The Implementation of Problem-Solving Based Laboratory Activities to Teach the Concept of Simple Harmonic Motion in Senior High School

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Abstract. Simple harmonic motion is considered as a relatively complex concept to be understood by students. This study attempts to implement laboratory activities that focus on solving contextual problems related to the concept. A group of senior high school students participated in this pre-experimental method from a group's pretest-posttest research design. Laboratory activities have had a positive impact on improving students' scientific skills, such as, formulating goals, conducting experiments, applying laboratory tools, and collecting data. Therefore this study has added to the theoretical and practical knowledge that needs to be considered to teach better complicated concepts in physics learning.

1. Introduction
Simple harmonic motion is an important concept for students to understand mechanics [1]. Because of the complexity concepts, students can’t understand the basic knowledge of concepts, such as determining the causes of simple harmonic motion, understanding harmonic motion equations in springs and pendulums, and understanding the general equations of simple harmonic motions [2]. The spring that is stretched or compressed around the equilibrium position is proportional to the force applied by F following Hooke's law. The recovery force given by the spring is given [3].

\[ F = -kx \]  

Where \( k \) is the spring elastic constant and the measured \( x \) displacement of the equilibrium position. The negative sign indicates that the displacement and displacement forces are in opposite directions. The period of simple harmonic oscillator is found to depend on the rigidity of the spring and also on the oscillating mass \( m \). Spring period is given by [4].

\[ T = 2\pi \sqrt{\frac{m}{k}} \]  

A simple pendulum consists of a small object tied with a string at the end. The pendulum period is given by [5].

\[ T = 2\pi \sqrt{\frac{l}{g}} \]  

Where \( l \) is the length of the pendulum and \( g \) is the acceleration of gravity. Based on the movement of the pendulum and springs periodically, we get a simple harmonic motion equation to get the time function graph. A simple harmonic motion equation is given by [6].

\[ y = A \sin \frac{2\pi}{T} t \]
Where \( y \) is the deviation and \( A \) is the amplitude. While \( T \) and \( t \) respectively are period and time.

Physical learning in the laboratory is considered a significant learning facility [7]. Physical learning through laboratory activities allows students to be directly involved in the learning process [8]. Knowledge gained by students through these activities can be well understood and remain durable in students' memories when using the laboratory [9]. Not all laboratory activities make students understanding better, failure to teach laboratory activities due to lack of teacher understanding in designing laboratory activities and selecting appropriate laboratory teaching methods [10]. Students play a role in the failure of teaching in the laboratory, they often do not understand the concatenation of concepts learned with the activities undertaken in laboratories [11].

A learning model that is able to relate concepts learned in practical activities is the Laboratory Problem Solving (PSL) model. This learning model aims is to support the concepts being studied during laboratory activities. The PSL model was adapted from the concept of problem solving in a group developed by the University of Minnesota USA. To produce better output, the PSL model has at least 10 steps, ie, objectives, preparations, problems, equipment, predictions, question methods, exploration, measurement, analysis, and conclusions [12]. One of the goals of this model helps students change a misconception about the physical phenomena based on the given problem [13].

The PSL model has characteristics among which students can solve problems using brainstorming and investigating problems. Dig up existing knowledge and connect new knowledge through case studies and work in groups. Can operate laboratory equipment related to given theory. Students can use the existing media and can perform analytical techniques. Students can analyze and describe, discuss the results of practicum data by way of written reports, posters, and oral presentations. Students can work in groups [14]. Based on the explanation above, this study aims to apply the PSL model in simple harmonic motion learning and determine its effect on the improvement of cognitive ability and scientific ability of students.

2. Experimental Method
The study was conducted in Islamic high schools with a total of 26 students consisting of 13 male students and 13 female students. Characteristics of students based on psychology have moderate IQ. Based on the observation of physics learning in the laboratory is not sufficient to help students understand the topic or concept being studied. The worksheets used during the activities do not have enough content and design to ensure students understand what to do in the laboratory.

