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Project-Based Learning Effect on Improving Students' Creative Thinking in Static Fluid Learning

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Abstract. The low creative thinking ability of students in understanding physics concepts, especially in static fluid material, is one of the problems that needs attention in the learning process. Therefore, this study aims to determine how the Project Based Learning (PjBL) learning model that uses a scientific approach affects students' ability to think creatively about static fluid material. The research method used is a quasi-experimental design with a Nonequivalent Control Group Design. The research subjects consisted of two eleventh grade high school students, namely the experimental class using the scientific PjBL model and the control class using the Inquiry Learning model, each consisting of 30 students. The research instrument was a descriptive test consisting of eight questions developed based on Torrance's creative thinking indicators, including fluency, flexibility, originality, and elaboration. The data obtained were analyzed through normality tests, homogeneity, and N-gain calculations. The results showed that the average N-gain of the experimental class's creative thinking ability was 0.41 (medium category), higher than the control class which only reached 0.29 (low category). Specifically, significant improvements were seen in the fluency and flexibility indicators, while the originality and elaboration indicators also increased although relatively lower. Thus, it can be concluded that the application of the scientific PjBL model is more effective in improving students' creative thinking abilities compared to the Inquiry Learning model in static fluid learning. These findings are expected to contribute to the development of physics learning strategies oriented towards strengthening creativity, independence, and active involvement of students in the knowledge construction process.

Keywords: project based learning, scientific approach, creative thinking, static fluid

1. Introduction

Along with the advancement of the industrial 4.0 era, education has a strategic role in preparing individuals who are ready to face and adapt to the dynamics of advances in science and technology. The main focus of education in the 21st century is mastery of *the Four Cs* (4C) skills, which include critical thinking and problem-solving skills, creative thinking, effective communication, and working with others [1]. The application of these skills requires a transformation of the learning paradigm, shifting from a conventional teacher-centered model to a learner-centered model, where teachers act as facilitators. In this context, education is an important part of developing high-quality human resources [2]. Therefore, the government plays a major role in this process by providing support through investment in education and ensuring that every citizen has access to quality education [3].

In the context of science education, and physics in particular, students' creative thinking skills are an indicator of the success of the learning process. The physics learning process at the secondary school level is often considered difficult and intimidating. According to the majority of students, physics is one of the most difficult subjects in secondary school [4]. In the world of education, students' creative thinking skills are still relatively low. This condition can be seen from the tendency of students to only focus on memorization and single answers, so they are less accustomed to generating new ideas or solving problems in various ways[5]. This is in line with the opinion of Wulandari et al. (2019), who stated that the application of conventional learning models causes low student creativity [6]. In addition, Mashitoh et al. (2021) stated that several factors contribute to low student creativity. These factors include the lack of habit for students to solve non-routine problems, students' difficulty in understanding learning materials, and the lack of appropriate learning media [7]. Creative thinking skills in physics learning are very important because they help students find new ideas and solutions to various problems [8].

The application of an appropriate learning model is very important so that students are motivated to actively and creatively participate in the learning process. One model that is considered effective and widely used today is *Project Based Learning* (PjBL) [9]. PjBL is a learning model that provides learning through real projects so that students can design, implement, and evaluate their own projects [10]. The learning process should be able to foster creativity and creative thinking skills in students, with the support of a learning model that provides space for the creation of innovative and relevant work, both individually and through group work [11]. The results of the researcher's interviews with 12th grade students at SMAN 87 Jakarta who had studied using the *Project Based Learning* model showed that they felt more involved and motivated because they could relate the material to their direct experiences through projects. They considered the learning process to be more interesting than conventional methods that focus on theory. However, some students also wanted more challenging practical projects to deepen their understanding of the concepts. These findings show that PjBL has great potential in increasing motivation and engagement in learning, but it still requires the development of project variations to be more optimal.

