JPII 9 (4) (2020) 465-476

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

THE EFFECT OF STEM-PjBL AND DISCOVERY LEARNING ON IMPROVING STUDENTS' PROBLEM-SOLVING SKILLS OF THE IMPULSE AND MOMENTUM TOPIC

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DOI: 10.15294/jpii.v9i4.26432

Accepted: October 1st 2020. Approved: December 28th 2020. Published: December 31st 2020

ABSTRACT

This study aims to investigate the effect of Science, Technology, Engineering, and Mathematics-Project Based Learning (STEM-PjBL) and discovery learning on students' problem-solving skills. The research is a Quasi-Experiment with a Nonequivalent Pretest-Posttest Control Group Design. The participants involved are 53 students of class X from a high school in Malang, where 28 students studied with STEM-PjBL, and 25 students studied with discovery learning. This research was conducted on the impulse and momentum topic. In this analysis, the researchers have developed a set of problem-solving instrument with a particular field approach to impulse and momentum topics to obtain an instrument with a reliability of 0.81. This instrument collects student problem-solving data before and after learning both in the experimental class and in the comparison class. Problem-solving skills data were analyzed using descriptive statistics and inferential statistics. The results showed a significant difference in the scores of students' problem-solving skills in the experimental class and the comparison class ($p<0.05$). The problem-solving skill in the experimental class (Mdn=78.74) was higher than the comparison class (Mdn=70.00). In STEM-PjBL learning, students are better trained and challenged to solve problems in everyday life. Compared to the comparison class, learning in the experimental class is more able to accommodate students' ideas and make students more interested in learning. In conclusion, STEM-PjBL has a significant positive effect on improving students' problem-solving skills rather than discovery learning.

Keywords: STEM-PjBL; problem-solving skills; discovery learning; project

INTRODUCTION

In daily life, problems are always present, they cannot be avoided, but they must be resolved. As a result, a person needs certain skills to complete it. Education is an attempt to improve skills related to how to solve problems. Specifically, in science learning, one of the aims is to prepare students for 21st-century skills (Halim & Meerah, 2016), including problem-solving skills (Huang & Asghar, 2016).

The skill to solve problems is one of the skills needed in the world of work (Rios et al., 2020). Therefore, the skills to solve problems need to be developed at various levels of education (Greiff et al., 2013; Scherer & Beckmann, 2014; Root et al., 2020). This certainly has implications so that the learning process also needs to be directed to develop problem-solving skills. The results of observations made in several schools in Malang indicated that most teachers still teach traditionally, including in physics. Teachers often explain concepts, provide examples of problems, then solve them mathematically. This makes solving physics problems more associated with mathematical solutions only (de Ataíde & Greca, 2013). Even though they do a practicum, students just follow the guidelines. Therefore, an authentic problem-solving process is not carried

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out. As a result, students are not trained to develop scientific solutions to a phenomenon or problem. This condition is confirmed by preliminary studies that students' problem-solving needs to be improved (Purwaningsih et al., 2020).

In recent decades, problem-solving has begun to receive serious attention from researchers in physics education. Problem-solving is seen as one of the most important skills a person has (Leak et al., 2017; Saadati et al., 2019; Walkington et al., 2019; Rott, 2020; Safaruddin et al., 2020;). With good problem-solving skills, students can understand a concept of science more deeply (Scherer & Beckmann, 2014; Xie & Masingila, 2017; Lim & Han, 2020), choose a method of solving a problem more efficiently (Sumirattana et al., 2017), and choose a more diverse model (Akben, 2020). In particular, problem-solving in physics can educate students in solving complex problems not only in the classroom but also in the world of work later (Williams, 2018). Even so, according to Docktor et al. (2015), most students' problem-solving skills are still low; even in the early stages of planning, they have difficulty. More specifically, in the Indonesian context, students' problem-solving skills are still relatively low when compared to students in other countries (Scherer & Beckmann, 2014; Pisa, 2015; Hasibuan et al., 2019).

Several attempts have been made to improve students' problem-solving skills. In several studies, innovative learning such as problem-based learning (Argaw et al., 2016), problem-posing learning (Akben, 2020), and modeling-based learning (Demirhan & Şahin, 2019) was found to be able to improve students' problem-solving skills. These lessons can make students learn actively through concrete problems.

