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The Effect of STEM Approach in Problem-based Learning for Increasing Students' Problem-solving Ability in the Topic of Environmental Pollution

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Abstract.
Environmental pollution is a manifestation of the interaction between living things and their environment. However, students still have low problem-solving ability (PSA) in this topic. Meanwhile, STEM approach implementation in problem-based learning (PBL-STEM) to grow students' PSA is still rarely used. This study aims to improve students' PSA by implementing STEM approach in PBL on the environmental pollution topic. This quasi-experimental research uses a pre- and post-test design. This study was done on a group of 64 7th grade students, who were equally divided into experimental class (PBL-STEM) and comparison class (PBL) In completing the worksheet during learning, the experimental class students were required to be more active in terms of thinking, than the comparison class students. This study uses the environmental pollution problem-solving ability test instrument, which consists of 13 essay items with a Cronbach alpha reliability of 0.785. Pre- and post-test data were analyzed using independent t-test, N-gain, and d-effect size. The results showed that students who studied through PBL with the STEM approach had significantly better PSA than students who studied through PBL. Also, students in the experimental class had a larger N-gain increase compared to the comparison class, both in total topics and subtopics of environmental pollution. Even in the subtopic of noise pollution, the PSA of the subjects in experimental class improved one level higher than the subjects in comparison class. Both classes had the same increase in succession from large to small, namely, water, soil, air, and noise pollution. The practical implementation of the research resulted in a d-effect of 0.782 medium category. Therefore, the STEM approach in PBL affects increasing students' PSA on the topic of environmental pollution. In future research, it is recommended to add "Religious" and "Art" aspects of STEM, and be equipped with formative assessment in the whole learning process.

Keywords: STEM approach, problem-based learning, problem-solving ability, environmental pollution

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1. INTRODUCTION

The interaction of living things and their daily environment can cause environmental damage, namely environmental pollution [1]. Therefore, humans are a factor causing environmental pollution [2]. Meanwhile, environmental pollution topic is very important for students because it has a serious impact on the environment, a strong influence on society, and solutions to overcome it [3]. However, students still have an average learning achievement of 49.76 on environmental pollution [4]. This is supported by the results of interviews with several science teachers that students still have difficulties, especially in determining the types of pollution. Also, teachers still have difficulty in integrating the concepts and principles of environmental pollution so that they become themes or issues in integrated learning [5]. Students who have difficulty understanding environmental pollution topic can influence their thinking in finding solutions to solving environmental pollution problems [6]. Meanwhile, students who understand physics concepts well have the opportunity to be able to solve the problems presented in physics learning [7].

The 21st century is in dire need of problem solving ability (PSA) [8]. One of the six research areas of learning physics is PSA [9]. Indeed, meaningful learning of physics really requires PSA [10]. This is because problem solving skills require strategies for using prior knowledge and information gathering [11] to sharpen concepts and at the same time develop problem solving strategies [12]. However, students still have problem-solving skills that are still not optimal. Research shows that on several physics topics, namely Optical [13], Heat [14], Fluid Static [15], Energy [16], and Modern Physics [17] students still have low problem solving abilities. It appears that research on PSA on the topic of environmental pollution is still rarely done.

Several learning models have succeeded in overcoming the low problem-solving skills of students, such as IBL-STEM on energy topics [18], Moodle-Problem Solving model [19] and PBL-STEM [20] on optics topic, and PjBL-STEM on electromagnetic induction topic [21]. It appears that PBL and STEM are able to improve students' PSA. In addition, research on improving problem-solving skills on the topic of environmental pollution is still rarely done. Therefore, STEM integrated PBL solutions have a great opportunity to build PSA on the topic of environmental pollution.

