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Faraday flashlight project-based STEM to enhance problem-solving skill of students

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Abstract. The problem-solving skills is one of necessary competence to compete in twenty-first century. However, research about the impact of Project-based learning based science, technology, engineering and mathematics (PjBL-STEM) towards problem solving skills in the topic of electromagnetic induction is still limited. Faraday flashlight project as representative of basic development of modern technology in the topic of electromagnetic. The purpose of this research is to investigate the effect of Faraday flashlight in STEM integrated PjBL learning towards the increase in students' problem-solving skills. The mixed methods involved 36 senior high school students as participants. The research instrument was the Problem-Solving Skills Test, observation (panduan observasi), and interview. Data were analyzed by paired sample t-Test, N-gain, effect size, and data reduction. The result shows that PjBL-STEM had enough effect on students' problem-solving skills. This condition was caused by each syntax of PjBL based STEM, which could help students enhance their problem-solving skill. Students' skills in describing problems, utilization of Faraday induction approach, specific application of physics, and logical progression had increased in medium categories. However, mathematical procedures had a high category. Based on effect size criteria, PjBl based STEM had high effect on all problem-solving skill indicators.

1. Introduction

Nowadays human use electromagnet in almost all fields of technology, especially in telecommunication, computer, medical, etc. Electromagnet is one of basic technology which was developed by scientist and had marked a progress in engineering [1]. Varieties of these technologies can't be separated from science, engineering and mathematics [2]. The topic of electromagnet contains abstract concept [3] so that students have difficulty in understanding the connection between Lorentz's force and Lenz's law [4], and the phenomenon of Faraday's law [5]. The concept understanding of students can affect their ability to solve problems [6].

Technology will develop as long as humans is faced by problems [7]. In the twenty-first century, science and technology will help a nation to compete and human is required to have problem-solving skill [8]. On the other hand, physics learning can contribute to the development of technology and to facilitate the training of problem solving skills [9]. However, an initial study still showed that students still have low aspects of problem solving skill [10]. Other studies show that on the topic of Modern-Physics [11], Heat-Temperature [12], and Energy-Heat [13], students still have poor problem solving



skill. On the other hand, few learnings, such as Moodle integrated problem-solving model [14] and STEM integrated PBL on the topic of Optical Instruments [15], and STEM integrated IBL in the work-energy [16] has been implemented as an effort to tackle students' difficulties in their problem solving skills. It's apparent that there is still room for research in the topic of electromagnet induction with STEM approach to enhance problem solving skills.

The research of STEM education, in the last decade, are undergoing an intense development. However, STEM education in Indonesia is still rare to be implemented due to the difficulties intergrating with K13 [17]. Beside that, the topic of electromagnetic are rarely done with project-based learning in the twelfth grade of senior high school due to the limitation of time [18]. It's clear that the research of PjBL-STEM on electromagnetic to measure problem-solving skills are still few.

Electromagnetic learning can be improved if students can produce a form of product of technology. Technology is designed and made by engineers by using problem-solving process which based on science and mathematics [19]. The learning approach which can train students in making technology is STEM (science, technology, engineering, and mathematics). Some researchers showed that STEM learning has positive effects on students' ability to make technology. STEM learning can train social-science problem-solving skill which is a challenge in this era and apply the skill to better the technology [20]. In addition, STEM learning involve collaboration, problem-solving, conceptual mastery and high order thinking so students can learn to innovate to develop technology [21]. Implementing STEM approach needs learning model. STEM learning gives direct experience in solving the contextual problem which involves project [22]. Students' activity in making products in STEM [23] can be in the form of projects in the implementation of project based learning. Therefore, the most appropriate learning model to support STEM implementation is project-based learning (PjBL) [7]. Besides to acquire concepts, knowledge, facts, and histories, making projects in PjBL can encourage the development of problem solving and critical thinking skills [24]. It's clear that STEM integrated PjBL can improve students' problem solving skills.

Faraday flashlight project is one of the projects in the topic of electromagnetic induction in PjBL-STEM learning [25]. This project is considered suitable because it implements all principles and concepts in the topic of electromagnetic induction, such as flux magnetic, solenoida coil, Faradays' law, and Lenz's law. The purpose of this research is to investigate the impact of the making of the Faraday flashlight project in STEM integrated PjBL learning towards the improvement of students' problem solving skills.

