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Project Based Learning Integrated STEM to Increase Students' Scientific Literacy of Fluid Statics Topic

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Abstract. Learning in the 21st century deals with literacy skill. In fact, studies investigating Project-Based Learning Integrated Science Technology Engineering and Mathematics (PjBL-STEM) to develop students' scientific literacy are under-explored. This research investigated the impact of PjBL-STEM on students' scientific literacy of Fluid Statics topic in three classes, these are, Experiment (PjBL-STEM), Comparison (PjBL), and Control (traditional). In Quasi-Experimental Nonrandomized Control Pretest-Posttest Design environment, students in PjBL-STEM and PjBL classes made three products (Hartl apparatus, miniature of multi-level parking lot, and simple boat). Fluid Statics Scientific Literacy Test with seven discourses and eleven essay items was used with 0.908 Cronbach's alpha reliability. Data was analysed with one-way ANOVA, post hoc Tukey, N-gain, and Cohen's effect size. The results showed that three classes had significantly different scientific literacy, where PjBL-STEM was the highest and PjBL class is higher than the traditional class. The literacy improvement of Experiment class included in "high" category and both Comparison and Control classes were in "medium" category. The effect of operational implementation of all pairs of classes belonged in "very large" category in the enhancement of students' scientific literacy. Students' response was similar in PjBL-STEM and PjBL classes, though it is higher than traditional class in the final questionnaire.

1. Introduction

Fluid Statics, which covers the topics of density, pressure, Pascal's Law, and Archimedes' Law, needs Newton's first and third laws [1]. It is It is also related to daily activities (such as swimming, breathing, and drinking) and technologies (such as barometer, hydraulic lift, hydraulic brake, and ship) [2]. However, students consider Fluids as a very difficult topic [3]. Students have misconceptions about buoyant force and hydrostatic pressure [4], and the phenomenon of floating and sinking [5]. Students thought that the shape of the object [6] or the volume of the fluid [7] of the container affect the hydrostatic pressure. Students have difficulties understanding the use of the brake fluid in hydraulic lift and in iron or steel surface of a ship [8]. These difficulties can have an impact on the low level of students' scientific literacy.

Scientific literacy plays an important part in the global competition [9] because it is a very important skill for the development of science and technology, which includes ethnical, moral, and global issue [10]. In the domain of competence, scientific literacy has three indicators [11]. The first indicator is related to how to gain scientific knowledge from certain phenomenon and explain it scientifically. The second indicator is about how to design and evaluate a product or an outcome of the work process, like experiments, technology, and engineering. The last indicator is about how to elaborate or interpret a conclusion which is based on scientific data gathering [12]. It is apparent that students need to have scientific literacy skill [13] to solve problems in the topic of Fluid Statics. However, students still have relatively low level within the scientific literacy indicators [14, 15]. In fact, students' literacy posits in a very low level [16]. This occurs because students only depend on mathematical formula when faced with a query or problems in physics [17]. Therefore, there needs to be a learning which encourages students to apply mathematical formula with as much emphasis on knowledge gain from the topics that are discussed so that students' misconceptions will not arise.

Scientific literacy skill is one of the focused aspects of learning in the 21st century [18]. Numerous studies have been explored with regard to learning methods and the students' scientific literacy such as scientific approach within the topic of dynamic electricity [19], STS model with the topics of buffer solution [20], laboratory experiment within the topic of physics geology [21], STEM-Inquiry based learning within the topics of Newton's law [22], and problem-based STEM within the topic of temperature [23] are proved to be able to increase students' scientific literacy. However, the use of inquiry learning was not successful in increasing the competence of evaluating and designing scientific literacy within the topic of global warming [24], and problem-based STEM was only effective in increasing scientific literacy within the topic of Fluid Statics [8]. It is evident that research on Fluid Statics is still limited. Additionally, research on STEM integration is under-explored. Therefore, research on the improvement of scientific literacy within the topic of Fluid Statics with STEM approach in still scant.

