Building Scientific Literacy and Physics Problem Solving Skills through Inquiry-Based Learning for STEM Education

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Abstract. This study aims to determine the influence of Inquiry-Based Learning for STEM Education towards scientific literacy and physics problem-solving skills. This study used a quasi-experimental with pretest-posttest control group design. The population in this study is X grader students in SMA Negeri 1 Gondanglegi and the samples were chosen by cluster random sampling technique, resulted X MIA 1 as an experimental group and X MIA 2 as the control group. Each group consists of 26 students. Data collection was done by pretest and posttest for physics problem-solving skills. The result of t-test showed that \( p = 0.013 < 0.05 \) and the average of the experiment group is 64.99 while the control group is 54.67. The experimental group was also measured in term of scientific literacy by using descriptive statistics and analyzed by using coding based on scientific literacy's rubric. The descriptive statistic showed that the average result of scientific literacy was 50.92. The result in this study by using inquiry-based learning for STEM Education showed that the physics problem-solving skills on the experimental group is different by the control group, and there was an effect on student's scientific literacy on experimental group.

1. Introduction
One of the materials in physics learning is work and energy. The concept of energy is an important concept in explaining the abstract phenomena of physics and often become the starting point in physics problems solving [1,2]. The scope of work and energy is broad enough for students because it discusses not only one principle but several principles [3]. Students difficulties are sometimes related to work and energy are commonly stated as misconception in applying the concept of negative and positive work without seeing the movement direction of the object [4]; students also don't recognize the relationship of cause and effect in work and energy theorem, and they don't recognize the difficulty in determining the magnitude of the work made by some components of particular effort [5]. If the students’ understanding is inadequate, students will be unable to solve the physics problem, because the physics learning can never be separated from solving a problem [6].

Physics problem-solving skills is the expertise which is gained from an investigative activity, where the solver develops a solution to solve the problem [7]. The ability of students in solving the physics problem can be seen from understanding the concept and through the problem-solving procedures [6,7,8]. The four-stage problem-solving processes include the understanding of the problem, devising a plan, carrying out the plan, and looking back or evaluating [7].

Physics problem-solving skills is one of the basic concepts of scientific literacy that encompasses the elements of scientific inquiry and scientific knowledge [9,10]. Scientific literacy has been defined as a capability of students to be involved in scientific issues related to science manner[11]. The scientific literacy assessment does not only measure the level of understanding related to scientific knowledge but also measure the scientific process and student's abilities to apply in the real-life
context [12]. Scientific literacy can be measured through 4 domains: scientific context, scientific competence, scientific knowledge and attitude [13].

To build the physics problem-solving skills, the application of learning that focuses on the activity of students can be performed. It aims to construct students’ knowledge, through the inquiry-based learning model [14,15]. Inquiry-based learning is a learning that involves the process of inquiry, asking the question, and making an investigation to gain the new insights [16]. Currently, inquiry-based learning can be developed according to the 21st-century demands by connecting real-world problems by involving STEM Education [17]. STEM Education is an integrative learning, that enables various learning methods to be used to support its application, one of them is the inquiry-based learning model [18]. STEM Education is an integration of Science, Technology, Engineering, and Mathematics. It functions to prepare students in facing the challenges of the 21st century and makes the student as a center of learning activities [19]. Some research show the advantages of STEM Education; from the Engineering process in STEM. It is able to motivate the students in developing real-world problem-solving skills [20]; by submitting the scientific questions in the inquiry phase, the students will be able to generate curiosity. They can generate their curiosity to know more about STEM products [21]. Inquiry-based learning in STEM Education also helps students to achieve high achievement and be an active learners [22,23]. The purpose of this study is to know the influence of inquiry-based learning in STEM Education on students physics problem-solving skills and students’ scientific literacy, especially on work and energy physics topic.

2. Method

This study used a quasi-experimental with pre-test and post-test control group design. The experimental group was taught by using inquiry learning in STEM Education and control group was taught by inquiry learning only. The population consists of all students of X Grader in SMA Negeri 1 Gondanglegi and the sample consists of 52 students; 26 students in the experimental group and 26 students in the control group. The sample was chosen by cluster random sampling technique. The students’ problem-solving skills were measured by using an essay test. The instrument consists of using learning implementation plan with the worksheet. Pre-test and post-test results are analyzed by a prerequisite test, initial equality test, and hypothesis test. The prerequisite test results showed that the data is normally distributed and homogeneous so it can be used as the Independent Simple t-Test. The post-test result of the experimental group was analyzed by using descriptive statistics and coding based on problem-solving rubric and scientific literacy.

STEM Education was applied in inquiry-based learning in experimental groups where the components of science and mathematics were implemented through the presentation of problems of scientific phenomena to the preparation of investigation hypotheses. During the process of data collection and data analysis, the students utilized the existence of technology to design (engineering) STEM products as a solution of the topic of problems using theories and approaches of physics. Students were trained in their mathematical skills during the process of data analysis to take into account the accuracy of STEM products they create based on theories of science.

3. Result and Discussion

Based on the result of the hypothesis test, students’ physics problem-solving skills of experimental group and control group is different (p = 0.013 <0,05). It was shown by the higher score of experiment group which reaches average score of 64.99 compared to the control group which reaches score of 54.67. The average percentage of the procedures of students' physics problem-solving skills from the posttest data is shown in Figure 1.
Figure 1. The Result of physics problem-solving skills of the experimental group and the control group. Figure 1 shows that the average physics problem-solving ability of students in the early stages of understanding the problem of both the experimental group and the control group is equal to 57%. In the second stage of planning problem solving, the results showed that in the experimental group reaches higher percentages of 70% and the control group as many as 58%. Furthermore, in the third stage it is showed that the average of students' ability in carrying out problem-solving of the experimental group is higher by 81% than control group which is 66%. The conclusion of the problem-solving result shows that the experiment group average is higher than 57% and the control group is 41%.