2. Methods

This paper uses a mixed method with an embedded experimental design by Creswell [26]. The subjects were 36 twelfth grade students in state senior high school in Pasuruan, Indonesia. In this paper, PjBL was used as learning model which has syntax and STEM as learning approach. PjBL syntax, as proposed by Hugerat [27], has six steps: orientation, preparation, project plan, project implementation, post project, and assessment and evaluation. The components of STEM, as proposed by Han, are science (observation, questioning, data collecting, analyzing, and communicating) [28], technology (human process by engineer and science to modify their surroundings to fulfill their needs and desire, and it can be in the form of manufacture, artifact, prototype, etc) [29], engineering (problem identification, alternative solution, selection of best solution, design, prototype making, testing and refinement, communication, and assessment) [30], mathematic (patterns and relations of the phenomenon of nature) [31]. The problem solving skills has 4 indicators, such as meaningful description, physics approach, specific application of physics, mathematic procedure, and logic [8]. STEM components are integrated to all PjBL steps to enhance students' problem solving skills.

Faraday flashlight project using steps of PjBL based STEM can be implemented starting from the beginning of problem identification until the solution is realized. Orientation step contains science component which is to formulate questions, and technology component due to the use of animation or simulation to motivate students. In project preparation, there is engineering component in the form of problem identification, in which students identify and determine the goals and scope of the problem.

This step will exercise the meaningful description indicator. In project plan, science components in STEM are involved, where there are activities such as making a hypothesis, collecting information, and analysis. Engineering components involve activities, such as information collection, selection of best solution, and design. This step will exercise physics approach and math procedure indicators. In the Implementation step, students make prototype based on plan as the product of technology. This step will exercise special application on physics indicator. In Post project step, student make presentation of the product in front of the class. In last step, Assessment and Evaluation, students evaluate and verify their hypothesis and communicate the results by presentation with poster as complement product. This step will exercise logic indicator.

The research instrument were PjBL based STEM lesson plan, problem-solving tests, interview, and learning observation. The validity and reliability of all instruments have already been tested. Data was analyzed by normality, paired sample t-test, N-Gain, and effect size.

3. Result and Discussion

Faraday flashlight project was done with PjBL based on STEM learning to train the students in problem-solving skills. The normality test showed that the pre-test and post-test had the value of Sig. 0.055 and Sig. 0.893, respectively, so both are considered normal. Paired t-test resulted in the value of Sig. 0.000 so it can be said that there is difference on the average score on the pre-test and post-test. This means that the learning with Faraday flashlight in PjBL-STEM was able to significantly increase students' problem solving skills. This result is in accordance to the result of previous study, which showed that PjBL-STEM was successful in enhancing students' problem solving skills in the topic of electromagnetic induction [32]. In effects, the implementation of PjBL based STEM can help students to grasp the concept and to improve their problem-solving skills [33,34].

The result of the analysis of N-gain and d-effect showed that students have, respectively, 0.504 (medium category) and 0.561 (adequate category). These conditions caused by each PjBL based STEM component could help students to exercise their ability to think and solve the problem well. Engineering design, especially, can enhance students' abilities to finish complex problems [35]. The increase of the N-gain has surpassed the threshold that was obtained in active students learning with the score of 0.48 [36]. The result of N-gain and d-effect on each problem solving skill indicator is presented in Table 1.

Table 1. N-gain and d-effect of the problem-solving skill of each indicators

Indicator	N-gain		Effect Size	
	Value	Category	Value	Category
Meaningful Description	0.575	medium	1.958	High
Physics Approach	0.485	medium	2.469	High
Special application on physics	0.443	medium	3.298	High
Math Procedure	0.859	high	2.192	High
Logic	0.336	medium	2.855	High

The effect of PjBL based STEM toward meaningful description indicator had a medium gain but had a high effect. This condition is caused by the problems that were faced by the students during preparation step of PjBL. The problem statement said that some people in the forest need to make a source of light with only a magnet, coil, and lamp as available tools. The result of this problem was 97,4% of students could answer correctly. The other students had responded, but not with proper answer. There were also blank answers. Based on the result in this step, students felt encouraged and felt that the problem was contextual. Based on research which was done previously [37], by learning with engaging and interesting contextual problem can make students to receive information easily. Based on the interview, students who were doing well on meaningful description component and physics approach would able to answer the particular application on physics successfully. The student who had highest score on pre-test was able to solve the problem systematically on post-test. The student who had the lowest score on pre-test was able to increase their score on meaningful component and math procedure in post-test.