As an active learning program, several reports have shown that Project Based Learning (PjBL) has a positive effect on improving the quality of science education. This is because students carry out activities from designing to realizing the design into a product (Mihardi et al., 2013). This model also makes students play an active role in investigating phenomena in everyday life (Lee et al., 2019) and doing a variety of activities that are different from usual. Studies also show that students respond positively by improving several skills (Van, 2016) and are motivated to pursue careers in science, technology, engineering, and mathematics (STEM) (Auer et al., 2017). Furthermore, with projects, students' scientific skills and engineering skills can be improved (Annetta et al., 2019).

STEM learning is needed by students in improving various 21st-century skills (Schmidt & Fulton, 2016). Many students in various countries believe that STEM can guarantee their future careers (Tseng et al., 2013). This learning trains students to make solutions to a problem from a variety of perspectives. Furthermore, as interdisciplinary learning, STEM can be taught by several learning strategies such as problem-based learning (Lou et al., 2011; Parno et al., 2020), inquiry-based learning (Cedillo, 2018; Yuliati et al., 2018), and project-based learning (Tseng et al., 2013; Capraro & Capraro, 2016; Vogler et al., 2018).

Furthermore, as a form of reformative learning, discovery learning has also had a significant influence on science education development. In discovery, students build their knowledge inductively by following the examples and learning structures presented by the teacher (Ozdem-Yilmaz & Bilican, 2020). Clements and Joswick (2018) recommended combining discovery learning with learning technology. Technology integration in learning is packaged by considering its relationship with content and teacher's pedagogy (Koehler & Mishra, 2005). This is a new challenge for teachers to integrate technology into the learning process. Discovery learning in this study was carried out with the help of a virtual laboratory.

Several researchers have conducted studies related to the implementation of STEM learning, PjBL, and discovery learning in science education. Recently, Shanta and Wells (2020) found that technology-based learning and engineering design significantly affect students' problem-solving skills. In line with that, Priemer et al. (2020) and Lin et al. (2015, 2020) explained that learning by integrating science, technology, engineering, and mathematics can improve student problem-solving. Another report shows that as a type of life skill, student problem-solving can improve in a project-based learning environment (Wurdinger & Qureshi, 2015). In line with this, with qualitative and quantitative data, Song (2018) confirmed that PjBL can help students solve problems collaboratively.

Discovery learning was found to be able to train students' specific abilities both in terms of content and skills (Abrahamson & Kapur, 2018; Chase & Abrahamson, 2018). Several studies have also found that discovery learning can improve students' problem-solving (Hudha & Batlolona, 2017; Wartono et al., 2018, Yuliati & Munfaridah, 2018). This can happen if the discovery process is accompanied by teacher guidance

(Alfieri et al., 2011; Cáceres et al., 2019). In summary, these studies show that PjBL, STEM, and discovery learning have the potential to improve students' problem-solving. However, STEM does not already address the learning steps as an approach to the learning process. Therefore, STEM learning with PjBL (STEM-PjBL) seems to have the ability to improve student problem-solving. Unfortunately, research on this model is still rare. Therefore, a study comparing STEM-PjBL with discovery learning was performed.

The characteristics of the impulse and momentum topic are also considered in choosing a learning model in this study. Impulse and momentum are fundamental in Physics learning, which, according to Xu et al. (2020), students' habit of solving impulse and momentum problems is built from the surface to deep understanding. It is also the foundation to learn advanced physics such as machine and structural design, advance dynamic, and structural mechanics (Fang, 2012). The concept of impulse and momentum is also close to students' life and applicable in technological products such as helmet construction, crumple zones in a car, airbag construction, and the crack of the bat. Based on these features, impulse and momentum are commonly used in engineering and technology such that constructivist learning, such as STEM-PjBL and discovery learning, can be implemented. However, the meaning and effect of both learning instruction in impulse and momentum topic has been unclear so far.

By comparing two types of learning whose characteristics are relatively the same, the advantages and disadvantages of a model when applied in learning can be identified. Similar research has been carried out by comparing two types of learning models, namely Problem-based Learning (PBL) and PjBL, which was conducted by Dole et al. (2017). They used qualitative data to see the effect of the two types of learning. A similar study was conducted by Suhartono et al. (2019) by comparing the group investigation learning model with the direct instruction model. In this study, the effect of PjBL-STEM and discovery was investigated quantitatively. The information obtained can be useful for the physics curriculum, especially for teachers. The findings can be used as consideration for teachers in designing future learning. This research aimed to explore the effect of PjBL-STEM learning and discovery learning on students' problem-solving skills. We also investigated the features of STEM-PjBL and discovery learning that could improve students' problem-solving. Besides, this study also analyzes how the developed physics problem-solving measurement instrument can describe students' problem-solving. Furthermore, empirical evidence regarding the advantages and disadvantages of these two constructivist studies is also discussed.

