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To cite this article: Parno *et al* 2020 *J. Phys.: Conf. Ser.* **1521** 022025

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# The effect of project based learning-STEM on problem solving skills for students in the topic of electromagnetic induction

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**Abstract.** Problem solving skills is one of six topical areas of physics education research, whereas the research about implementation of Project Based Learning-Science Technology Engineering and Mathematics (PjBL-STEM) to enhance students' problem solving skills is still lacking. This research purposed to reveal the impact of PjBL-STEM on students' problem solving skills in the topic of Electromagnetic Induction with a quasi experiment non-equivalent group design. Grade XII students of Senior High School 2 Pasuruan Indonesia were distributed to Experiment class (PjBL-STEM) (N=36) and Comparison class (PjBL) (N=38). Students worked on two projects, which were light shake and transformer. Problem Solving Skills Test with 0.681 Cronbach's alpha reliability was used as research instrument. Data analysis was done with t-test, effect size, and N-gain. The result showed PjBL-STEM gained problem solving skills significantly higher than the PjBL. Both classes had medium category in the skill's improvement. With "Very Large" effect size, the operationalization implementation of PjBL-STEM model had very large impact than PjBL class in increasing students' problem solving skills. The final questionnaire revealed students in both classes had positive response (Agree and Strongly Agree), which were quite similar towards the implementation of the learning model.

## 1. Introduction

Almost every modern device or machine, from a computer to a washing machine to a power drill, has electric circuits at its heart [1]. It related with electromagnetic induction phenomenon. However, students have misconceptions about the phenomenon of Faraday's law [2], and difficulties in describing microscopic reference involving Lorentz's force as action field in Lenz's law [3]. These difficulties arise because the concept of electromagnetic induction is considered as an abstract concept [4]. The low understanding of these concepts among students can affect their ability to solve problems [5]. It's apparent that students are still struggling to understand the abstract concept of electromagnetic induction which can hamper their ability to solve problems, even though this concept is essential to almost all modern technology and devices.



Problem solving skills can be a complex in nature and is one of six topical areas of physics education research [6]. However, there's still crisis of students' problem solving skills. An early study showed that students still lack problem solving skills in the definition of problem's description, determination of the physics concept, the application of the physics concept, and in the aspect of mathematical procedures [7]. Students also still have unsatisfactory level of problem solving skills in other topics, such as Heat and Temperature [8], Energy of Heat [9], and Modern Physics [10]. It's apparent that the topic of Electromagnetic Induction is rarely used as a subject of research in this area. Few learning models had been implemented to tackle the low level of students' problem solving skills, such as Inquiry-Based Learning for STEM in the work and energy [11] and problem-solving model with Moodle [12] and PBL-STEM on the topic of Optical Instruments [13]. It's evident that the implementation of STEM approach to help the issue of problem solving skills in the topic of Electromagnetic Induction is still rarely done.

The contributing factors to the low problem solving skills can come from the students or the teacher. The use of mathematical equation is commonly used by students as the sole means to solve physics problem without strategy to understand the problem [14]. Such students still consider that the problems to be scientific problems which are abstract in nature. This is also made worse as the teacher give little amount of interest to indulge in technological problems that happen in day-to-day life or to train students' problem solving skills [15]. In reality, teachers can make an effort to indulge the students about technological problems and train students' problem solving skills in learning by creating an Engineering product. It's apparent that the problems about students' problem solving skills are related to the elements of science, technology, engineering, and mathematics (STEM). Therefore, STEM approach is the most appropriate alternative of learning method to grow students' problem solving skills. Product engineering in STEM learning has strong relation with project creation in Project Based Learning (PjBL) learning approach. The result of the research showed that STEM-integrated PjBL can increase STEM literacy in the topic of Energy [16]. This means that PjBL-STEM integration to enhance problem solving skills of students in the electromagnetic induction is still limited.

In 21st century, one most needed skill is problem solving skills [17]. STEM can be the correct approach to hone 21st century skills [18] in physics learning [19] to have better quality in learning process [20]. STEM involves the students to solve day-to-day problems by working on unclear problems to be a clear solution with team effort [21]. STEM makes the learning context meaningful [22]. STEM implementation in learning can motivate students to plan, construct, and make use of the technology and also to train cognitive, psychomotor, and affective skill and to apply their knowledge [23]. The STEM approach can make students to be better at solving problem, inventing new things, and to be independent, logical thinker, and technology literate [24]. It's clear that STEM approach can make students be better problem solvers.

PjBL is a learning model relevant with the demands in the 21st century. Its steps act as Curriculum Integration, Action Projects & Stewardship, dan Showcase Project [25]. PjBL organize a project in a class [26]. The project in PjBL is related to the area of Science, Technology, Engineering, and Mathematics. To integrate STEM into learning, activities focused on making products can be done in class [16]. The topics relating to PjBL project can be used to teach the concept of science, knowledge, history, facts, and the nature of science, and to hone problem solving and critical thinking skills [27]. Therefore, PjBL in STEM learning is expected to be able to increase students' problem solving skills.