Various efforts have been made to improve students' creative thinking skills by implementing innovative learning models. A study conducted by Noorhalida et al. (2023) proves that the use of the PjBL model in physics learning at the high school level has a significant positive effect, especially in improving students' creative thinking skills [12]. This model also makes students more active, creative, and exploratory. A study by Rohman et al. (2021) showed that the STEAM-integrated PjBL model improves the creative thinking skills of grade XI science students in high school [13]. A study conducted by Maysyaroh and Dwikoranto (2021) states that in dealing with low creative thinking skills and problem-solving abilities, students can be helped by implementing PjBL. This study found that project-based learning can help students think creatively in physics learning [14].

The application of project-based learning allows students to participate directly in physics learning so that they can develop creative, critical, and productive thinking skills independently [15]. By using the PjBL model, students do not only act as recipients of information, but they construct new knowledge from their previous experiences and knowledge. This process makes students more active and involved, as well as fostering curiosity and responsibility for their learning outcomes [16]. The PjBL learning model is implemented by summarizing various learning ideas and then realizing them in the form of projects. The process includes several important stages, namely formulating basic questions, designing projects, preparing schedules, monitoring progress, presenting results, and conducting evaluations. [6].

Unlike previous studies, this study specifically examines how the application of PjBL affects students' creative thinking skills, rather than simply cognitive learning outcomes as in many previous studies. The focus on creativity is important so that students not only understand the material but are also able to generate new ideas in problem solving. In addition, this study takes the topic of static fluids related to everyday life, such as the principles of hydrostatic pressure, Pascal's law, or capillarity, so that the results are expected to be more relevant to the real experiences of students.

Based on this background, this study focuses on examining the extent to which the application of the PjBL model combined with a scientific approach can help students improve their thinking skills regarding static fluid material. Through this study, the researcher not only wants to see the effectiveness of PjBL with scientific in the context of physics learning, but also how its application impacts students' creative thinking skills. Therefore, this study is expected to provide a more complete picture of the potential of scientific-based PjBL as an innovative learning model that can encourage active engagement, conceptual understanding, and creativity of students in static fluid material.

2. Method

This study used quantitative methods and was conducted in the odd semester at a public high school located in South Jakarta. The research design used was *Quasi Experimental Design* with a *Nonequivalent Control Group* Design, where the two groups involved, namely the experimental group and the control group, were not selected randomly [17].

The population in this study consisted of 252 students in grade XI. The researcher used *nonprobability sampling*, which is a sampling method that does not give equal opportunity to be selected as a sample [18]. Purposive sampling was the nonprobability sampling method chosen by the researcher. This study involved thirty people as the control group and thirty people as the experimental group.

The data collection technique used tests in the form of *pre-tests* and *post-tests*, as well as non- tests in the form of documentation. The research instrument used was essay questions. Quantitative research using the experimental method aims to determine how a treatment affects certain variables under controlled conditions [17]. The data analysis method used in this study began with a prerequisite test in the form of a normality test. After that, the hypothesis was tested with an *N-gain* test and a learning completeness test.

The creative thinking ability test instrument in this study was an essay test consisting of eight items, based on Torrance's aspects of creative thinking. These aspects include *fluency*, flexibility, originality, and elaboration. The level of creative thinking of each student is reflected in their learning outcomes. Creative thinking skills are divided into four levels [19]. Level 4 or highly creative if students meet all four indicators, namely fluency, flexibility, originality, and elaboration. Level 3 or creative if students meet three indicators, namely fluency, flexibility, and originality. Level 2 or moderately creative if students meet two indicators, namely fluency and flexibility. Level 1 or less creative if students only meet the fluency indicator [19].

Table 1. Skills indicator description.

