Proceeding of the 4th International Conference on Education, Vol. 4, 2018, pp. 97-103

ISSN 2424 - 6700 online
DOI: https://doi.org/10.17501/icedu.2018.4111

EXPLORATION OF PHYSICS PROBLEM-SOLVING SKILLS WITHIN PHENOMENON-BASED LEARNING IN SENIOR HIGH SCHOOL STUDENTS

Lia Yuliati[1] and Parno[1]

[1]*Universitas Negeri Malang, Indonesia*

Abstract: Problem-solving skills are cognitive processes that help students find solutions to problems. The results of preliminary studies and previous research show that students have difficulty in solving optical problems. Students tend to solve optical problems with mathematical procedures without going through the process of identifying and analyzing how to solve problems. This research aimed to explore students' problem-solving skills on optical materials and find their solutions through phenomenon-based learning. The research used a mixed method on 30 high school students in East Java, Indonesia. The data was obtained by using open-ended questions (Cronbach Alpha = 0.82). Data analysis was done quantitatively and qualitatively. Data were collected using tests and interviews regarding phenomenon-based learning. The results showed that problem-solving skills were classified into useful description 18%, physics approach 17%, the specific application of physics 11, mathematical procedures 33%, and logical progression 21%. Most students used a mathematical approach rather than a physics approach to solving optical problems. Phenomenon-based learning helps students understand physics through problems presented with phenomenon and problem solving based on phenomena.

Keywords: problem-solving skills, optics, phenomenon-based learning

Introduction

Characteristics of Physics materials in schools can be concrete and abstract. Abstract concepts will lead to different thoughts on students when learning them. This resulted in the concept of physics into one material that is difficult to study in science education so the understanding of fairly fundamental concepts is weak or lacking (Docktor, et al., 2015). Ideally, after studying physics students get meaningfulness to the concepts learned so as to apply the concept in everyday life. This is consistent with the purpose of physics learning that students are able to master the concepts and principles of physics to develop knowledge, skills, and confidence so that it can be applied in everyday life (Serway & Vuille, 2014). One of the goals of physics education is the ability to solve problems in daily life (Selcuk,et al, 2008; Gok & Silay, 2010).

Previous research results have shown that students tend to have difficulty solving problems. Students tend to more easily solve problems with mathematical procedures without going through the process of analyzing how to solve problems (Danika, et al., 2017). In addition, indicators of physics learning success one of them can be seen from the ability of students in solving problems. Problem-solving activities of students can make their thinking more flexible (Bentley & Whitten, 2007).

Problem-solving skills are important goals in the 21st-century education system. Problem-solving skills require a special skill to solve a problem in daily life and social life (Selçuk et al, 2008). Problem-solving ability is a special ability that students have in analyzing the problems encountered so that students can determine what steps will be done. These problem-solving skills are linear and hierarchical (Selçuk et al, 2008). In addition, problem-solving refers to the efforts of students in determining the resolution of the problems at hand (Selçuk et al, 2008; Gok & Silay, 2010). Solving this problem also refers to the information that can be extracted by students during the learning process.

Corresponding Author's Email: lia.yuliati.fmipa@um.ac.id

The development of learning should be oriented towards constructivist theory from an early age (Poedjiadi, 2005) and phenomenon-based learning (Silberman, 2007). A phenomenon based learning strategies that take advantage of the phenomenon as a learning resource (Basu, et al, 2014; Louca & Zacharia, 2014). Students can create a representation of the phenomenon investigated so as to be involved in cognitive processes (Louca & Zacharia, 2014). Students can also develop causal explanations for the relationships between objects observed in phenomena (Basu, et al, 2014). The phenomenon that is presented through simulation can develop students' ability assembles and analyze the question and select and develop solutions to the problems being studied (Yu, et al, 2015). A phenomenon-based teaching is embedded in a problem-solving environment, where the teacher starts by posing questions or problems and the students "build answers together to questions or problems posed concerning a phenomenon that interests them" (Silander, 2015)

The phenomenon based learning paradigm corresponds to the nature of physics. Physics is a branch of science that studies nature. Physics is derived from the thought through a systematic process with the use of scientific methods. Thought results are built on observations and experiences during data collection. The data is then interpreted so as to produce an explanation of the facts and concepts that evolve into principles, laws, and theories are tested truth (Yuliati, 2008).