Environmental pollution topic is closely related to solving the problems of everyday environmental damage. PSA can be grown through Problem-based Learning (PBL) [22]. However, the handling of contextual problems in the topic of environmental pollution does not only require a theoretical solution, but also requires a technological product solution. Therefore, in an effort to improve students' PSA in learning the topic of environmental pollution, besides requiring PBL treatment, it also requires integration with the STEM approach. Students investigate authentic and meaningful problems [23], and students become independent learners [24] which is the hallmark of PBL. On the other hand, through the STEM approach, students learned to master how to find solutions to problems which can be done by applying the theory they learned in order to design and build real-life products of technology in the miniature scale [25]. Indeed, the quality of the learning process can be improved [26, 27] while at the same time make the context of learning to be more meaningful if the STEM approach is integrated into physics learning [28–31]. It is clear that STEM-integrated PBL has a great opportunity to cultivate students' PSA. Thus, the purpose of this study was to develop students' PSA through PBL-STEM on environmental pollution topic.

2. RESEARCH METHOD

This research uses design of quasi-experimental setting with a pre- and post-test design [32]. The subjects of this study were 64 seventh grade students in a junior high school in Malang, Indonesia, which were equally distributed in the class with PBL-STEM, which is called experimental class, and the class of PBL, which is called comparison class. PBL learning is carried out through 5 syntaxes [23], the STEM approach has 4 aspects, namely science, technology, engineering, and mathematics, which are integrated into the learning process as a whole [33, 34], and PSA have 5 stages, namely problem description, determination of alternative problem solutions, selection and application of alternative solutions, evaluation/mathematical procedures, and reflection on problem solving [7]. The following presents the implementation of PBL-STEM to improve PSA.

Table 1: PBL-STEM model design to cultivate problem solving ability.

PBL-STEM Syntaxes	**Steps of Problem Solving Ability**
Student orientation towards problems *(Science)*	Problem description
Organizing students to learn *(Science)*	Problem description
Assist with independent or group investigations *(Technology, and Mathematic)*	Determination of alternative solutions to problems
Develop and present the work and exhibit it *(Science, Engineering, and Mathematic)*	Selection and implementation of alternative solutions Evaluation procedures/mathematics
Analyze and evaluate the problem solving process *(Science, and Mathematic)*	Reflection on problem solving

In completing the worksheet during learning, the experimental class students are required to be more active and think than the comparison class students. On the subtopic of air and noise pollutions, students of both classes are required to complete the same worksheet. However, on the subtopic of soil pollution, experimental class students must determine the tools and practicum materials, make a practicum design, and predict the shape of the practicum data table. Also, on the subtopic of water pollution, experimental class students determine and choose the optimal tools and materials, and make and choose the best designs from miniature products of water purification technology.

This study uses the environmental pollution problem solving ability test instrument. This instrument consists of 13 essay items with a Cronbach alpha reliability of 0.785, covering the subtopics of soil, air, water, and noise pollutions, and each test item contains problem solving indicators. Pre- and post-test data were analyzed using independent sample t-test [35], N-gain [36], and d-effect size [35].

3. RESULT AND DISCUSSION

The result of mean and standard deviation for the experimental and comparison class data were 60.03 (7.59) and 57.99 (7.96), respectively. Both of these pretest data met the assumptions of data normality and homogeneity of variance. Therefore, the difference test between the two used independent t-test. The results of this difference test indicate that the experimental and comparison classes have a pretest score that is not different from each other (Sig. (2-tailed) = 0.298). This result can be interpreted as, at the beginning of the research, both classes start with the same initial state of PSA. Thus, the results of posttest data analysis can be attributed to the presence or absence of PBL-STEM influence.

The average score and standard deviation of the posttest data for the experimental and comparison classes were 81.24 (4.35) and 77.81 (4.43), and both met the assumptions of data normality and homogeneity of variance. The results of the independent t-test analysis showed that the posttest data of the experimental class was significantly higher than that of the comparison class (Sig. (2-tailed) = 0.003). This means that the PBL-STEM treatment in the experimental class is able to grow problem-solving skills significantly better than the PBL treatment in the comparison class.