Skills	Description	Question Number
Fluency	1. Generating various ideas related to a problem or stiation. 2. Presenting verious solutions to a problem. 3. Having the ability to find many ways to complete a task or challenge.	2
Flexibility	1. Proposing various alternative solutions from different perspectives. 2. Adapting ideas or strategies to different stuations. 3. Presenting various approaches to solving problems.	1, 3, 7
Originality	1. Generating solutions that are unique and different from most people. 2. Presenting new ideas that have never been tried berfore. 3. Proposing innovative methods for dealing ith problems or challenges.	5, 6
Elaboration	1. Developing a detailed plan to implement the idea. 2. Developing initial solutions into more detailed and applicable ones. 3. Adding elements or details to the idea to make it more comprehensive.	4, 8

The test instruments used have been assessed by four expert judgments. The content validation of the instruments was assessed from two aspects, namely language and material. The results of the expert assessment were then processed using the content validity index (CVI), which was calculated from the average content validity ratio (CVR) [20]. In terms of language, the CVI score obtained was 0.86, indicating a highly suitable category. Meanwhile, in terms of material, the CVI score obtained was 0.86, which was also in the highly suitable category. Based on the content validation results, all questions were declared valid and proceeded to the instrument test. This test was conducted on students who had studied static fluid material, with 50 people completing the creative thinking skills instrument.

The normality test determines whether the collected data follows a normal distribution or not [21]. The *Shapiro-Wilk* normality test was used in this study with the help of *Software Product and Service Solution* (SPSS). Generally, this test is used on samples of less than 50 to produce more accurate decisions. The homogeneity test is used to determine whether two variances are similar by comparing the distribution of data from both variances [22]. In this study, the homogeneity test was performed using the *Bartlett* test in SPSS. The *Bartlett* test uses statistics that follow a specific distribution, producing a critical value when the sample size in each group is the same. However, the critical value can also be adjusted to produce more accurate calculations if the sample sizes between groups are different [23]. After the data met the prerequisites of normality and homogeneity, the improvement in ability was analyzed using the *N-gain* calculation [24].

The relationship between each stage in *the Project Based Learning* (PjBL) model and the indicators of students' creative thinking abilities can be seen in Table 2. The table illustrates how each step in PjBL, from problem identification to project reflection, is carried out.

Table 2. Relationship between the PjBL model and creative thinking indicators.

PjBL Stages	Activity	Creative Thinking Indicators
Determining fundamental questions	The teacher presents the learning topic to be studied, which is the application of static fluid concepts through a project to build a simple hydraulic bridge. As a first step, the teacher shows a video or pictures of how a drawbridge works, using hydraulic principles to raise and lower the road surface. After that, the teacher stimulates the students' curiosity by presenting a contextual problem. Students provide answers directly based on their understanding.	*fluency*
Project planning	Once the students understand the problem, the teacher guides them to design a solution through a simple hydraulic bridge construction project. At this stage, the students are divided into small groups. Each group discusses the initial design of the hydraulic bridge to be built, including the bridge structure design, the lifting mechanism with a hydraulic system, and the materials and tools required.	*flexibility, originality*
Schedule preparation	After the hydraulic bridge design is approved by the teacher, the students and the teacher draw up a project activity schedule so that the implementation runs in a focused and efficient manner. At this stage, the teacher helps each group determine the work stages, implementation time, and achievement targets for each activity.	*fluency*
Project monitoring	The teacher monitors the students' activity, progress in the project development process, and provides assistance when difficulties arise. Meanwhile, students carry out the project according to the agreed design, record each stage, and discuss any problems that arise during the project development process.	*flexibility, originality, elaboration*
Project assessment	Teachers test the simple hydraulic bridge projects that has been completed, measures the achievement of standards, and evaluates the progress of each student after implementing the Project Based Learning.	*elaboration*
Evaluation student experience	Each group presents their project while the other students give feedback. The teacher and students reflect on the learning activities and results of the resulting project.	*fluency, flexibility, originality, elaboration*

3. Result and Discussion

The results of the study investigated the effect of the PjBL learning model on students' creative thinking skills in static fluid material. The data collected included pre-test and post-test results from the experimental and control groups.