To empirically explore students' problem-solving skills, we employed STEM-PjBL class and discovery class. Three research questions lead to this study. First, how does STEM-PjBL learning impact the students' problem-solving skills of impulse and momentum? Second, how does discovery learning impact students' problem-solving skills of impulse and momentum? Third, how the physics problem-solving instrument developed can describe students' problem-solving skills?

METHODS

This research is a Quasi-Experiments with Nonequivalent Pretest-Posttest Comparison Group Design (Best & Kahn, 2006). There are two groups involved, namely the experimental group and the comparison group. The two groups were given different treatment where the measurement of problem-solving skills was carried out before (pre-test) and after (post-test) treatment. The design of this study is shown in Table 1.

Table 1. Pretest – Posttest Non-Equivalent Comparison Group Design

Group	Pretest	Treatment	Posttest
Experimental Class (EC)	O1	X1	O2
Comparison Class (CC)	O3	X2	O4

*Where O1: The observation of the experimental class pretest; O2: The result of the experimental class post-test; O3: The observation of the comparison class pretest; O4: The observation of the comparison class post-test; X1: The experimental class treatment; X2: The comparison class treatment.

The sample in this study was not determined randomly because it was not possible to change an established class structure, but two classes were selected with equal ability levels based on data from teacher assessments. This research was conducted in a high school in Malang. The research subjects were involved as many as 53 students of class X, consisting of 28 students in the experimental class and 25 students in the comparison class.

Treatment in the experimental class follows the STEM-PjBL syntax developed by Laboy-Rush (2011), consisting of reflection, research, discovery, application, and communication. The strength of PjBL lies in the fact that PjBL does not only integrate knowledge from various disciplines but also between theory and practice. Meanwhile, STEM learning is interdisciplinary learning that emphasizes problem-solving activities from various perspectives (Martín-Páez et al., 2019). Therefore, PjBL and STEM learning are suitable to be applied simultaneously (Laboy-Rush, 2011; Jalinus et al., 2019;). Students in the experimental class learn by constructing a water rocket project that incorporates classroom learning (hands-on) with the use of Edmodo. Students create, test, revise, and communicate the water rockets they make in groups. Students discuss and collaborate with teachers on the Edmodo platform. Meanwhile, treatment in the comparison class uses discovery learning syntax, which consists of 6 steps, namely stimulation, statement problems, data collection, data processing, verification, and generalization (Carin & Sund, 1993). In the comparison class, students conduct simulated experimental tasks, which are explored explicitly in the classroom and the Edmodo. Several studies have shown that the use of virtual laboratories could support discovery learning (Levy et al., 2018). Karlsson et al. (2013) stated, however, that this kind of learning environment should be able to provide additional tools that can connect student learning experiences with relevant phenomena. In summary, aside from variations in learning models, the learning tasks in the experimental class were primarily carried out in a hands-on manner, whereas in the comparison class, they were carried out in a virtual laboratory.

The dependent variable in this study is the impulse-momentum of problem-solving skills. The measurement instrument used is a test consisting of six items in the description concerning five indicators, recognize the problem, represent the problem in formal terms, plan a solution, execute the plan, and evaluate the solutions. This instrument is specially developed with a series of systematic processes. In contrast to other studies, the problem-solving instrument in this study uses domain-specific instruments on the topic of impulses and momentum. According to Walker et al. (2016), a specific domain approach can be used to measure problem-solving on a particular topic. Furthermore, this instrument is constructed with authentic properties, involves engineering design, and is related to work systems for technological products such as trampolines, pistols, and aircraft.