One of the trends of learning focus in Physics [25] and the 21st century learning [26] nowadays is to improve students' scientific literacy. In Physics learning, students can understand the concepts and apply them in daily contextual problems with the help of scientific process skill [27]. This means that contextual day-to-day problem solving needs scientific literacy skill. Meanwhile, problem solving can also be done with the help of STEM approach in which students are involved in teamwork [28] with the whole integration of the aspects of science, technology, engineering, and mathematics [29]. The application of STEM approach is compatible with the characteristics of Fluid Statics. Fluid Statics contain complex concepts to understand, mathematical formulas, and is related to daily activities. STEM approach has been proven to be able to refine the quality of learning process [30] so that students are equipped with overall better attitude, knowledge, and skill [31, 32] to be applied in the process of designing, developing, and using technology optimally [32]. Furthermore, STEM can create meaningful learning context [33] to prepare the students to be independent learners, better problem solvers, logical thinkers, and innovators [34]. It is apparent that STEM has a big potential to increase students' scientific literacy.

The integration of STEM aspects in learning is reflected in the construction and finishing of a product as the solution of a contextual problem [35]. Product creation is in accordance with the Project Based Learning (PjBL) learning approach which organizes certain project in the class [36]. PjBL acts as Curriculum Integration, Action Projects & Stewardship, and Showcase Project. So, it is suitable with the demands of the 21st century learning [37]. Research showed that STEM-integrated PjBL (PjBL-STEM) can increase STEM literacy within topic of Energy [35]. It is also evident that the implementation of PjBL-STEM integration to enhance scientific literacy of students within the topic of Fluid Statics is still scant.

PjBL-STEM is expected to be able to help improve students' scientific literacy. This research investigated the impact of PjBL-STEM on students' scientific literacy within the topic of Fluid Statics in three classes called Experiment (PjBL-STEM), Comparison (PjBL), and Control (traditional learning). In particular, this research presents the category of the improvement, the effect of operational implementation, and the response of learning.

2. Method

This study used Quasi-Experimental Nonrandomized Control Pretest-Posttest Design [38]. Three classes with a total of 102 grade ten students in one secondary school in Malang were used in this research. They were treated in Experiment (PjBL-STEM), Comparison (PjBL), and Control (traditional) classes.

The PjBL-STEM consisted of 7 steps which are: Identifying Problem and Constraints, Researching, Forming Ideas, Analyzing Ideas, Modeling or Prototype Building, Testing and Refining, and Communicating and Reflecting [39]. In PjBL-STEM model, the engineering aspect dominates the most. The engineering aspect consisted of 7 steps: Problem identification, Data gathering to detect alternate solutions, Solution identification, Plan and construction, Testing, Revision, and Evaluation [40]. The PjBL consisted of 6 stages, which are: Pre-preparation, Preparation for the project, Planning for the project, Project implementation, Post-project, and Assessment and evaluation [41]. Students in PjBL-STEM and PjBL classes made 3 products (Hartl apparatus, miniature of multi-level parking lot, and simple boat). In PjBL-STEM class, the project is a solution of certain problem. However, in PjBL class, the project came directly from the teacher. In PjBL-STEM, students conduct a test to evaluate the performance of the project to see if it fits the project's aim, and to refine if necessary, while in PjBL students only present the data of the project as it is. The Control class received traditional learning, comprising conventional methods with general activities such as examining daily phenomenon, listening to oral explanation by teachers about the concept and its practical application, solving written exercises and presenting the findings in front of the class.

The data was collected through pre-test and post-test. Fluid Statics Scientific Literacy Test with 7 discourses which was consisted of 11 essay items was used with 0.908 Cronbach's alpha reliability. This instrument was developed based on scientific literacy indicators especially for fluid statics. The data was then analyzed by using one-way anova with post hoc test, Cohen's effect size [42], and N-gain [43].

3. Results and Discussion

The pre-test data showed that students in Experiment, Comparison, and Control classes had average score and standard deviation of scientific literacy of (in brackets), respectively, 35.38(8.88), 34.58(8.51), and 34.76(8.96). Three classes had similar average score and variant. This indicates that students in the three classes began with almost the same level of scientific literacy at the beginning of the research.