The phenomenon can be a source of investigation. Students observed the phenomenon and collecting relevant experience of the phenomenon being studied (Louca & Zacharia, 2014). Then, students identify problems, formulate hypotheses, design experiments, collect and analyze data, and draw conclusions about Physical phenomena. In conducting the investigation stage, the students had a discussion about scientific phenomena they observe. By observing the phenomenon, students can build knowledge and use it to develop and test phenomenon-related explanations (Kipnis & Hofstein, 2008) to answer causal questions (Lawson, et al, 2000).

The phenomenon is thus seen as an authentic object of observation, a systemic framework for the things to be learned (systemic model), a metaphorical framework for the things to be learned (analogous model), a motivating "base" for attaching the things to be learned (Silander, 2015). The term phenomena are often employed to indicate things as they appear in our surroundings or experiences that are observable and can be explored. Phenomenon-based learning starts with observation of a phenomenon from different points of view. The teacher demonstrated about the phenomenon of the material being learned. Phenomenon-based learning consists of five dimensions: holistic, authenticity, contextuality, problem-based inquiry learning, and learning process. Holistic refers to the multidisciplinarity of phenomenon-based learning, which is not integrated into traditional school subjects but rather focuses on a systematic, comprehensive exploration of current and actual events in the real world. Authenticity implies the use of methods, tools, and materials, which are necessary for real-world situations to solve problems that are relevant to students' lives and significant in the community. Contextuality refers to learning of phenomena as systemic entities, which are meaningful in a natural context and setting (Silander, 2015).

This article presents research results that aim to explore students' problem-solving skills and find their solutions through phenomenon-based learning. The research undertaken focused on exploring how students solve optic problems after learning with a phenomenon-based learning.

Method

This research used an exploratory research with mixed-method research: Embedded Experimental Model. This method collected quantitative and qualitative data together before and after conducting the research intervention (Cresswell & Clark, 2007). The research design used in this research is shown in Figure 1.

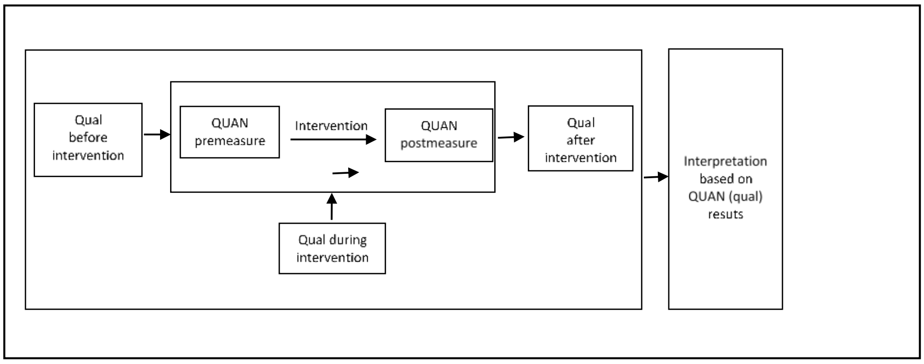

Figure 1. Embedded Experimental Model (Cresswell & Clark, 2007)

The research was conducted on 30 students in 10th grade at one of senior high school in East Java, Indonesia. The students consisted of 16 women and 14 men. These students have a good concept mastery of Physics concept that has been measured by a written test before. The data were collected by interviews, observation and open-ended questions test (Cronbach Alpha = 0.82) before and after phenomenon-based learning. Test results and interviews are categorized using the problem-solving rubric. Qualitatively, the data were analyzed using the problem-solving rubric presented in Table 1. Quantitatively, the data were analyzed using the paired t-test statistic descriptive, N-gain score, and the d-Cohen effect size.