Before being used, this instrument has been validated and tested. The results of construct and content validation were carried out by experts consisting of two lecturers and one user teacher. Furthermore, the instrument for measuring the problem-solving skills that were declared valid by the validator was tested empirically on 35 students. The results of the empirical test showed that the eight items tested were declared valid with differentiating power showing values that varied from 0.11 to 0.63. The test of the difficulty level of the questions showed a value that varied from 0.26 (difficult) to 0.71 (easy). To measure students' problem-solving skills, the items used were six items with moderate difficulty level, with the reliability of 0.812 (within very high criteria). The six questions represent the competencies that students are expected to achieve and are used both by students in the experimental class and students in the comparison class.

The data in this study were students' problem-solving scores obtained from the pretest and post-test results. Data were tested using descriptive statistics and inferential statistics. The normality and homogeneity tests of each of the pretest and post-test results were carried out before testing the hypothesis. This hypothesis test was selected based on the initial test results. Besides, N-gain is also calculated to determine the increase in students' problem-solving scores. The hypotheses tested in this study are as follows.

H_0 : There is no significant difference between the problem-solving skills of the experimental class students and the comparison class.

H_a : There is a significant difference between the problem-solving skills of the experimental class students and the comparison class.

RESULTS AND DISCUSSION

Analysis of STEM-PjBL and Discovery Learning Implementation

To show how STEM-PjBL learning and discovery affect students' problem-solving skills, an overview of the learning process in both classes presents. The outline of the learning implementation process in each course was presented in the following paragraphs.

The comparison class used discovery as a model of learning. The first phase in this learning model is stimulation, where students watch the rocket launch phenomenon through video. Through the film, students discuss issues and refer to the physical content that has been examined collaboratively. This level is undoubtedly the initial stage of the problem-solving skill training of students. The next step is a problem statement in which students create hypotheses and evaluate variables that impact the furthest range of rockets. The critical difference between the class of comparison and the experimental course is the stage of data collection. Comparative class students conduct virtual studies through the interactive.ck12.org portal. Via these tests, students have seen the relationship between the rocket mass and the furthest range of rockets. Regulated variables are the rocket power and the time to burn the rocket. After data collection, the next stage of discovery learning is data processing. Students analyze the data, then relate it to the hypothesis proposed through the verification stage. The proposed hypothesis would be proved true or not at the verification point. In the last step, i.e., generalization, students express the outcomes of the practicum by presentations in front of the class.

In the experimental class, the practices of STEM-PjBL learning tended to be able to improve the problem-solving skills of students. The first stage of STEM-PjBL learning is the stage of reflection. The lesson begins with the presentation of the rocket launch phenomenon through video. As a group, students discuss why rockets can be launched and how they relate to the laws of physics, particularly momentum and momentum. This process can be the initial stage in the development of problem-solving skills for students. The next activity is the process of research; students examine the problem in more detail to obtain a physical and mathematical solution. After that, students begin designing a water rocket, including the size and materials of the rocket prototype. This design is the preliminary stage for the project; the teacher must approve this stage. Besides, the discovery stage was accompanied by the launch of a water rocket. This activity is carried out outside class hours with activity reporting through video. The next step is the phase of the application.

The goal of this stage is to train students' problem-solving skills, particularly in the mathematical field. Rockets have been tested to provide students with a real science learning experience. The field tests were carried out and contested between groups to find the rocket with the furthest range to win. This practice is a challenge for students to be enthusiastic and innovative in solving any problems found during manufacturing and research. In this method, students can flexibly apply their ideas to the repair of the water rockets they create. For example, students may change the length of a rocket or change the shape of a rocket wing. According to the teacher who teaches the class, "making rockets directly and then experimenting with students is more able to accommodate the diversity of ideas of students in the classroom than observing them through a virtual laboratory." After discussion, it was decided that two variables had a major impact on the range of rockets, namely water mass and wing shape. Each group measured the variables that allowed the rocket to reach high, varying the mass of the water and the shape of the wing. Students will then test the suitability of practicum results with the concept of physics, and the results obtained will be used to develop the product. In the last stage of contact, the experimental group of students came to school after the results had been collected. Students obtain assignments by uploading a video of the production process for the feasibility of a water rocket, pictures of the answers to the STEM Water Rocket Worksheet, and post-tests to Edmodo. This stage provides opportunities for students to present and account for the results obtained.

Analysis of Students' Problem-Solving Skills

There are five parts of problem-solving skills measured in this study, namely, recognize the problem, represent the problem in formal terms, plan a solution, execute the plan, and evaluate the answer. The problem-solving skills of students in the experimental class and the comparison class are presented in Figure 1.