Kolmogorov-Smirnov normality test on pre-test data of Experiment, Comparison, and Control classes resulted in the value of (Sig. 0.076), (Sig. 0.170), and (Sig. 0.050), respectively. Therefore, all three classes were in normal category. Levene's homogeneity test concluded that the variant of three classes had the value of (Sig. 0.851), thus the result is homogen. As both normality and homogeneity assumptions are fulfilled, one-way Anova test was conducted and resulted in the value of (Sig. 0.925). This means that between class groups, there was No Difference. This means that students in the three classes had no significance difference of scientific literacy at the beginning of the research. Therefore, if there are changes in scientific literacy score at the end of the research, it is purely because of the different treatment of learning in the three classes.

The post-test data showed that students in Experiment, Comparison, and Control classes had average score and standard deviation of scientific literacy of (in brackets), respectively, 87.61 (5.45), 80.30 (5.50), and 70.05 (5.37). It is evident that PjBL-STEM learning was able to improve students' scientific literacy better than PjBL or traditional method. Also, it can be seen that PjBL learning was able to improve students' scientific literacy better than traditional method.

Kolmogorov-Smirnov normality test on post-test data of Experiment, Comparison, and Control class resulted in the value of (Sig. 0.080), (Sig. 0.200), and (Sig. 0.050), respectively. Therefore, all three classes were in a normal category. Levene's homogeneity test concluded that the variant of the three classes had the value of (Sig. 0.939), thus the result is homogen. As both normality and homogeneity assumptions are fulfilled, one-way Anova test was conducted and resulted in the value of (Sig. 0.000). This means that between class groups, there was Difference on students' scientific literacy because of the different treatments of learning model in the three classes. The result of post hoc Tukey for PjBL-STEM and PjBL, PjBL-STEM and Traditional, and PjBL and Traditional pairs indicated Sig. 0.000-Differences, Sig. 0.000-Differences, and Sig. 0.000-Differences, respectively. It is evident that the scientific literacy score in all classes were significantly different. Based on the average score of the post-test data, the order of the class from the highest to the lowest score is PjBL-STEM, PjBL, and traditional classes. Thus, it can be concluded that PjBL-STEM can improve students' scientific literacy better than PjBL and traditional learning, and that PjBL can improve students' scientific literacy better than traditional learning.

Students in PjBL-STEM and PjBL classes created 3 projects: Hartl apparatus (hydrostatic pressure), miniature of multi-level parking lot (Pascal's law), and simple boat (Archimides' law). Traditional class created no project. Engineering steps were implemented in the learning process in PjBL-STEM class in order to finish the three projects. After the contextual introduction of the problems was presented at the beginning of learning process, the students were encouraged to ask as many questions as possible to help formulate the problem statements. Meanwhile, students in PjBL class were presented a brief lecture before the contextual introduction was given, so the students didn't produce as many questions as PjBL-STEM class. The projects chosen in PjBL-STEM class were considered as the best solution, which were chosen amongst few other possibilities provided by the students to solve the problem statements. Different process occured in PjBL class in which the project was made as a result of direct instruction from the teacher.

As the students were working on the projects, discussions were held in PjBL-STEM class to evaluate the advantages and disadvantages of the main materials to acquire the best possible materials in creating the projects. Students in PjBL class only used any available materials to create the project without any process of evaluating. It is apparent that students in PjBL-STEM class were working to solve contextual problems by integrating the concepts of science, engineering, and mathematics [21]. This is suspected as the cause as to why students in PjBL-STEM class gained better experience in the topic of Fluid Statics and resulted in higher gain in scientific literacy score than PjBL class. Students were working in team and shared knowledge or concepts with each other to plan and design the projects [44]. The concepts learned separately in the past were united together according to the needs and relevant experience so that the students became more interested in learning [45]. Furthermore, STEM integration led the students to be more motivated in pursuing the interests in career or in the world of science and mathematics [34]

Students in PjBL class presented the class project and obtained comments or criticism for the work. Students in PjBL-STEM class took a step further by conducting a test of the products to receive feedbacks regarding whether the result had satisfied the purpose of the project and to make revision if needed. Besides, students also worked on a poster which contained all information about the products and the required steps in the production process. Written reports were also worked on by students in PjBL-STEM class. This illustrates how PjBL-STEM had created the products based on engineering process. Through an engineering activity, STEM learning was successful in making the students to be actively involved in solution making process to solve a problem which makes the students comparable with designers or creators of the products in technology [46]. Engineering acitivities in PjBL-STEM class was able to make students active so that deeper knowledge could be gained in class [47]. Furthermore, STEM learning can increase students' ability to recognize concepts or knowledge in a contextual problem [48] and also enrich students' experience in many practical activities in the field [49]. It can be seen that integrating STEM into learning can positively impact students' learning process [50] so that it results in the increase of literacy skill in science and technology [51]. The result of this research is in accordance with the research on the integration of STEM in PjBL to increase students' scientific literacy [52].

