Analysis of problem-solving ability of physics education students in STEM-based project based learning

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Abstract. This study is a quantitative descriptive. This study aimed to describe the problem-solving abilities of physics education students in the 2nd School Physics Laboratory course. The subjects of this study were 65 people consisting of 2 classes with the determination of the sample using the purposive sampling technique. Data collected is done through a problem-solving ability instrument which includes four indicators recognizing problems, planning solutions, solving problems, and evaluating. Based on the results of the data analysis, the conclusion is that students' problem-solving abilities have been at a high level with a percentage average of 79. The caused by learning that applies STEM-based Project-Based Learning (PjBL). The learning helps develop students' abilities in planning, communicating, solving problems, and making the right decisions from the problems given. This learning can train students' skills in planning, organizing, negotiating, and making conventions about the issues of the task to be done, who is responsible for each task, and how the information will be collected and presented.

1. Introduction

Research on the ability to solve physics problems has become the focus of research in recent years. There is because 21st-century education demands various abilities that must be mastered and possessed by prospective 21st-century teacher students, one of which is the ability to solve problems [1]. One of the expected targets of modern education is to educate student teacher candidates who can solve the problems they encounter in everyday life and social life. As prospective teachers, they will have expected to solve the problem they find easily [2]. The ability to solve problems is one of the 21st-century skills that are the focus of physics learning. That needs to will be given to physics education students as professional physics teacher candidates [1].

Problem-solving ability is a fundamental thing that must be owned by students as prospective teachers [3]. Students are said to be successful in the learning process if they can solve problems using basic knowledge. Problem-solving is not only emphasized quantitative aspects such as mathematical equations and procedures. But also emphasizes qualitative analysis aspects in the form of choosing the right concepts and principles in solving problems [4].

Problem-solving ability is a person's ability to find solutions through a process that involves obtaining and organizing information [5]. In the problem-solving process, students need to find solutions based on concepts/laws rationally and reflect on the problem-solving process and solutions [6]. In physics learning, physics problem solving is related to physics concepts [5]. The factors that influence solving physics problems are the knowledge structure possessed by students and the character of the problem faced by students [7].

One of the significant components in the problem-solving of physics is to identify the physics principles that are relevant to the problem [8]. Based on students' ability problem solve that can divide into two, namely those with high abilities and low abilities. Students who have high ability tend to use...
arguments based on physics concepts. They tend to evaluate solutions and tend to use representational aids. On the contrary, students who have low ability tend to use quantitative arguments such as the use of formulas in solving physics problems [5,9].

Outline of physics problem-solving consists of recognizing problems, implementing strategies, planning strategies, and evaluating solutions [5]. These steps are modified based on the problem-solving steps Young and Freedman and Heller et al. The indicators for each of these steps can be seen in Table 1. These indicators are modified from [5], [10]. This indicator indicates the physics problem-solving ability used in this study [5,10].

Table 1. Stages and Indicators of Physics Problem Solving Ability

| Stage                        | Indicator                                                                 |
|------------------------------|---------------------------------------------------------------------------|
| Recognizing the problem      | Identify problems based on basic concepts                                 |
| Planning strategy            | Determining the right concept for problem-solving                        |
| Implementing strategy        | Solve problems according to plan                                         |
| Evaluating solution          | Draw conclusions from the answers obtained and re-check the results obtained |

One form of learning that involves a problem-solving process is Science-Technology-Engineering-Mathematics (STEM) Education-based learning. STEM is an approach used by integrating Science, Technology, Engineering, and Mathematics in the learning process. In this case, physics represents the science studied by prospective teacher students. The application of technology is a supporting tool to help students understand the concepts being studied. The application of engineering aims to train students to design, assemble, draw, and of other activities so that students understand the procedures for solving problems. Furthermore, mathematics aimed to simplify the concept of science itself in a more systematic and mathematical form.

STEM learning provides opportunities for students to learn science, mathematics, and engineering by solving problems that have real-world applications [11]. Application STEM in learning can be an alternative to science learning that can encounter 21st-century education [12]. STEM in learning can encourage students to design, develop, utilize technology, sharpen cognitively, and apply their knowledge[13]. STEM can also train students to use their knowledge to create problem-solving designs related to the environment by utilizing technology [12].