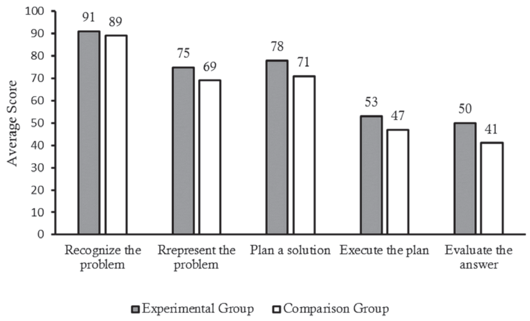

Figure 1. The Problem-Solving Skills Results of Experiment Group and Comparison Group

Figure 1 shows that the students' problem-solving scores in the experimental class were higher than those in the comparison class on all problem-solving dimensions. Even so, students tend to decline in scores from the process of recognizing the problem to the process of evaluating the answer. This is because students need higher thinking skills from the stage of recognizing the problem to the stage of evaluating the answer.

Before testing the hypothesis, the data distribution normality test and the homogeneity of variance test were carried out as a prerequisite test. The normality of the data was tested using the Shapiro-Wilk statistic (Field, 2017). The analysis showed that the pretest scores in the experimental class were normally distributed, W(28)=0.941, $p>0.05$, but the comparison class was not normally distributed, W(25)=0.913, $p<0.05$. Meanwhile, the variance of pretest scores between the experimental class and the comparison class was the same, F(1.51)=0.468, $p>0.05$. In other words, the pretest data were homogeneous. The results of the prerequisite test indicated that the parametric hypothesis test assumptions were violated so that the different tests on the pretest results of the experimental class and the comparison class were carried out using the non-parametric test, namely the Mann-Whitney test. The analysis results are shown in Table 2.

Table 2. Comparison of Problem-solving Scores Between the Experimental Class and the Comparison Class before Treatment

Score	Experimental Group	Comparison Group
n	28	25
Median	37.50	33.30
IQR	19.79	20.41
U	250.50	
p value	0.076	

Table 2 shows that there is no significant difference between the problem-solving scores of the experimental class (Mdn = 37.50) and the comparison class (Mdn = 33.30), U = 250.50, $p>0.05$. This result means that students in the two classes have the same problem-solving skills and are not influenced by previous learning.

After being given the treatment, the post-test was carried out in the experimental class and the comparison class. Furthermore, the prerequisite test and hypothesis testing were carried out on the post-test data. The results of the analysis showed that the post-test data on problem-solving skills in the experimental class were not normally distributed, W(28)=0.906, $p<0.05$, but the comparison class was normally distributed W(25)=0.942, $p>0.05$. Meanwhile, the results of the analysis of data variance showed that the post-test data was homogeneous, F(1.51)=0.529, $p>0.05$. Based on these results, the hypothesis test used in this study is a nonparametric difference test, namely the U Mann-Whitney test with a significance level ($\alpha = 0.05$); the results are shown in Table 3.

Table 3. Post-test Analysis Results

Score	Experimental Group	Comparison Group
n	28	25
Median	78.74	70.00
IQR	12.08	12.95
N-Gain	56%	49%
U	181.50	
P value	0.003	
r	0,057	

Based on Table 3, the N-Gain score for the experimental class is 56% and is considered quite effective, while for the comparison class, it is 49% and is considered less effective (Hake, 1999). This shows that students who learn with STEM-PjBL increase higher than students who learn with discovery learning.

Based on data analysis using the Mann-Whitney test, the significance value obtained is 0.03 where the value is smaller than the significance value ($\alpha = 0.05$), which indicates that H_0 is rejected and H_a is accepted. These results indicate that statistically, there is a significant difference between the problem-solving skills of students who learn using STEM-PjBL learning (Mdn=78.74) and students who learn using Discovery Learning (Mdn=70.00), U=181.50, $p<0.003$ with value-r (effect size) of 0.057. The effect size score shows that the effect of STEM-PjBL learning is in a broad category (Morgan et al., 2004).