Learning that awakens PSA emphasizes on hands on activity [15]. This can happen in learning the topic of environmental pollution which is closely related to everyday contextual problems and their solutions in the form of miniature technology products. These two characteristics are indeed fulfilled by problem-based learning [37] and STEM approach [38] so that students' PSA can be improved. In this study, PBL presents contextual problems in each subtopic. The subtopics of soil, water, water, and noise, respectively, present daily problems in the form of soil conditions in Batu city, as a producer of apples, which are dry in the dry season and smell bad; forest fires; the current condition of the upstream of Brantas is dirty and not as clear as it used to be; and airports that are close to residential areas and have the potential to trigger accidents because the distance between the runway and residential areas is only 1.5 km. While the STEM approach requires students to determine practicum tools and materials, make practicum designs, and predict the form of practicum data tables in the soil subtopic; and engineering design product when making miniature water purification technology. This means that the STEM approach provides opportunities for students to cultivate a collaborative attitude so that sharing of concept understanding can occur when working together in making technological miniature products [39]. The existence of the STEM approach in PBL is what causes the PSA of the subjects in experimental class to be better than the PSA of the subjects in comparison class. This happens because the STEM approach can develop skills in how to implement science and mathematics to solve everyday contextual problems in PBL [40]. In addition, the integration of the STEM approach in PBL can indeed increase students' motivation which in turn can incite the growth of students' daily contextual problem solving skills [7]. The results of the N-gain analysis in both classes are presented in the following Table 2.

Table 2: Result of N-gain in experiment and comparison class.

Parameter	**Class**	
	Experiment (n=32)	**Comparison (n=32)**
N-gain	0.531	0.472
Category	Medium	Medium

From Table 2, it can be seen that students in the students in PBL-STEM class acquired problem solving skills with better N-gain than the PBL class. The experimental class gains can exceed the threshold of N-gain average (0.48) from active learning [41], while the comparison class is around this threshold value. It can be inferred from this result that the application of STEM in the learning process can build students' PSA. The N-gain information of each subtopic of environmental pollution is showed in Table 3.

Table 3: Result of N-gain of each subtopic of environmental pollution.

Class	**N-gain Value of Subtopic of Environmental Pollution (Category)**			
	Soil	**Air**	**Water**	**Noise**
Experiment	0.610 (Medium)	0.485 (Medium)	0.620 (Medium)	0.391 (Medium)
Comparison	0.537 (Medium)	0.438 (Medium)	0.610 (Medium)	0.295 (Low)

Both classes have the same increase in succession from large to small, namely, water, soil, water, and noise pollutions. This means that students in both classes actually have the same order of difficulty in this environmental pollution sub-topic. However, the experimental class students had a higher N-gain increase than the comparison class in all subtopics of environment pollution. In fact, in the noise subtopic, the experimental class students obtained N-gain which was a level above the comparison class. The result shows that the implementation of STEM in PBL has an effect on improving the PSA of the students.

In the water subtopic, students in both classes have the highest N-gain. This happens because students make engineering products only on this subtopic. Students of both classes are involved in the same investigation, namely water purification. However, the experimental class students determine as many tools and materials as possible and choose the optimal one, make as many designs as possible and choose the best one, and test whether the miniature product of water purification technology works or not. While the comparison class students make these products based on the tools and materials, and designs that have been provided. It can be seen from this result that the students in experimental class are more involved, both mentally and actively, in activities so that they have higher gains compared to the students of the comparison class. It appears that the STEM approach in PBL is able to instill students' problem solving skills, which in turn can foster students' creativity and curiosity [25].

In the soil subtopic, the experimental class students were also involved in higher activities than the comparison class students. In soil pollution practicum, experimental class students must determine the types of tools and practicum materials, make a practicum design, and predict the shape of the practicum data table. Meanwhile, in the practical class comparison of tools and materials, designs, and practical data tables have been provided in the worksheet. This is what is suspected to cause the N-gain of the subjects in the experimental class to be better than the subjects in the comparison class. It seems that while solving the problem of soil pollution, experimental class students are able to integrate abstract concepts from every aspect of STEM so that knowledge about the subject being studied is more understood [39].