In the second problem-solving component, PjBL based STEM had medium gain and high effect toward students' physics approach. The gain and effect were caused by project plan steps, in which students explain the background concepts. In this step, 71.2% students were able to determine the main concepts which were related to the hypothesis, which are electric motion force and Lenz law. Hypothesis lead to many possible alternative solutions, and the students agreed to choose the best one and proceeded to make the design. Students were able to explain the background concepts, which were electromagnetic motion force, time, magnetic field, and lenz law. Students were also able to mention the main tools such as coil, specific magnet that was neodymium magnet, and lamp. According to [8], nature had high engagement toward physics phenomena so physics real problems and contextual problems are interesting to solve. Based on the result, there is still a misconception of physics concept when students explain Lenz law. Research in [8] concluded that contextual problems are very complex and students need a deep understanding in physics to be able to relate one concept to another concept. So, students need a challenge to recognize the scopes of problems to focus on specific concepts.

The effect of PjBL based STEM toward problem-solving components in special application on physics had medium gain and high effect. This condition is caused by this component train in the project implementation step. As many as 75% of the groups finished their project at school. Along with the implementation at school, students tested and refined the project. According to observation, most of the groups did the project well. According to the interview, some of the students felt that they had the capability to do the project well. Based on observation, students could apply the project similar to the design which had already been agreed in their group with few number of revisions. This condition showed that students could apply physics to special problems. Research in [38] concluded their research that when students could collect the information, made hypothesis, and chose best solution, it meant that students had already focused on the problem and ready to apply the solution.

However, students' mathematic procedure skills after learning by using PjBl based STEM had high gain and effect. Based on interviews and observation, this condition is due to the fact that students to solve the problem using mathematic first before trying to apply the physics concepts. Students felt that the problem can be solved when the value on mathematic equations had been fulfilled. According to [39], only mathematics as nature model can help the analysis process to solve the problem. Based on the results, although there's a dominant use of mathematical equations among students, they were still done incorrectly. Students still felt difficult to represent the nature to the mathematic model. PjBL based STEM trains this problem-solving component in project plan step. Based on research on [8,40], students felt it difficult to engage each concept to its mathematics equations. This condition is caused by the poor concept understanding so students could not use multirepresentation.

The last problem-solving component that was logic. Actually PjBl based STEM trains students to think logically in all steps from the start until evaluation. However, there was a special step which can be used to tell if the students can think logically or not, which was assessment and evaluation step. After students got the data from the presentation on post-project, they analyzed and concluded based on the hypothesis. If some of the concepts didn't match with the results, the students can conclude in the evaluation step that refinement must be done. Assessment is done by evaluation to make better improvement for the next project. Lastly, students made poster of their work with the systematics as follows: background of the problem, goal, solution, tools, procedure to make the product, and conclusion. As many as 78% of the students worked the poster well. Based on research, students are able to formulate conclusion from the topic which they learned. Students had also improved their skill when making conclusions, because initially they showed that they can make irrational conclusions but they had made rational and logical conclusions in the end of learning. This condition shows that PjBL based STEM can train students how to think logically. Based on research by [8,41], problem could be solved when students think logically and systematically, and one of learnings which can help students to think logically and systematically is learning which implement problem-solving process.

4. Conclusion

Project-based learning-based STEM had high effect on problem-solving skills. The effect was positive and could help students grasp the problem solving well. Each step of PjBL based STEM trains all components of the problem-solving skill. This condition showed by the result of effect size all problem-solving components which had high effect. However, the gain in some components, which are describing the problem, the use of Faraday induction approach, specific application of physics, and logical progression had the gain in medium category, but mathematical procedures had high category of N-gain. It was caused by the fact that students still has poor understanding of concept and still had a mindset that problem will be solved when the math procedure is solved. It means that physics equation still had the main role in solving the problem. Overall, PjBL based STEM gave positive effect on problem-solving skills, which could help students to face the competition in twenty-first-century.

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