The set of activities as stated above shows that PjBL-STEM class was practicing formative assessment, although in unstructured manner. Students had tried to formulate as many questions as possible about the problem, chosen the best solution, evaluated the advantages and disadvantages of main materials, and presented the product to gain feedbacks. These are strategic forms of formative assessment [53]. This formative assessment is focused more on students' learning gain rather than on the evaluation about what they have learned [54]. Therefore, a formative assessment is needed to be embedded in systematic and structured way into learning models (PjBL-STEM, PjBL, or traditional class) to have better potential to increase students' scientific literacy.

The N-gain analysis on pre-test and post-test data on Experiment, Comparison, and Control classes had the score and category (in brackets) of 0.808 (high), 0.699 (medium), and 0.541 (medium), respectively. It is evident that Experiment class had one level higher gain than both Comparison and Control class. Every step in PjBL-STEM learning was executed to increase the score of scientific literacy indicators. Through PjBL-STEM learning, the indicator of "explaining phenomenon" was improved under the step two, four, and seven; the indicator of "creating and evaluating an experiment" was improved in all the steps; and the indicator of "interpreting data collection" was improved under the step six and seven. All steps or stages in PjBL-STEM cover the aspect of engineering. This aspect is an implementation of scientific knowledge and skills in technology to make useful product [55] as the design of the best solution which was chosen by the students in groups from a certain problem [54]. In other words, engineering design can improve students' ability to solve complex problems [57]. Indeed, PjBL was proven to be able to invoke engagement, classroom culture and interest in STEM [58]. However, Comparison class was able to gain an improvement which almost reached high category. Indeed, PjBL in Comparison class was nothing like conventional class. Among the three classes, only the traditional class had little gain over the threshold of an average N-gain found in the active learning at the score of 0.48 [59].

The scientific literacy has 3 indicators. The improvement of pre-test and post-test in each indicator is shown by their respective N-gain score. The N-Gain score for each indicator is shown in Table 1.

Table 1. Result of the N-Gain score in each indicator of scientific literacy

Indicator	N-gain Classes (category)		
	Experiment	Comparison	Traditional
Explaining phenomenon	0.714 (High)	0.674 (Medium)	0.606 (Medium)
Creating and evaluating an experiment	0.816 (High)	0.624 (Medium)	0.404 (Medium)
Interpreting data collection	0.928 (High)	0.830 (High)	0.673 (Medium)

From Table 1, it can be seen that in every indicator, PjBL-STEM class had higher gain than PjBL class and PjBL class had higher gain than the traditional class. The gains of PjBL-STEM and PjBL class in the "explaining phenomenon" indicator were measured in slightly close gap. This happens because students are already accustomed to facing contextual daily phenomena. The "creating and evaluating an experiment" indicator gain of the Experiment class far surpassed the Comparison class because the students in this class had conducted evaluation about the best materials for the project, designed the experiment and did the experiment to test the project. The "interpreting data collection" indicator had the highest gain in all three classes. This is caused by the students who are already accustomed to solving mathematical equations in the subject of Physics. However, Experiment class had the highest gain with slightly large gaps compared to other classes. This is caused by the involvement of students in the Experiment class to determine dependent variables, independent variables, and control variables in the project and draw conclusions which showed relation between dependent and independent variables.

This research covers 5 subtopics in Fluid Statics, which are Hydrostatic pressure, Pascal's Law, Archimides' Law, Capillarity, and Viscosity. The N-gain score for each topic is presented in Table 2.