Both classes have the lowest N-gain in the Noise pollution subtopic. This means that the both class students actually have the lowest understanding or have the highest difficulty on the Noise pollution subtopic. However, the students of experimental class had an increase in PSA one level higher than the comparison class students in the subtopic of noise pollution. This can be explained through how students solve problems on test items number 11 and 12. Test item number 11 has an indicator of the item "Given a case in the form of a place to live near the airport, students can determine the impact that will be received on health". In this test item, experimental and comparison class students had N-gains of 0.403 (Medium) and 0.297 (Low). PBL class students are only able to provide alternative solutions, namely to be free from experiencing environmental pollution problems. However, the PBL-STEM students, besides being able to provide alternative solutions, are also able to provide evaluations, namely the biggest impact felt is noise pollution. Even the students of experimental class were capable to describe the application of problem solving, namely in order to overcome disturbances that could arise, such as communication disorders, bodily functions, and psychology. This is what causes students in the STEM approach to have an N-gain one level higher than students without the STEM approach.

The test item number 12 has an indicator of the item "Given a statement regarding Government Regulations regarding airports, namely the ideal distance from the runway to settlements is 5 km, then students can determine the benefits of the regulation on the environment". In this test item, students in the class of experimental and control have the N-gain of 0.344 (Medium) and 0.196 (Low). PBL class students are only able to provide alternative solutions, namely to minimize accidents and so that people do not experience disturbances due to airport activities. However, the experimental class students, besides being able to provide alternative solutions, are also able to provide evaluations, namely to avoid things that are dangerous and minimize accidents and reduce noise pollution levels due to airport activities. Even the students in class of experimental were successful in describing the application of problem solving, namely so that residents around the airport did not feel the noise pollution caused by airport activities. This is what causes students in the STEM approach to have an N-gain one level higher than students without the STEM approach. Table 4 contains the results of the d-effect analysis.

Table 4: Result of effect size analysis in the experiment and comparison classes.

Parameter	Pair of Experiment and Comparison Classes
d-effect size	0.782
Category	Medium

It appears that the practice of implementing pairs of PBL-STEM and PBL classes has a medium effect. This effect occurs because the experimental class students make products through complete product design engineering steps [42]. In addition, this effect size analysis has the consequence that the implementation of PBL-STEM and PBL class pair learning in schools can have a medium impact on improving students' PSA.

This research resulted in improving students' PSA through the integrated PBL STEM approach on the topic of environmental pollution. Increasing students' PSA can be pursued even higher through student activities and a more optimal learning process. Therefore, in future research it is recommended to add “Religious” and “Art” aspects of STEM, and be equipped with formative assessment in the whole learning process.

4. CONCLUSION

Based on the results and discussion, it can be concluded that students in the PBL-STEM class managed to have more superior PSA than students in the PBL class. This is supported by the improvement in N-gain in the experimental class which is better than the comparison class. In each environmental pollution subtopic, the experimental class students had a higher N-gain increase than the comparison class. Even in the subtopic of noise pollution, the students of experimental class had an improvement in PSA one level above the comparison class students. Both classes have the same increase in succession from large to small, namely, water, soil, water, and noise pollutions. Students of both classes have the lowest understanding or have the highest difficulty on the noise pollution subtopic. The practical implementation of the research, in a d-effect of 0.782 medium category so that the implementation of PBL-STEM and PBL class pair learning in schools in general can have a medium impact on improving students' PSA. Therefore, the STEM approach in PBL has an effect on increasing students' PSA on the topic of environmental pollution. In future research, it is recommended to add “Religious” and “Art” aspects of STEM, and be equipped with formative assessment in the whole learning process.

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