students understand that there are linkages across fields of science [30].

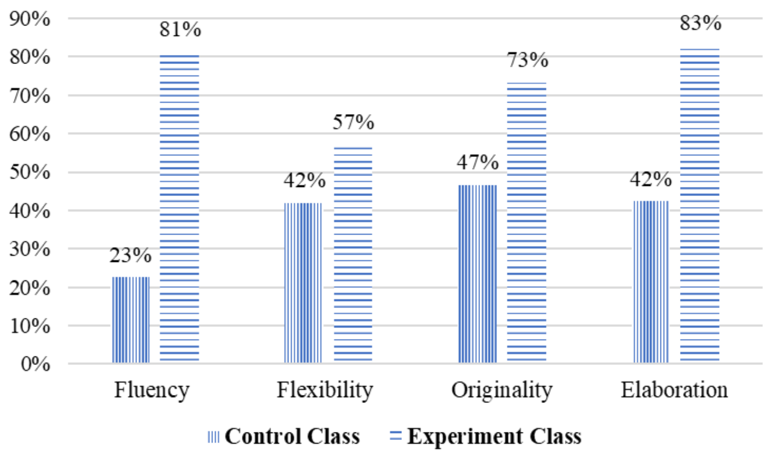

***Fig 2.** Student Creative Thinking Skills Analysis*

The students' creative thinking skills data on each indicator (fluency, flexibility, originality and elaboration) is processed using Ms. Excel software. The results of the analysis of creative thinking skills are listed in figure 2. Figure 2 shows the analysis of the creative thinking skills of each indicator in the experiment class higher than the control class. This result was obtained because the integrated PjBL-STEM model integrated into experimental classes, while the control classes only receive conventional learning. In the experiment class, the average value of creative thinking skills was 73.75%, while the control class only gained a creative thinking skill score of 38.42%. In the experiment class, the elaboration indicator has the highest percentage score compared to others, indicating that students have the ability to solve the problem in detail. While the fluency indicator has the lowest score compared the other, indicating that students do not have various answers related to the different problems.

The implementation of PJBL-STEM in experiment class increase all aspects of student's creative thinking skills. This result is indicated by the n-gain value shown in Figure 3. Fluency and Elaboration indicators obtain n-gain values with high criteria, Originality indicator obtained n-gain value with medium criteria, while the Flexibility indicator obtained the n-gain value with low criteria. This indicated that the PJBL-STEM had facilitated students to improve their creative thinking skills.

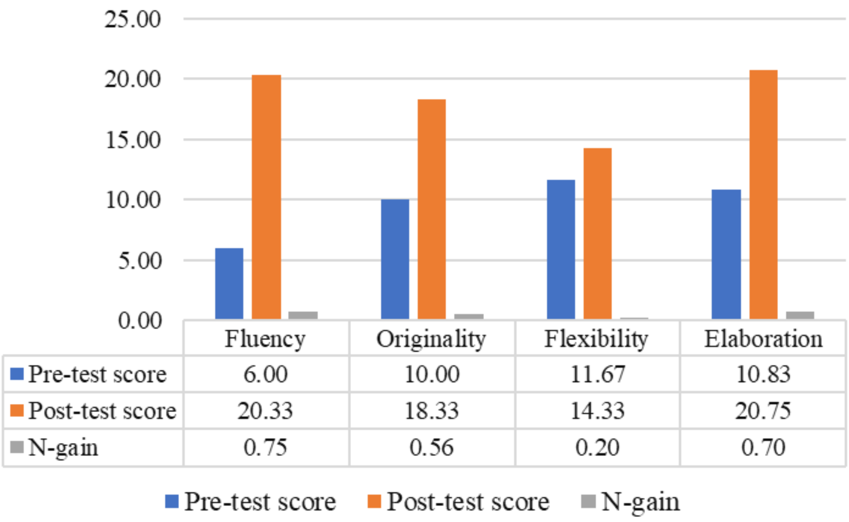

Fig 3. *Average Scores of Pretest, Posttest, and N-gain for Each Indicator of Creative Thinking Skills*

The highest increase in critical thinking skills was found in the fluency indicator. This result is the same as previous research, which shows that the fluency indicator has the highest increase after being given STEM-based learning [31]. The increase in creative thinking skills on the fluency indicator shows that students are fluent in explaining solutions to a problem. Students are expected to have various alternative answers related to the problem of building in areas with mushy soil structures by applying the concept of pressure.

CONCLUSION AND SUGGESTION

Based on the results of the research, it can be concluded that PjBL-STEM model can improve students' creative thinking skills in the static fluid topic (Pascal's law). Although control class can equally enhance creative thinking skills, the average score in the experiment class is greater than the control class. Based on the results of statistical analysis, it can be seen that there is a significant difference between the experiment class and the control with a sig value of 2 tailed < of 0.05.

The result of the study provides some implications for future physics learning and research. The teachers/schools are suggested to improve high-level thinking skills in students, especially creative thinking skills. A learning model of PjBL-STEM is needed to enhance the imagination, creativity and activity of students. For future research, applying the PjBL-STEM model should be developed with other, more challenging physics learning topic.

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