Table 2. N-gain score of subtopics of Fluid Statics in each class

Subtopics	N-gain Classes (category)		
	Experiment	Comparison	Traditional
Hydrostatic pressure	0.847 (High)	0.609 (Medium)	0.498 (Medium)
Pascal's Law	0.769 (High)	0.756 (High)	0.561 (Medium)
Archimides' Law	0.677 (Medium)	0.622 (Medium)	0.308 (Medium)
Capillarity	0.903 (High)	0.787 (High)	0.720 (High)
Viscosity	0.904 (High)	0.946 (High)	0.875 (High)

From Table 2, it can be seen that generally the scientific literacy gains in every subtopics in PjBL-STEM class are higher than PjBL class, and PjBL class gains are higher than the traditional class. This is because of the different learning implementation in the three classes. For the subtopics of Capillarity and Viscosity, all three classes showed the gain in High category. This means that the students are relatively able to understand the concepts of both subtopics. However, the gains in the subtopics of Archimedes' Law were the lowest in all three classes. Moreover, the traditional class had obtained the lowest gain with slightly wide gap compared to other two classes and almost touched the threshold of Low category score. This might be caused by the project making activities (simple boat) in PjBL-STEM and PjBL class, which did not occur in the traditional class at all. Students still had difficulties in learning the subtopics. For the subtopics of Hydrostatic pressure and Pascal's law, PjBL-STEM and PjBL class worked on Hartl apparatus and miniature multi-level parking lot projects so that the gains in scientific literacy were relatively far higher than the traditional class.

The effect size of students' scientific lliteracy in the Experiment, Comparison, and Traditional classes was analyzed. The result of the practical significance is presented in Table 3.

Table 3. Result of effect-size analysis in Experiment, Comparison, and Control classes

Parameter	Pair of Classes		
	Experiment and Comparison	Experiment and Control	Comparison and Control
d effect size	1.315	3.197	1.858
Category	Very large	Very large	Very large

From Table 3, it can be seen that all three class pairs had the effect size in "very large" category. This means that the practical implementation of PjBL-STEM and PjBL learning in every class pair had the effect or impact in "very large" category regarding the improvement of students' scientific literacy in the topic of Fluid Statics. Therefore, PjBL-STEM and PjBL learning are much recommended to be implemented in the topic of Fluid Statics in senior high school level to increase the students' scientific literacy.

The result of the students' response towards the learning acivity is presented in Table 4.

Table 4. The "agree" (A) and "strongly agree" (SA) response in Experiment, Comparison, and Control classes

Classes	Students' response (%)		Total (%)
	A (agree)	SA (strongly agree)	
Experiment class	48.92	50.00	98.92
Comparison class	52.01	44.69	96.70
Control class	39.31	39.17	78.48

From Table 4, it can be seen that the students' response in PjBL-STEM and PjBL classes was similar and was much higher in percentage than the traditional class in the final questionnaire. This indicates that the students were very comfortable in the learning environment of either PjBL-STEM or PjBL. This is due to the fact that both PjBL-STEM and PjBL classes were not conventional classes. This result was in accordance with the finding that Physics STEM Education Learning is able to provide students with more satisfaction than conventional class [60]. However, PjBL-STEM class' response on "Strongly Agree" was higher than the "Agree" section, whereas the opposite happened in PjBL class. This indicates that the students were more comfortable in learning in PjBL-STEM class than PjBL class.

4. Conclusion

Based on the result and discussion above, it can be concluded that the learning model was successful in increasing students' scientific literacy. ThePjBL-STEM model is able to improve the students' scientific literacy better than PjBL model and the traditional learning method. The PjBL model is able to improve the stduents' scientific literacy better than the traditional learning method. The literacy improvement of the Experiment class belonged in High category, whereas both Comparison and Control classes were in the Medium category. The PjBL-STEM and PjBL classes made 3 products, which were Hartl apparatus, miniature of multi-level parking lot, and simple boat, with little differences in the activities and the learning process as well as the project completion. The effect of operational implementation of all pairs of classes belonged in "very large" category in the enhancement of the students' scientific literacy. The PjBL-STEM and PjBL models are very much recommended to be implemented in learning the Fluid Statics topic in the senior high school level to improve the students' scientific literacy. Students' response is similar in PjBL-STEM and PjBL classes, though the students' response was higher than the traditional class in the final questionnaire. Lastly, it can be clearly seen that the students are very comfortable in the learning environment of either PjBL-STEM or PjBL. In this study, formative assessment had been done in unstructured way. Therefore, in the future study, formative assessment strategy can be embedded into PjBL-STEM learning to gain even higher scientific literacy.

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