3.1. *Descriptive data*

Table 3. Result of descriptive statistical tests of pre–test and post-test scores.

Data	Experimental Class		Control Class	
	Pretest	*Posttest*	*Pretest*	*Posttest*
N	30	30	30	30
Highest Value	30	61	32	52
Smallest Value	25	54	25	47
Average	27.27	57.63	28.53	50.43
Median	27	58	28.5	50
Mode	27	58	28	49
Standard Deviation	1.484	2.125	2.047	1.888

The pre-test and post-test results in the experimental and control classes provided data on the creative thinking skills of the students. The instrument used consisted of five descriptive questions that had been previously tested and analyzed. The pre-test was given to determine the initial abilities of the students before the treatment, while the post-test aimed to see the extent to which their creative thinking skills had improved after learning with different treatments in each class.

Table 3 shows an interesting picture of the development of students' creative thinking skills. Initially, the average pretest score of the experimental class (28.53) was slightly higher than that of the control class (27.27). However, after the treatment was given, a more noticeable difference was seen. The average posttest score of the experimental class jumped to 57.63, while the control class only reached 50.43. This means that both classes did experience an increase, but at different levels. The control class learned through the Inquiry Learning model, while the experimental class used PjBL with a scientific approach. From the difference in score increases, it is clear that students in the experimental class experienced higher creative thinking skills development compared to the control class. This finding suggests that the application of PjBL is more capable of triggering student creativity in learning.

3.2. *Normality Test Data*

The Shapiro-Wilk approach in SPSS was used to test data normality. The test results for the pretest and posttest data from both groups are shown in Table 4.

Table 4. Normality test results.

Class	Normality Test			
	Shapiro-Wilk			
	df	α	Sig	Decision
PreTest Experiment	30	0.05	0.072	Normal
PostTest Experiment	30	0.05	0.194	Normal
PreTest Control	30	0.05	0.146	Normal
PostTest Control	30	0.05	0.404	Normal

To ensure that the data could be analyzed accurately, a normality test was conducted using Shapiro-Wilk. This test is quite sensitive to small sample sizes, so the results are very important to note. In the experimental class, the pretest significance value was 0.072 and the posttest significance value was 0.194. Meanwhile, the control class obtained a significance value of 0.146 before the test and 0.404 after the test. Since all these values are greater than 0.05, it can be concluded that the data from both classes are normally distributed. In other words, the available data meet the requirements for parametric tests to be used in the next stage of analysis.

3.3. *Bartlett's Homogeneity Test*

The homogeneity test was conducted to determine whether the data from the control and experimental groups were the same. The results of the homogeneity test are presented in Table 5.

Table 5. Results of the homogeneity test

Bartlett's Homogeneity Test				
Class	*Box's M*			
	α	*Box's M*	Sig	Decision
Pre-Test	0,05	2.946	0.089	Homogen
Post-Test	0,05	0.405	0.528	Homogen

A homogeneity test was conducted to ensure that the data from both groups had uniform variance. The results of Box's M test show a value of 2.946 with a significance of 0.089. Because this significance value is greater than 0.05, the null hypothesis is accepted, indicating that there is no significant difference in covariance between the experimental and control groups. In other words, the data can be considered homogeneous so that parametric statistical tests can be used to continue the analysis.