Project based learning with integration of STEM can hone and increase problem solving skills of students. This research is going to study the gain or loss, if any, in problem solving skills of students. The scores of Experiment (PjBL-STEM) and Comparison (PjBL) class will be measured and analyzed. The effects of the learning methods will be discussed.

## 2. Methods

This study used a quasy experiment non-equivalent group design [28]. Grade XII students of Senior High School 2 Pasuruan Indonesia were distributed to Experiment class (PjBL-STEM) (N=36) and

Comparison class (PjBL) (N=38). Students worked on two projects, which were light shake and transformer. The PjBL-STEM had seven steps in this learning setting [29], which are Identifying of Problem and/or Constraints, Researching, Forming Ideas, Analyzing Ideas, Modeling or Prototype Building, Testing and Refining, and Communicating and Reflecting. The most dominant aspect is the engineering aspect, which has 7 steps: (1) Problem identification, (2) Data gathering to detect alternate solutions, (3) Solution identification, (4) Plan and construction, (5) Testing, (6) Revision, and (7) Evaluation [30]. The Comparison class implemented PjBL only, which consists of six stages, which are Pre-preparation, Preparation for the project, Planning for the project, Project implementation, Post-project, and Assessment and evaluation [31]. Students in two classes worked on two projects, which were light shake and transformer. In PjBL-STEM, project is made as a solution of the problem, while in PjBL the project came directly from the teacher. In PjBL-STEM, students need to assess in detail the performance of the project to see if it fits the project's aim, while in PjBL students only present the data of the project as is.

Pre-test was conducted at the beginning while post-test was conducted at the end of the whole learning process. Electromagnetic Induction Problem Solving Skills Test with Cronbach's alpha reliability of 0.681 was used as research instrument based on indicator on problem solving skills [32]. Data analysis was done with t-test [33], N-gain [34] and Cohen's d-effect size [33].

### 3. Result and Discussion

The data for the pre-test score's mean and standard deviation of Experiment class and Comparison class are, respectively, 15.17(5.48) and 14.84(4.15). It can be seen that the two classes have similar score in problem solving skills at the beginning of learning process. To know the similarity of two classes' problem solving skills at the beginning, t-test was conducted. There are no differences between Experiment and Comparison classes (Sig. 0.775) in regards to beginning students' problem solving skills. Therefore, the loss or gain of problem solving skills of students at the last of the research can only be credited to the different treatments in two classes.

The data for the post-test score's mean and standard deviation of Experiment class and Comparison class are, respectively, 57.78(9.62) and 41.63(9.94). It can be seen that Experiment class' problem solving skills was higher than Comparison class. It shows that students learning with PjBL-STEM gained problem solving ability better than those learning with PjBL.

We conducted t-test to find out the problem solving skills' differences after the experiment in two classes. Difference is detected among the two classes (Sig. 0.000) in terms of problem solving skills of students. The resulting difference was caused by the different learning approaches, which are PjBL-STEM in Experiment class and PjBL without STEM in Comparison class. Each learning approach affects students' problem solving skills and makes them change in the end.

PjBL-STEM approach is deemed better than PjBL without STEM in engaging the students to be active and to give them motivation. This is due to the presence or absence of problem identification in both classes. In PjBL class, students only worked on the pre-determined project which was given by the teacher. Meanwhile, in PjBL-STEM class, students made a product based on problem identification in the beginning of learning process. The students get contextual task to finish problems by integrating the concepts of science, engineering, and mathematics [29]. The product design and planning made the students work together and share with one another their knowledge about the concept [35]. Thus, the separately taught concepts can be useful to provide them with relevant experience. Students then felt the want to know more [36]. Moreover, with STEM integration, students can feel encouraged to pursue their interest in career and in science and mathematics [24].

To finish the project in PjBL class, students only needed to present the project in front of the class. In PjBL-STEM class, students needed to test and refine the performance of the product. This is why PjBL-STEM class' post-test score was better than the PjBL. This indicates that the conceptual understanding of PjBL-STEM class in Electromagnetic Induction topic is better. Problem solving skills is often related to conceptual understanding. If students have good understanding, they have better chance in solving their problem [37]. The problems' solution can be acquired by implementing the knowledge,

skills, and understanding [38]. Problem solving skills is the applying of knowledge or thinking and the ability to get certain goals [39].

N-gain analysis of pre-test and post-test data showed that Experiment class 0.502 is higher than Comparison class 0.315. This indicates that PjBL-STEM learning is better than PjBL to enhance problem solving skills of students. This order of quality is the same with above findings in t-test of the post-test score. This can be caused by the use of STEM aspect in PjBL-STEM class, especially the Engineering aspect. Engineering design can enhance students' abilities to finish complex problems [40]. PjBL increased engagement, classroom culture and interest in STEM [41]. Both Experiment and Comparison class has N-gain score in medium category. However, the N-gain in Comparison class is below the threshold of the average N-gain score while the N-gain in Experiment class is above it. The average was obtained in active students learning with 0.48 score [42].