This study used a pre-experimental method with a pretest-posttest group design [15]. Instruments used to obtain data are cognitive tests and student experiment observation sheets. The cognitive test aims to determine the improvement of cognitive abilities at the cognitive level of C1 (remember), C2 (understand), C3 (application), and C4 (analysis). Data were analysed by using N-Gain test on equation 5.

\[
N - Gain = \frac{posttest - pretest}{100 - pretest}
\]  

(5)

Measurement of cognitive ability is obtained from pretest and posttest results. Interpretation of N-Gain improved essay results was \( 0 < G < 0.3 \) low category, \( 0.3 \leq G < 0.7 \) medium category, and \( 0.7 < G \) high category [16]. The experimental observation sheet aims to know the scientific skills, namely the formulation of experimental objectives, experimenting, using tools, and collecting experimental data. The students' scientific skill calculations are derived from the average skills observed during laboratory activities.

3. Result and Discussion

3.1 Cognitive Skills
Aspects of cognitive abilities are examined based on Bloom's revised taxonomy that measures the ability to remember (C1), understand (C2), apply (C3), and analyse (C4). The instrument used is a
multiple choice test. Improved cognitive abilities were tested using the N-Gain test. The results of the calculations are presented in Figure 1.

![Figure 1. Diagram of the result cognitive skills](image)

Figure 1 shows the N-Gain test results of each cognitive aspect. Based on the results that have been obtained there is an increase in each cognitive ability. The $C_1$ (remembering) cognitive abilities increased by 0.47, $C_2$ (understanding) cognitive abilities increased by 0.43, $C_3$ cognitive skills (applying) increased by 0.37, and $C_4$ cognitive (analysing) increased by 0.61. The results of this increase belong to the category of moderate increase. The increase of cognitive abilities might be due to the PSL model that involves active role of students to complete the student activity sheets in the classroom.

Students are also trained to formulate experimental objectives and hypothesis that they present at the beginning of the lesson based on presented-problems. By formulating objectives and experimental hypothesis, this stage instills students to cultivate curiosity and show their enthusiastic to test the hypothesis by doing experiment to get data. The data that has been obtained is then discussed and analysed. This analytical process makes students think to relate concepts to simple harmonic motion contained in reference with the obtained data. Stages of data analysis helps students understand the mathematical equations found in simple harmonic motion materials. The existence of the relationship between the PSL model and the students' understanding of the concepts supported by the researchers stating that 74% of students find the PSL model helps them to understand the concept being studied [17].

In addition to the increase in cognitive skills can be connected some characteristics of the model PSL. Characteristics of the one are building on existing knowledge and acquiring new knowledge through case studies [18]. A description of the relationship between the PSL model, cognitive abilities, and simple harmonic motion concepts is presented in Table 1.

| PSL Model | Cognitive Skills | Concept of Simple Harmonic Motion |
|-----------|------------------|----------------------------------|
| Problem   | Analysing        | Answer the problem of characteristics of simple harmonic motion in spring and pendulum, as well as simple harmonic motion equations. |
| Equipment | Remembering      | Selects the tools used in the experiment and discusses experimental procedures on springs and pendulums. |
Cont. table 1.

| Cont. | Number 1. |
|-------|-----------|
| **Prediction** | **Understanding** |
| Write down what will happen from what will be experimented. |
| **Method question** | **Remembering** |
| Discuss questions about simple harmonic motion experiments procedures. |
| **Exploration** | **Understanding** |
| Conduct discussions to determine will be measured and analysed. |
| **Measurement** | **Applying** |
| Take data from several physical quantities such as time, period, frequency, mass, length of rope. |
| **Analysis** | **Applying** and **analysing** |
| Discuss experiment data and find relationships between multiple magnitudes. Apply mathematical equations to calculate other physical quantities. Create a graph of experimental results. Analyse the graph for explanation. |
| **Conclusion** | **Understanding** |
| Communicate the results of experiments that have been done by connecting it to the concept of simple harmonic motion. |

Table 1 describes the relationship among the PSL model, cognitive skills, and the concept of simple harmonic motion. The relationships of the cognitive domain in the C₁ (remembering), C₂ (understanding), C₃ (applying), and C₄ (analysing) categories are related to the PSL model. One of the researchers states that the PSL has a structured procedure to help students understand the concepts being studied. The student's active process is very effective in constructing knowledge as well as developing his cognitive abilities [19].

**Scientific Skills**

Aspects of scientific skills measured in this study include the ability to formulating experimental objectives, conducting experiment, using tools, and collecting experimental data. Research was conducted for three meetings. Table 2 presents the mean value of scientific skills shown by students in each meeting.