After measuring the students' physics problem-solving skills, the experimental group of posttest results was used to measure the scientific literacy of the students based on the scientific literacy indicator which is presented in Figure 2 and completed with an example of problem-solving skills in Figure 3.

Figure 2. The result of the experimental group’s scientific literacy. Figure 2 shows that although the scientific literacy of the students appears to be evenly distributed in all three aspects, the scientific context has the highest percentage than the other that is 35%. This is because the issue raised as the scientific phenomenon in the learning process was chosen based on the students' personal experience so that students can recognize scientific situation related to scientific knowledge and scientific competence to solve the problems. The implementation of scientific competence refers to the mental process in building scientific literacy capability. It is influenced by the understanding of scientific knowledge which refers to the basic concepts of science (physics) that needed to understand scientific issues. However, the scientific knowledge of students has the lowest percentage that is 31%, so that the scientific competence will be low too that is 34%.

Figure 3. A roller coaster is designed to have a looping trajectory, with radius $R = 4$ m, then it is connected to a spring which the mass of the spring is ignored. Assume there is no friction between the train and the track (conservative). The train was launched from A and passed through the loop without bouncing off the track. Give your opinion, how to get the train through the loop path without going back and without bouncing out? What is the minimum height $(h)$ required for the train to pass through the loop, without falling on point C? (include the free body diagram)
Tabel 1. The students' post-test answers are complemented by an assessment of problem-solving skills and scientific literacy.

| Student Answers | Description of problem-solving skills | Description of Scientific Literacy |
|-----------------|--------------------------------------|------------------------------------|
| Superior        | Understanding of the problem         | Scientific literacy context        |
| Superior        | Problem-solving pathway              | Scientific literacy knowledge      |
| Calculation     | Complete and right                   | Scientific literacy knowledge & competence |
| Superior        | Reporting                            | Scientific literacy competence     |

Based on Table 1, the process of understanding the problem and planning the problem can be identified through the experimental group, so the assessment of understanding the problem and planning the problem is superior understanding of the problem and superior problem-solving pathway categories. On the planning phase, the students draw free body diagrams on the top of the loop. It is used to facilitate the analysis of problem-solving planning and to identify the loop radius and peak height of the loop using mechanical energy laws and the concept of circular motion. By carrying out the problem-solving phase, students can do the calculation based on the formulation that has been determined from the previous stage so that the assessment is calculation are complete and right. In the final step, students are able to make conclusions based on the problem-solving path and able to relate the results of answers with the concept of physics, so that the category is superior reporting assessment. Table 1 also shows that the student recognizes the scientific situation well so they can write the issues that should be solved and identify the most important information that needed to solve the problem. It makes their scientific contexts are multidimensional. Scientific knowledge can be seen from how students plan problem solution. Figure 3 use one of the scientific knowledge that is epistemic, which this knowledge helps students to provide scientific arguments based on scientific concepts and evidence correctly. The element of scientific competence can be recognized from how the student gave a conclusion at the end of the problem-solving. In this case, the expected element of competence is that students can interpret the problem situation with scientific argument and accompanied by systematic problem solution planning. In this case, students can answer the scientific knowledge correctly and scientific competence completely, so that students are at a multidimensional level.

Students are able to solve problems if they are able to recognize the concept of the problem [24]. The difference between students who have low and high problem-solving skills in solving physics problems can be seen from how students organize and use knowledge, as well as relating how the concepts they already mastered when solving the problem [25]. Inquiry-based learning in STEM
Education, do not only involve students to investigate the questions but it is able to solve the real-world problems, one of them is through the design of a roller coaster trajectory. Through inquiry-based learning in STEM Education, students will carry out the problem-solving tasks from teachers and proven in previous research. There will be a significant relationship between learning, teaching and problem-solving tasks that teachers have given to students [26]; through the inquiry phase, it is expected to effect on students' math skills. Students were not only able to design, but they will learn how to calculate and how to design the balance and the successful operation of a STEM product while it is being operated [21].

Furthermore, the inquiry-based learning context for STEM Education was chosen based on the students' personal experiences related to the roller coaster game. This is in accordance with the statements submitted by the OECD (2014) that problems and solutions may arise from different situations or contexts based on individual experience. Context becomes a stimulus for students to gain knowledge and competence through scientific phenomenon. The experimental group is also trained to conduct a scientific investigation so it influences the scientific literacy of students [27]. Scientific literacy will be better if it is solved through scientific inquiry. Scientific inquiry can help students explaining what are students observing and remember what happened so that the knowledge and competence of the scientific literacy of students are growing [28]. Based on Figure 2, students in the superior category will be placed as in the multidimensional level. It can be interpreted that scientific literacy is based on problem-solving skills. In order for students to be scientifically literate, students then should have the basics concept of good problem-solving skills [29].

4. Conclusions

The results showed that students' physics problem-solving skills with inquiry-based learning in STEM Education were different from those with inquiry-based learning only. The difference is found between the average obtained in each group and the learning activities that have been done. The students who have high problem-solving skills are able to scientifically literate and make correct problem-solving procedures that affect the scientific literacy of students. It is resulted that students are able to make scientific decisions to solve the problems appropriately. This study is recommended for further researchers who wish to explore more in-depth problem-solving skills and scientific literacy of students on inquiry-based learning in STEM Education for the work and energy topic.

5. References

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