STEM learning emphasizes several aspects of the learning process, namely (1) asking questions and defining problems; (2) developing and using models; (3) planning and conducting investigations; (4) analyzing and interpreting the data; (5) using mathematics; information and computer technology; and computational thinking; (6) building explanations (science) and designing solutions (engineering); (7) engage in evidence-based arguments; (8) obtain, evaluate, and communicate information [14]. The application of STEM in learning can be supported by various methods and learning models. That is because STEM is integrative. Many research results explain one of the learning models that can use in STEM learning, namely PjBL. PjBL can make students apply their academic abilities and creativity to solve given problems [15].

PjBL is a learning model based on a problem that involving students in design, problem-solving, decision making, or investigative activities [16]. PjBL can guide students to solve the problems given and more emphasis on the products produced. The products produced by students can be in the form of ideas or devices. Problem-solving and product solving can be done by individuals or groups. Working in groups can encourage students to work together but still be responsible for their work independently. In addition, in groups, students can manage learning independently according to the circumstances of their respective groups [16,17]. In the finishing of products, students can use science and technology. So that students indirectly understand the functions and benefits of science and technology in everyday life [12].
A further characteristic of PjBL is that students can choose the activities and work carried out during the learning process. Students can be communicative and creative in developing practical thinking as they engage in inquiry, active discovery, exploration, and decision making. Knowledge is based on experience and experimentation in real life [17]. In addition, PjBL makes learning meaningful by connecting new learning with the period of experience they have. PjBL is also an inclusive approach, where all students can participate to the best of their ability [18].

Based on the preliminary research in have the shape of learned observations, that known that previously learned had not trained problem-solving skills. The learning is done by explaining the physics phenomena that occurred and concepts used to solve and underlie these phenomena. So that students are less trained to recognize and solve the problems given. Therefore, researchers are interested in applying the STEM-based PjBL model to practice the problem-solving skills of physics education students. This study aimed to describe the problem-solving abilities of physics education students in the School Physics Laboratory 2 course.

The use of PjBL will have expected to be an alternative science learning that can face 21st-century education. A combination of STEM and PjBL will have expected to actualize the problem-solving abilities of physics education students as prospective physics teachers. This thing has must be trained for pre-service teachers because pre-service professional teachers must have skills in problem-solving so that they can design interested and meaningful learning.

2. Methods
This research is quantitative descriptive. Descriptive research aims to describe, interpret or explain a variable or situation. This study aims to describe the problem-solving abilities of physics education students in the School Physics Laboratory 2 course. The subjects of this research were physics education students of 2018, totaling 65 people. The research subjects consisted of 2 classes with the determination of the sample using the purposive sampling technique. The time of the research was have carried in the even semester of 2019/2020.

The data collecting technique was have carried through a problem-solving ability instrument. The instrument includes four indicators, namely recognizing problems, planning solutions, solving problems, and evaluating. Data analysis used a questionnaire was have analyzed with the percentage score generated from the Likert scale calculation. The Likert scale was have used to measure a person’s attitudes, opinions, and perceptions about an event by giving a score with a predetermined weight. The average percentage was determined by Equation 1.

\[ P = \frac{\sum C}{N} \times 100\% \]  

\( P \) is the percentage average, \( C \) is the collected score by students’ perception, and \( M \) is the maximum score of students' perceptions. The category of students’ perception can be confirmed in Table 1 [19].

| Percentage average | Criteria     |
|--------------------|--------------|
| 85 – 100           | Very high    |
| 70 – 84            | High         |
| 55 – 69            | Moderate     |
| 40 – 54            | Low          |
| 0 – 39             | Very low     |

Based on Table 2, the results of the analysis are categorized as good if they have a value of 70.

3. Result and Discussion
The research was have done in the School Physics Laboratory 2 course. Students were given simple problems but contextual with the problem that occurs in everyday life. These problems are in the form of simple physical phenomena that occur in everyday life. Furthermore, students were have asked to solve these problems using the PjBL model. One example of the problems given to students has shown in Figure 1.
In essence, the project-based learning model is designed to solve complex problems. This model is needed in conducting investigations and understanding problems[20]. Implementation of PjBL in the learning by dividing the students into several groups. Each group consists of eight people. Working in groups can encourage students to work together but remain responsible for their work. In addition, students can manage learning independently so that according to the circumstances of each group member [16,17].

After being given a problem, students were have asked to solve the problem. Students are allowed to identify as many problem agendas as possible that are relevant to the given problem. Students were allowed to collect relevant information by reading literature, observing objects, interviewing resource persons, or conducting their trials. Furthermore, students are given independence and flexibility to design project plans that will carry out. Students work in groups to plan how their project will carry out.