3.4. *N-Gain Test per Indicator*

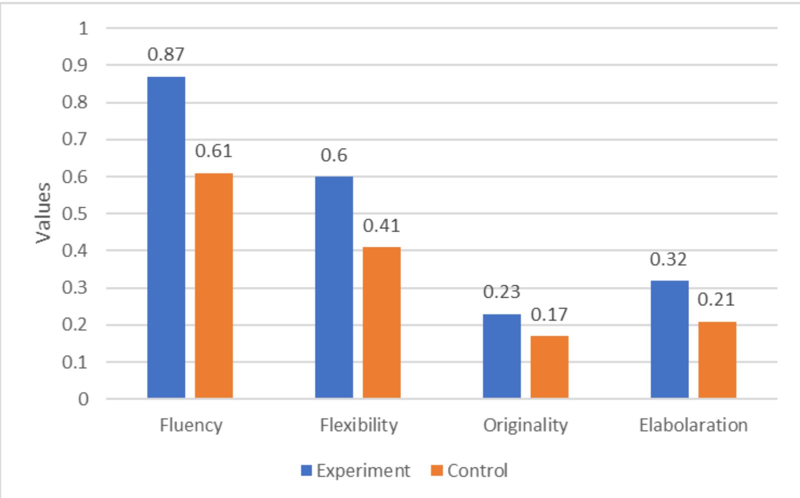

Figure 1. N-gain Results per Indicator.

When viewed from each creative thinking indicator, the experimental group showed a more consistent improvement than the control group. In terms of fluency, the N-gain value of the experimental group reached 0.87, higher than the control group's 0.61, indicating that they were better at recognizing the core of the problem and connecting it to their prior knowledge. In terms of flexibility, the experiment recorded an N-gain of 0.60, while the control group only scored 0.41, indicating that the students were better trained in choosing the right solution strategy. Furthermore, in terms of originality, the experiment scored 0.23, almost double that of the control group's 0.17, reflecting the students' increased confidence in generating their own ideas. Finally, in terms of elaboration, the difference was not as significant as the other indicators, but the experimental group's score (0.32) was still better than the control group's (0.21), indicating that there was an improvement in the students' reflective abilities, although it still needed to be strengthened.

3.5. *N-Gain Test Result*

The N-gain analysis results show a significant difference between the two groups. The experimental class that followed the scientific PjBL learning model obtained an N-gain of 0.41 and was categorized as moderate, while the control class that used the Inquiry method only achieved 0.29 and was classified as low. This difference illustrates that the scientific PjBL approach is more capable of encouraging an increase in students' creative thinking skills than conventional learning methods.

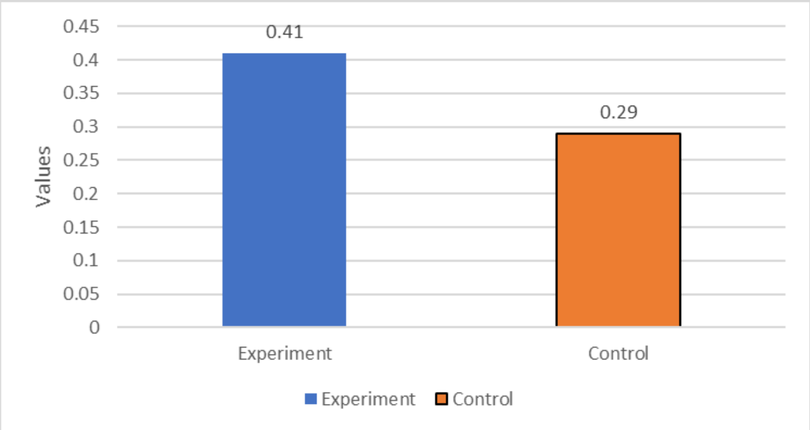

Figure 1. N-gain Results.

3.6. *Analysis of Student Answers*

The analysis was conducted by observing the students' answer sheets, particularly the fluency indicator, which includes generating various ideas related to a problem or situation, presenting various solutions to a problem, and having the ability to find many ways to complete tasks or challenges from data in tables or graphs. The results of the analysis show that students in the experimental class were able to present more diverse ideas, provide many alternative solutions, and find various ways to complete tasks. Meanwhile, students in the control class were only able to generate a few ideas and tended to be limited in finding ways to solve problems.

The flexibility indicator measures students' ability to propose various alternative solutions from different perspectives, adapt ideas or strategies in different situations, and suggest various approaches to solving problems. The results of the analysis show that students in the experimental class were better able to provide many alternative solutions, adapt strategies to the conditions faced, and use various approaches to problem solving. In contrast, students in the control class tended to mention only one or two alternatives without clear variations in approach.