The students' problems solving scores trend tend to decrease along with the problem-solving steps in both groups. We argued that the complexity level of the problem-solving phases, from the recognition of the problem to the evaluation of the problem, is becoming increasingly difficult. For example, tasks that students must complete through recognize the problem are relatively easy, such as visualizing situations in the form of sketches, writing down relevant and irrelevant information, giving symbolic names, writing down questions that must be answered, and identifying physical approaches that might be useful for reaching solutions. In contrast, in the evaluation stage, students need to check the results of calculations in the form of conformity of the results, whether the results are reasonable or not, and the results obtained are complete or not. According to Meli et al. (2016), problem-solving in physics is closely related to mathematical modeling. Students are most often able to recognize problems and design solutions, but they struggle to do so in the final execution. Any of the reasons for this condition are the problem-solving is very complex mathematical systematization (Niss, 2017) or student comprehension that are incomplete (Milbourne & Wiebe, 2018).

The difference in problem-solving skills related to recognizing the problem between the experimental class and the comparison class is relatively small, with only two points difference. This may occur because the learning activities carried out in the experimental class and comparison class is still relatively the same, namely identifying problems through the video presented. What is surprising is that there is a fairly large score gap in evaluating the answer indicator. Students in the experimental class were better at evaluating answers than students in the comparison class. This may be because, in the experimental class, students are accustomed to evaluating their projects. Students identify critically the factors that can maximize the results of the projects they create. The role of student thinking at this learning stage is very dominant. This is in line with the findings of Tas et al. (2019) that learning in which students are active and responsible for their learning process can improve their metacognitive strategies. Besides, the challenges in PjBL also support the development of this strategy (Kavousi et al., 2020). Meanwhile, in discovery learning, evaluation is carried out by verifying the findings with the previously made hypotheses. This study indicates that the ability to evaluate answers is better if it is developed in project learning than discovery learning.

Overall, this study shows that STEM-PjBL is better at improving students' problem-solving skills than discovery learning. This may happen because, in this study, learning in the experimental class provides a challenging and more real learning experience than discovery learning. For example, in the experimental class, students were challenged to make a device that was able to produce a more distant water rocket. Teachers can provide learning engagement by providing challenges to students (Duncan, 2020; Morrison et al., 2020). Meanwhile, in the comparison class that uses discovery learning, students learn to discover concepts through virtual lab experiments. The virtual lab program used possibly has not been able to pinpoint the factors that can affect the range of a water rocket. In this lesson, students can show posters depicting the forces acting on the rocket before, during, and after sliding correctly. Unfortunately, understanding this concept is not applied directly to solving real problems. Training students to solve real problems can improve problem-solving skills (Yu et al., 2015; Zhong & Xu, 2019).

PjBL makes learning more focused because students can make products, test, and communicate results. On the other hand, STEM defines the interdisciplinary learning process by integrating four different disciplines. The process of creating and analyzing rocket motion does not only require understanding the concepts of impulse and momentum but involves scientific skills. Practices that involve cognitive processes and hands-on activities such as modeling are essential for scientists and engineers (Park et al., 2020). STEM education needs to ensure that as students prepare to become scientists, they need to be involved in the practice of building and modifying learning tools (Dickerson et al., 2016).

The activities carried out in STEM-PjBL learning guide students to work in groups. Collaborative STEM practice can support students in learning to solve problems together (Chen et al., 2019). Students explore the problem of why a rocket can launch and then find out how it relates to the laws of physics, especially impulse and momentum. This process can be the initial stage in developing students' problem-solving skills.

In STEM-PjBL, students analyze problems in more detail to obtain a physical and mathematical solution. In this study, students designed a water rocket complete with sizes and materials. This design is the preparatory stage for doing a project where at this stage, students must get the teacher's approval before continuing the design process. Furthermore, students make water rockets outside of class hours by reporting activities via video. The purpose of this activity is to facilitate students to connect the information obtained with the knowledge they have in designing projects. Besides, technical aspects are also trained through project assignments. This is important because the technical aspects are directly involved in the problem-solving process (Bybee, 2010). STEM-PjBL can encourage students to engage in hands-on activities that can improve students' ability to explore learning and respond to the challenges of a changing world (Chen & Lin, 2019). Through the process of engineering solutions, students' problem-solving skills can improve (Shanta & Wells, 2020).