Table 1. Physics Problem Solving Skills Criteria

Criteria	Description
Useful Description	Assesses a solver's process of organizing information from the problem statement into an appropriate and useful representation that summarizes essential information symbolically, visually, and/or in writing.
Physics Approach	Assesses a solver's process of selecting appropriate physics concepts and principles to use in solving the problem.
Specific Application of Physics	Assesses the solver's process of applying physics concepts and principles to the specific conditions of the problem.
Mathematical Procedures	Assesses the solver's process of selecting appropriate mathematical procedures and following mathematical rules to obtain target quantities
Logical Progression	Assesses the solver's processes of staying focused on a goal while demonstrating internal consistency.

(Docktor, et al., 2016)

Result and Discussion

The results of the descriptive statistical analysis for physics problem-solving skills are shown by paired t-test, N-gain score, and d-Cohen effect size. The paired t-test showed that there was a significant difference in problem-solving skills. The significance value is 0.00 (Asymp Sig. 2-tailed). The N-gain score was 0.6. There is an increase in problem-solving skills of students in the medium category. The d-Cohen effect size was 4.9. The results of the descriptive test statistic are presented in Figure 2.

Table 2. Results of descriptive statistic test for physics problem-solving skills

Statistic	Pretest Score	Posttest Score
Subject	30	30
Maximum score	33.91	93.04
Minimum Score	5.22	44.35
Mean	18.34	68.91
Median	18.26	72.17
Modus	16.52	74.78

Phenomenon-based learning has several benefits for students. New experiences about phenomena can lead to questions in the minds of students (Karplus, et al., 1977). Through phenomenon-based explanations, students may acquire better memories than the teacher's explanation (Kipnis & Hofstein, 2008). Some activities in phenomenon-based learning among other students observe phenomena, compile temporary explanations, conduct an inquiry prepare the final explanation and provide reasons to support the explanation.

In this research, students learn by a phenomena-based learning through demonstration activities about natural phenomena related to optic materials, experimental activities, discussions, evaluation, and reflection on investigation activities. Such learning helps students to practice explaining (Yao, et al., 2016) and to know concepts in concrete terms. The introduction of concepts in advance will make it easier for students to understand the abstract concept (Karplus, et al., 1977). Observation activities are also intended to provide an overview of the investigation that will be done so that the student worksheets can be arranged more simply.

After the observation activity, the students are asked to construct questions and explanations that are temporary about the phenomena that have been observed. It is based on the theory that composes a scientific explanation can enhance students' understanding of the ideas of science (NRC, 2012). The explanation is a temporary answer to be investigated through an inquiry. In learning, teachers can guide students through one big question then students develop it into a few small questions (Dolan & Grady, 2010).

After preparing the initial explanation, the students conducted an investigation in groups. Through investigation, students work together collaboratively to find out the truth of the initial explanations that have been prepared. Before beginning the investigation, the teacher ensures that students fully understand the goals and activities to be performed. The investigation activity is carried out by observing the phenomenon and experiments based on the worksheet. Investigation activity aims to train students to build knowledge, understanding the nature of physics and identify relationships between objects in the phenomenon as an ingredient to prepare the final explanation (Harlen, 2014). Data obtained from the investigation are presented in various ways. The data is interpreted to draw conclusions as the final explanation obtained from the group discussion. The explanation must be supported by the concepts and theories that students can hold his when communicating the results of the investigation (NRC, 2012).

Students problem-solving skills are explored through essays tests given at the end of the lesson. The test results were analyzed with rubric problem-solving skills and presented in Figure 3.

