The impact of problem-based learning and inquiry models toward students' science process skills on the vibrations and waves chapter

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Abstract. Science process skills are basic skills that help students develop higher-order skills. These skills can be trained in science learning with a scientific learning approach. This study aims to determine students' science process skills that are influenced by problem-based learning models and inquiry models. The research method used is an experimental method with a quasi-experimental design. The research sample consisted of two classes of students of class VIII SMP. Science process skills data is measured by a description test which has valid criteria and high reliability. Descriptive and inferential analysis techniques are used in the data analysis of science process skills. The results of the data analysis concluded that: (1) The students' science process skills after applying the problem-based learning model were classified as good, (2) the students' science process skills after being applied to the inquiry model were classified as very good (3) there was no significant difference between science process skills which are taught using problem-based learning models and inquiry learning models.

1. Introduction
Science is a collection of knowledge about natural objects and phenomena obtained from the thoughts and investigations of scientists who are carried out with experimental skills using scientific methods [1,2]. Science education in schools in the 21st century should be oriented towards developing strategies and solutions to solve problems in everyday life [3]. Therefore, in the science learning process, teachers must consider the use of approaches with various collaborations and participatory pedagogy so that students can develop their competencies and easily understand the concept of science. The science learning process that emphasizes providing a direct experience. For example, conducting investigations by utilizing the surrounding environment, can train students' scientific work skills (science process skills).

Science process skills (SPS) are basic skills that students must have to develop higher skills. The importance of the process skills being trained in teaching science, among others, can help students to develop their thinking skills, improve memory, and provide intrinsic satisfaction if they are successful in doing something, and help in learning scientific concepts [4]. SPS need to be developed because they consist of cognitive, manual and social skills that allow students to describe objects and events, ask questions, provide explanations of scientific knowledge and communicate ideas to others [5,6].

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The results of the International Program for International Student Assessment (PISA) study conducted by the Organization for Economic Cooperation and Development (OECD) in 2018, Indonesia in the aspect of scientific literacy has decreased compared to the previous year. The 2018 PISA study on the aspect of scientific competence with an average score of 396, which fell from an average score of 403 in 2015 [7]. The same thing is also shown from the results of the Trends in Mathematics and Science Study (TIMSS) survey by The International Association for the Evaluation of Educational Achievement (IEA), in 2015 Indonesia was ranked 44th out of 47 countries with an average competency aspect score. Science amounted to 397 [8]. These results certainly indicate that the ability of students to answer questions involving problem-solving skills and high-order thinking skills is still not optimal.

The results of observations of several junior high schools in West Kalimantan show that the science learning process has implemented a variety of innovative learning models. However, in practice, teachers are still not able to implement the learning optimally. It can be seen from the role of the teacher in learning which is still dominant compared to students. Learning has led to scientific activities, namely investigations and experiments carried out in groups, but teacher assistance is still often needed in group work so that it does not place students in the construction of knowledge. It, of course, causes the SPS of students to be untrained and not developed in learning so that it has an impact on student learning outcomes in science subjects, which is shown from the low results of students' daily tests on vibration and wave material (Table 1). The evaluation that was carried out also did not facilitate students in developing SPS; the teacher still used assessment instruments that were oriented at the level of remembering and understanding. Whereas by using SPS there will be an interaction between concepts/principles/theories that have been discovered or developed with the development of process skills itself so that students can solve problems found in everyday life [3,4].

| Class  | Total students | Number of Students Not Completed | Completion Percentage (%) |
|--------|----------------|---------------------------------|---------------------------|
| VIII A | 35             | 20                              | 43                        |
| VIII B | 36             | 23                              | 36                        |
| VIII C | 35             | 19                              | 46                        |
| VIII D | 35             | 24                              | 31                        |
| VIII E | 36             | 21                              | 38                        |
| VIII F | 34             | 23                              | 32                        |
| Total  | 211            | 130                             | 38                        |

Table 1 shows that the proportion of class completeness does not reach 75%; it means that there are still many students who have not reached the KKM score. These results indicate a lack of success in the learning process in the classroom. Learning outcomes that can be built because in the learning process in the classroom are still not maximal in the skills of students [5,9]. Therefore, it is necessary to study the most basic things in influencing the low science learning outcomes, including the selection and use of learning approaches [10,11].

Learning is a component consisting of various systems that are related to one another. These components include objectives, materials, learning models and evaluation. Based on the differences between these interactions, learning activities can be carried out using various learning models [12]. Many learning models can be applied by teachers, including Direct Instruction, Inquiry, Discovery Learning, Problem Based Learning, Problem Solving and many other models. However, not all learning models can train SPS.