Students in PjBL-STEM class built a product of science to finish certain problem. Students shared their opinions and analysed them to determine which to be included into the project. In groups, students performed testing to refine their products in front of the class while getting feedbacks and critics to improve the product. Students can also give estimation about price of the product at the market. This is different with PjBL where students are not as active. They were instructed to finish the pre-determined project given by the teacher and then present it. When one group was explaining their work, others were only permitted to share their criticism or comments. These different treatments in two classes lead to different set of activities which ended in different change in problem solving skills of students. From this illustration, it's proven why STEM can enrich experience of students with practical learning implementation [43]. This study covers two subtopics in Electromagnetic Induction in Problem Solving Skills Test instrument. Each subtopic had N-gain score that is presented in Table 1.

**Table 1.** N-gain scores of electromagnetic induction in subtopic each class.

Subtopic	N-gain Exp class	N-gain Comp class
Faraday's and Lenz Laws	0.576 (Medium)	0.202(Low)
Induced Electric Fields and Inductance	0.479 (Medium)	0.419 (Medium)

From Table 1, it can be said that the N-gain of PjBL-STEM class in both subtopics are higher than PjBL class. In the subtopic of Faraday's and Lenz Laws, the medium N-gain score of Experiment class is at one level above the low N-gain score of the Comparison class. As matter of factly, students had misconception about the phenomenon of Faraday's law [2] and difficulties about Lenz's law [3]. However, students in Experiment class designed and made light shake as the product of application of Faraday's and Lenz Laws, which was more than the ordinary project in Comparison class. This study covers 5 indicators in problem solving skills test instruments. The N-gain score for each indicator is presented in Table 2.

**Table 2.** N-gain score of critical thinking skills indicators in each class.

Indicators	N-gain Exp class	N-gain Comp class
Useful Description	0.663 (Medium)	0.384 (Medium)
Physics Approach	0.536 (Medium)	0.372 (Medium)
Specific Application of Physics	0.456 (Medium)	0.282 (Low)
Mathematical Procedures	0.589 (Medium)	0.343 (Medium)
Logical Progression	0.341 (Medium)	0.230 (Low)

From Table 2, it's proven that the N-gain score in PjBL-STEM class is higher than PjBL without STEM in all indicators. Furthermore, in two indicators, Specific Application of Physics and Logical Progression, students in Experiment class have medium N-gain score, which was a level higher than low N-gain score in Comparison class. This means that the students in Experiment class are better than the students in Comparison class in regards to their application of principal and laws of physics.



They're also more focused and precise in solving the problem presented to them. Problem solving skills can aid in solving problems for students by thinking of the relevant theories and concepts [44]. Also, students in Experiment class had produced clear, focused, and logical solution to the problem. Physics problem solving skills needs students identifying, determining and solving certain problems using logical, literary and creative thinking [45].

Analysis of problem solving skills effect size of students was conducted for both classes. The Experiment-Comparison class pair has the effect size  $d = 1.65$  in "Very Large" category. This result indicates that the operationalization of PjBL-STEM has the impact in Very Large category as compared to PjBL without STEM to increase problem solving skills of students. Therefore, the proposed PjBL-STEM is very recommended to be implemented widely in the attempt to improve students' problem solving skills.

The result of students' response towards the learning activity is both classes earned "agree" and "strongly agree" response in almost similar percentage, which are 95.75% for Experiment class and 96.25% for Comparison class. This means students are comfortable in both classes. Indeed, the activity in both classes was focused on making products, so both are not conventional class. This result is in accordance to the finding that Physics STEM Education Learning class is able to generate higher satisfaction than conventional class [46].

#### 4. Conclusion

Based on the results and discussion, conclusions can be drawn as follows. T-test result shows that different learning approach affects problem solving skills of students. The post-test score of Experiment and Comparison class are, respectively, 57.78 and 41.63, which means that students learning with PjBL-STEM had gained significantly higher problem solving skills than those learning with PjBL (Comparison class). N-gain analysis showed that Experiment class had higher score than Comparison class (0.502 compared to 0.315, respectively). Also, based on the threshold of gain average which can be obtained in active students learning, Experiment class obtained higher average score in Medium category, whereas Comparison class obtained average score way below the threshold in Medium category which almost reached Low category. Effect size analysis with the result of  $d = 1.65$  shows that the operationalization of PjBL-STEM model had a "Very Large" impact than PjBL without STEM class in increasing students' problem solving skills. The final questionnaire revealed students in both classes had positive response (Agree and Strongly Agree), which are 95.75% for Experiment class and 96.25% for Comparison class. The response was quite similar towards the implementation of the learning model. This means students are comfortable in both classes.

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