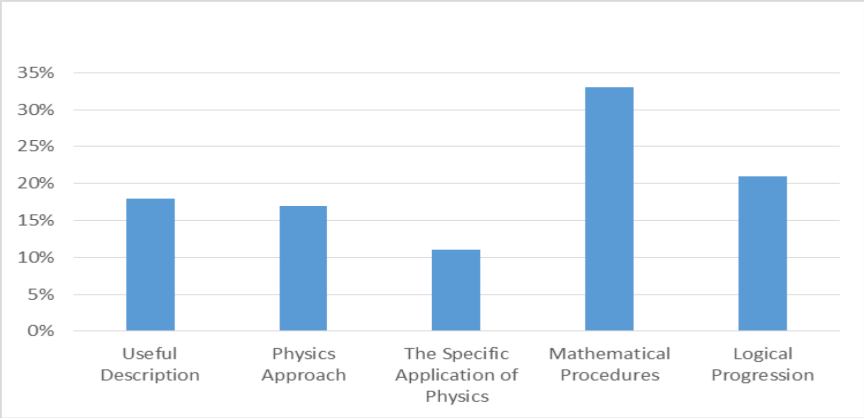

Figure 3. Physics Problem solving skills of students

Based on Figure 3, the problem-solving skills of physics at the optic material is dominated by the ability of mathematical procedures (33%) and only a small percentage are using the capabilities the specific application of Physics. This was confirmed the results of the analysis conducted student problem solving as shown in Figure 4.

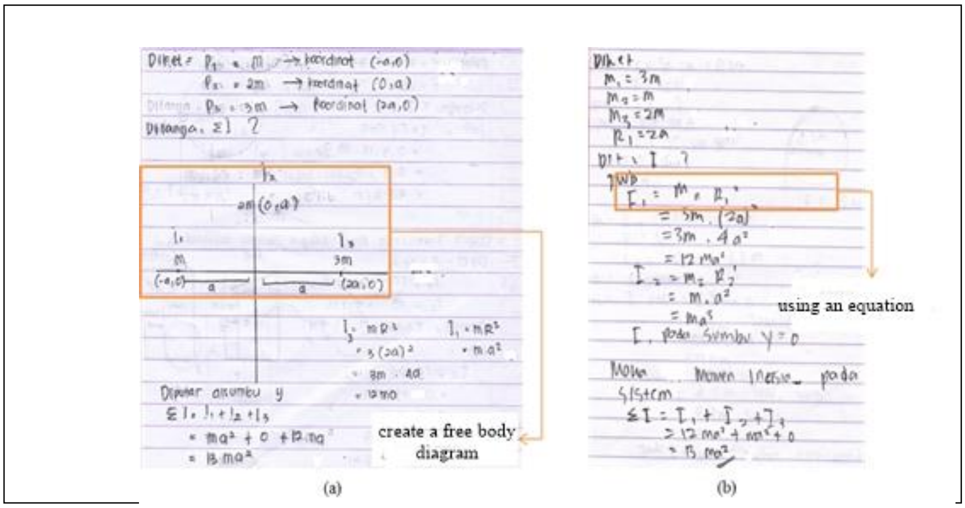

Figure 4. a) Student A used a physics approach by creating a free body diagram

b) Student B used mathematical equations directly

Most students solve physics problems using mathematical procedures. This is influenced by the ability to remember which is still dominant in the thinking pattern of students. The ability to remember is the lowest ability in Bloom's Taxonomy. In fact, in order to include the level of problem-solving skills, students need cognitive mastery at a higher level, namely to apply, analyze and create. Cognitive abilities at higher levels should be trained on the phenomenon based learning because this learning guide students master the concepts gradually, from an abstract concept to a concrete concept (Basu, et al. 2014; Dolan, & Grady, 2010).

Conclusion and Recommendation

Based on the results of research, the conclusion of the research shows that Student problem-solving skills on optical materials are still dominated by mathematical procedures. Conceptual mastery of physics needs to be improved because the mastery of this concept becomes the basis for the development of problem-solving skills. Mastery of the concept of has a positive influence on problem-solving skills. A phenomenon-based learning helps students understand physics through problems presented with phenomena and problem solving based on phenomena. This research recommends that students had difficulty to solve a problem so that the teacher should provide a scaffolding to identify the problem and find a solution the problem. So, the teacher should be teaching physics with a physics approach and not a mathematical perspective. The results of the research found that there were misconceptions in physics that the future researchers can explore the sources of misconceptions and be looking for ways to reduce these misconceptions.

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