The process of testing student project results is a crucial activity. At this stage, students work like scientists and engineers. Students explain each finding and find problems with the designs they make. This stage provides students with a real science learning experience. This is important because, according to Mills et al. (2020), the experience of making products can increase students' interest in learning. The trials were carried out in the field and contested between groups to find the rocket with the farthest range to win. This activity provides challenges to students so that students are enthusiastic and creative in solving any problems encountered during manufacture and testing. Of course, the teacher's role is needed in helping students face every challenge given (Kang & Keinonen, 2018). In this process, students can flexibly apply their ideas to repair the water rockets they make. For example, students can change the length of the rocket or change the shape of the rocket's wing. According to the teacher who taught in the experimental class, "*making rockets directly and then experimenting with them is more able to accommodate the diversity of ideas of students in the class than observing them through a virtual laboratory."* Kapici et al. (2019) recommend that virtual and non-virtual laboratories be combined for maximum results.

After conducting discussions, two significant variables are thought to affect the range of the rocket, namely water mass and wing shape. Each group tested the variables that caused the rocket's reach to be far by varying the mass of water and wing shape. Then students evaluate the suitability of the practicum results with the physics concept. The results of these activities are used to improve products that are made repeatedly. An iterative process is a characteristic of STEM learning (Zhou et al., 2020). Technology, Engineering, and Mathematics (STEM. The observations show that some students become active and motivated to complete the project. The teacher who taught in the experimental class shared that: *"Before implementing STEM-PjBL learning, Ardi (pseudonym) was always silent in learning, but when asked to do a project, Ardi was very enthusiastic and even seemed active in solving problems faced by his group."* The results of this study are in line with Sumarni and Kadarwati's (2020) research that STEM-PjBL can improve students' critical and creative thinking skills. STEM can increase students' interest in learning because it focuses learning on students, provides a meaningful, more interesting learning experience, trains high-order thinking skills, and improves problem-solving skills (Stohlmann et al., 2012).

In particular, STEM-PjBL facilitates students with learning challenges. However, presenting these conditions in learning is not comfortable (Wilson, 2020). In this study, students appeared to be more enthusiastic and active when trying to solve a given challenge. Through authentic challenges, students are conditioned to face challenges in real life. This challenge makes students carry out a continuous learning process by continuously revising their understanding so that what is understood can be following the modeling made (Morrison et al., 2020). This is very good for the development of students' abilities because the hope is that students are not only expected to be able to solve problems (questions) in school but can be automated in solving various problems faced in everyday life. In other words, students obtain life skills in a full and meaningful way from a formal learning process.

One of the interesting findings in this study is the use of instruments of problem-solving. The specific domain problem-solving instrument used seems to be able to provide an overview of student problem-solving. According to Reynders et al. (2020), to explicitly determine students' abilities, a particular measurement instrument for STEM education needs to be made. The questions in this study are real-life illustrations so that students can provide illustrations in design problem-solving. According to Niss (2018), students are better able to solve concrete problems than abstract ones. Students' cognitive load is lower if they solve problems like this. For the record, the learning process experienced by students is active, both in the experimental class and the comparison class. Both classes learn the concept of physics from its application in technology. Therefore, the construction of this instrument seems appropriate to the learning experience of these students. As a result, the competence that is measured is competence due to the intervention given. Besides, further exploration related to specific domain problem-solving instruments like this still needs to be done.

Although this study has provided evidence of how STEM-PjBL learning and discovery learning affect student problem-solving, several limitations are still found in this study. Students' skills to evaluate answers are still relatively low.

This result is in line with the findings of Wang and Barrow (2011) that students very often do not evaluate their answers at the end. Even teachers, according to Šeďová and Švaříček (2012), often have difficulty evaluating answers. Furthermore, the limitation of this study is that it only uses the experimental class and the comparison class. As a result, the results of the study cannot provide evidence of how these two lessons are different when compared to conventional learning, which is still being done so far. Further research can be carried out by adding conventional classes.

CONCLUSION

The results of this study indicate that there are significant differences in the problem-solving skills of students who learn using STEM-PjBL learning and discovery learning. The experimental class students obtained higher problem-solving scores than the comparison class students. Besides, the N-gain score shows that the problem-solving scores of students who study with STEM-PjBL have a more significant increase than students who study with the Discovery Learning model. STEM-PjBL makes students more challenged because they are asked to answer real problems by making water rockets. Meanwhile, in discovery learning, students only make observations through the virtual lab. Another result found is that the use of technology in both the experimental class and the class groups can increase the effectiveness and efficiency of learning. However, it is necessary to consider the level of flexibility of the technology used.

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