In planning the completion of the project, students prepare a schedule so that the project can be completed on time. At this stage, students' problem-solving skills are drill to critical thinking and good at estimating what is needed to be done for preparation, manufacture until the project can be complete on time. The next step after the preparation of the schedule is to monitor the progress of the project. That aims to see whether the project has been running according to plan or not. In completing the project, students can take advantage of science and technology so indirectly that students understand the functions and benefits of science and technology in everyday life [12]. The utilization of science and technology can train students in applying their knowledge to solve problems related to the environment by utilizing technology.

In implementing the PjBL model, process evaluation and evaluation of learning outcomes do out. Evaluations of Processes are carried out through student progress reports regarding the projects that are working. Evaluation of results does out through a problem-solving ability instrument which includes four indicators. That is recognizing problems, planning solutions, solving problems, and evaluating. The results of the analysis of the problem-solving abilities of physics education students are shown in Table 3.

### Table 3. Results of Problem-solving Ability Analysis

| Stage                  | Indicator                                      | Percentage | Criteria |
|------------------------|------------------------------------------------|------------|----------|
| Recognizing the problem| Identify problems based on basic concepts       | 84         | High     |
|                        | Determining the right concept for problem-solving| 86         | Very high|
| Planning strategy      | Create a troubleshooting trial procedure        |            |          |
| Implementing strategy  | Solve problems according to plan                | 77         | High     |
|                        | Perform data analysis based on experimental results |          |          |
| Evaluating solution    | Draw conclusions from the answers obtained and re-check the results obtained | 69         | Moderate |
|                        | Average                                        | 79         | High     |
Based on Table 3, the ability of students to recognize the given problem is at a high level. That is because students were given simple problems but contextual with the problem that occurs in everyday life. So that students can identify problems based on physics concepts. The ability to plan strategies is at a high level. At this stage, students can determine what concepts will be used to solve the given problem and make experimental procedures to solve the problem. Students can sequence the work steps and solutions that will be carried out and determine who is responsible for implementing these solutions. Furthermore, the stage of the ability to apply the strategy is at a high level. At this stage, students can solve problems according to the experimental procedures they have compiled. At this stage, students work together in solving problems but remain responsible for their respective work. After conducting the experiment and obtaining the data, the students then analyzed the data. At this stage, the students' ability to analyze data is at a high level.

The stage of the ability to evaluate the solution is at the moderate level. At this stage, the ability for students to conclude the answers obtained and re-check the results in moderate levels. That is because students only conclude the results of their experiments, have not connected these results with the physics concepts used, and do not relate them to the purpose of the experiments.

Based on the results of data analysis, it has been concluded that the problem-solving ability of physics education students in STEM-based PjBL learning is at a high level. It is in accordance with previous research [20] and [21] who stated that the PjBL model could improve students' problem-solving abilities. Another study conducted by [22] showed that learning with a STEM approach was able to improve students' problem-solving abilities.

STEM-based PjBL learning provides opportunities for students to solve real-world problems by applying science, math, and engineering. In addition, students actively engage in ill-defined tasks become well-defined outcomes through collaboration in groups [11,23]. STEM-based PjBL learning allows students to solve problems through prototyping and science-based design. When students have trained to solve a problem using the four STEM disciplines, students are encouraged to be more scientifically creative in solving problems [24]. Problem-solving abilities built by students will put students at an advantage in utilizing their potential as well as possible.

This STEM-based PjBL learning ends with a presentation of the results of project assignments that students have done. Based on the results of the project presentation, the researcher assessed that the students' ability to use technology is at a high level. It looks from the presentation of project results using video editing when explaining the problem-solving procedure.

4. Conclusion
Based on the results of the study can be concluded that the problem-solving abilities of physics education students are at a high level. The problem-solving ability carried out includes four indicators, namely a) recognizing problems, b) planning strategies, c) implementing strategies, and d) evaluating solutions. At the stage of recognizing the problem, students' abilities are at a high level. At the planning stage, the strategy, the student's abilities are at a very high level. At the stage of implementing the strategy, students' abilities are at a high level, and at the evaluating solutions, students' abilities are at a moderate level. STEM-based PjBL learning can train students to apply their knowledge to solve problems related to the environment by utilizing technology. In addition, it encourages students to work together but remains responsible for their respective work. STEM-based PjBL learning is recommended to use in other subjects or courses that have the same characteristics as the School Physics Laboratory 2 course.

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