The originality indicator is assessed based on the students' ability to produce unique solutions that are different from most people, convey new ideas that have never been tried before, and propose innovative methods in facing problems or challenges. The analysis results show that students in the experimental group presented more different and original answers, while students in the control group tended to give general answers without offering completely new ideas.

The elaboration indicator is assessed based on the students' ability to develop detailed plans to realize their ideas, develop initial solutions into more detailed and applicable ones, and add elements or details to their ideas to make them more comprehensive. The analysis results show that students in the experimental group were better able to expand and elaborate on the solutions they created, while the control group generally only re-explained existing solutions without much development.

The results of this study indicate that the application of a project-based learning model with a scientific approach is able to increase students' creative thinking skills in static fluid material more significantly than the inquiry learning method. This can be seen from the higher N-gain achievements of the experimental class, both overall and in each indicator of creative thinking, such as fluency, flexibility, originality, and elaboration. This is in line with Hadiyawati et al. (2024), who emphasize that project-based learning provides opportunities for students to build knowledge through direct experience, so that they are better trained in connecting physics concepts with real-life situations [25]. In the context of static fluids, project activities based on real problems, such as designing a simple model of hydrostatic pressure, have been proven to help students understand concepts while training their creativity in developing solutions.

This is in line with the findings of Wulandari, Sutrio, Doyan, & Rahayu (2024), who found that PjBL increases students' creative thinking and physics learning outcomes. For example, in terms of fluency and flexibility, students showed significant improvement after participating in PjBL [26]. This is in line with the findings of Chistyakov et al. (2023), which show that active student involvement in contextual projects increases their creativity and conceptual understanding of science material. Project-based learning helps students connect theory with everyday phenomena, develop cognitive aspects, and stimulate creative and reflective thinking skills [27]. Research on creativity in the concept of heat at Madani Palu Junior High School by Riska Handayani Tokio et al. (2024) shows that students' creativity was quite low at the beginning but increased after a more applied learning intervention. Thus, this study reinforces the evidence that PjBL is relevant to physics material, and that real contexts encourage creativity more than less contextual methods [28]. These findings are in line with the results of research by Kwon and Lee (2025), which revealed that the use of the Project-Based Learning model in static fluid learning was able to increase students' creativity and conceptual understanding. Through direct involvement in projects relevant to real life, students find it easier to connect theory with its application in the field, think more flexibly, and develop creative and reflective thinking skills in solving various physics problems [29]. Research conducted by Lou, Chou, Shih, and Chung (2017) also shows that the application of STEM-based Project-Based Learning (PjBL) significantly increases student creativity. Through the CaC_2 steamship project, students become more imaginative, curious, willing to take risks, and able to relate physics concepts to real-life situations [30].

However, this study has limitations. The relatively small sample size and short duration of the intervention potentially limit the generalization of the results, and it does not fully answer how PjBL affects the long-term retention of students' creative thinking skills. In addition, this study has not explored qualitative psychological mechanisms, such as students' intrinsic motivation, which is actually an important factor in project-based learning. Thus, further research needs to use a mixed- methods design with a broader sample coverage and add structured reflection instruments so that the influence of PjBL on students' creativity can be mapped more comprehensively.

4. Conclusion

The results of this study indicate that the use of the Project-Based Learning (PjBL) model with a scientific approach is able to improve students' creative thinking skills in static fluid material better than Inquiry learning. Students in the experimental class appeared to be more capable of producing diverse and original ideas, daring to offer new solutions, and able to connect physics concepts with real problems they face. Their ability to devise various solution strategies and develop ideas also improved, although not as much as the aspects of fluency and originality of ideas. Overall, the application of scientific PjBL not only helped students understand the concept of static fluids, but also encouraged them to be more creative, reflective, and independent in solving problems.

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