**Table 2. Results of scientific skills**

| Scientific skills          | Learning I(%) | Learning II(%) | Learning III(%) |
|----------------------------|---------------|----------------|-----------------|
| Formulating experimental objectives | 60.55         | 78.19          | 72.92           |
| Collecting experimental data | 59.17         | 73.33          | 85.56           |
| Experimenting              | 70.83         | 83.33          | 91.67           |
| Using tools                | 70.83         | 83.33          | 100             |

Table 2 presented data on to the results above, the aspect of formulating the objective of the experiment increased from the first meeting. This skill, however, decreased in the third meeting. The decrease is due to students having difficulty to relate problems with simple mathematical equations of harmonic motion.

The aspect of collecting data at each meeting increases, indicating that there are improvements in students’ ability to collect experimental data. The experimental aspect of each meeting increases. This might be due to students’ understanding of the experimental procedures and their cooperative work.
The use of tools in simple harmonic movement experiment at each meeting increases. This indicates that students are able to remember the function of the tools used in the experiment. One of the essential aims of laboratory studies is to develop an understanding in students about the nature of science [20]. The increase in students' scientific skills is also supported by researchers who reported that 67% of students expressed excellent laboratory activity to ask questions with teachers. While 66% of students revealed that the PSL stages presented in the worksheets made it easier for them to solve the problems [21]. The relationship among the PSL model, scientific skills, and simple harmonic motion experiments is presented in Table 3.

Table 3. Relationship model problem solving laboratory, scientific skills, and concept of simple harmonic motion.

| PSL Model | Scientific Skills | Concept of Simple Harmonic Motion |
|-----------|------------------|----------------------------------|
| Problem   | formulating      | Students are given a real problem on simple harmonic motion on spring and pendulum. After that the students are asked to formulate the purpose of the experiment based on the problem. |
|           | experimental     |                                   |
|           | objectives       |                                   |
| Equipment | Using tools      | Students use simple harmonic motion experiments. The tool is a tool and materials to be measured. |
| Exploration | Collecting     | Students conduct discussions with teacher-guided groups to determine what data will be measured. |
|           | experimental data|                                   |
| Measurement | Experimenting   | Take data from several physical quantities such as time, period, frequency, mass, length of rope. |

Table 3 presents a relationship between the PSL model, scientific skills, and the concept of simple harmonic motion. All three have relationships in helping students to transfer knowledge as well as develop scientific skills. In the implementation of research on the application of PSL model, there are several advantages and disadvantages. Both are presented in Table 4.

Table 4. The advantages and disadvantages of the implementation of research on the application of PSL model

| Scientific skills | Advantages of Students | Disadvantages of Students |
|-------------------|------------------------|--------------------------|
| Formulating       | Students are able to recognize the problems given. The problems are then discussed in groups to formulate the objectives of the experiment they will prove. | At the third meeting many students are still unable to formulate the experimental objectives of the experiment of applying a simple harmonic motion equation. |
| experimental      |                         |                          |
| objectives        |                         |                          |
| Collecting        | Students are able to complete the experiment table completely as instructed. | There are still some students who do not write the unit when filling in the experiment data. |
| experimental data |                         |                          |
| Experimenting     | Students experience an increase during the experiment. They work with groups and discuss to find ways to do the right experiments. | There is still less supportive activity from some students such as excessive chats and irresponsible with student worksheets. This causes the learning time to be long. |
| Using tools       | Students are adept at using simple harmonic motion experiments on springs and pendulum. And already able to know the function of the tool. | There are still some students who are not careful in reading the measuring tool. |
Table 4 presents an explanation of the advantages and disadvantages of students about scientific work skills. Although there is an increase in some aspects, the lack of students should be known in order to be considered for further research.

Based on the above discussion, it is found that PSL model is one of alternative learning models that can be applied in physics learning especially simple harmonic motion material. The learning process is not just a transfer of knowledge, but with the active involvement of students will make learning meaningful.

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4. Conclusion
Learning on using the PSL models provides benefits of students. First, the PSL model helps students understand the concept of simple harmonic motion, as evidenced by the increase of cognitive abilities in the medium category. Second, the PSL model provides improvements in students' scientific work skills on aspects of formulating experimental objectives, experimenting, using tools, and collecting experimental data. Third, the PSL models help students to be able to cooperate and discuss with their group of a conducive and orderly manner. Based on this, the PSL model has a positive impact on physics learning in the laboratory at the senior high school level to help students understand the concepts being studied.

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