Based on the facts that have been revealed, the learning model that is seen as stimulating students to develop SPS is the inquiry learning model and the problem-based learning model (PBL) [13,14]. The inquiry learning model is a learning process that is based on search and discovery through a systematic thinking process. The syntax of the inquiry learning model is orientation, formulating problems,
formulating hypotheses, collecting data, testing hypotheses, and formulating conclusions [15]. The inquiry learning model has the potential to solve students' science process skill problems because the syntax of the inquiry learning model is very suitable for the indicators of SPS [16–19].

PBL is learning in which the delivery of material is done by presenting problems, asking questions, facilitating investigations and opening dialogues [13]. Problem-based learning will encourage students to be able to compile knowledge themselves, foster student skills, train student independence, and can increase student self-confidence [20]. Several research results indicate that the use of PBL in science learning can improve the process of students' science skills [21,22]. Therefore, this study will analyze students' SPS by applying the model in problem-based learning and comparing the application of the learning model.

2. Methods
The experimental method used in this study was a Quasi-Experimental Design [13,23]. The research was conducted at one of the state junior high schools in West Kalimantan. The sample consisted of 62 students of class VIII who were divided into two classes and were selected by using cluster random sampling technique. One class applied the problem-based learning model, and the other class applied inquiry learning.

Students' SPS are measured using test questions in the form of essays [24]. The test questions used were seven questions with valid criteria and high reliability (0.89). The aspects of scientific process skills that are measured are adapted from basic process skills according to Funk [25], namely 1) observing, 2) predicting, 3) measuring, 4) classifying, 5) communicating, and 6) concluding.

Data on students' SPS were analyzed and categorized each aspect by the criteria in Table 2 [26]. The difference between the two effects of the application of the inquiry learning model and the problem-based learning model is known by using a parametric statistical test (t-test) with the condition that the two data are normally distributed and homogeneous. However, if one of the conditions is not met, the data is analyzed using a non-parametric test (Mann Whitney U test) [23]. Fully statistical test analysis uses SPSS version 20.

| No | Value Range | Criteria KPS |
|----|-------------|--------------|
| 1  | 81,25-100   | Very good    |
| 2  | 62,50-81,25 | Good         |
| 3  | 43,75-62,50 | Not good     |
| 4  | 25,00-43,75 | Not very good|

3. Results and Discussion
Science process skills of students in each aspect vary both for students who have applied inquiry learning models and students who teach with problem-based learning models [27] (Table 3). SPS in this aspect predicting, predicting, and classifying those who taught using the PBL model were lower than students who were taught using the inquiry model, while the students' SPS in the aspects of concluding, communicating and measuring those who taught using the PBL model was higher than students taught using the inquiry model. The SPS of students who teach with the PBL model is higher than the SPS of students who are taught using the inquiry model.

| No | Aspects of Science Process Skills | Problem Based Learning | Inquiry |
|----|----------------------------------|------------------------|--------|
| 1  | Observe                          | 74,44                  | 72,92  |
| 2  | Predict                          | 84,44                  | 92,19  |
| 3  | Conclude                         | 97,78                  | 78,91  |
Problem-based learning consists of five steps, namely problem orientation, organizing students to learn, guiding group experiences, developing and presenting work, and analyzing and evaluating the problem-solving process [28]. In the first step, students are given a stimulus in the form of phenomena in everyday life related to vibration and wave material. Based on this phenomenon, students formulate several problems which later will be selected one problem to be solved. The SPS aspect that can be trained in this step is predicting. Students’ skills in predicting will be sharpened by predicting answers to problems that have been previously proposed. The first step of this PBL was effectively used in training predictive skills [22]. It is evident when researchers pose a problem, students immediately respond by giving answers even though not all of them have answered correctly.

The second step in PBL is to organize students to learn. In this stage, the teacher conditions students to be ready to carry out the learning process. The teacher's role is to divide students into several groups, heterogeneously and direct students in the process of solving problems that have been previously proposed by experimenting. Students work together in groups during the learning process [29]. The aspect of SPS that is trained in this step is the ability to measure. When the experiment took place, as shown in Figure 1, students did not only take length measurements, but there were other quantities measured in the experiment, namely time and angle of deviation. Time is measured using a stopwatch and the angle of deviation using a protractor. From the experiments conducted, it could be seen that students were able to measure well. It means that the PBL step in organizing students to learn is quite effective to use. The results of student measurements are then written down in the worksheets that have been distributed.

![Figure 1. Student activities measuring time and student measurement results on PBL student worksheets](image)

**Table Observation 1**

| Number of vibrations (n) | Angle of deviation (°) | Length of string (cm) | Time (s) | Frequency (Hz) | Period (s) |
|--------------------------|------------------------|-----------------------|----------|----------------|------------|
| 5                        | 15                     | 30                    | 5,5      | 0,1            | 4,5        |
|                          |                        | 20                    | 4        | 1              | 0,8        |
|                          |                        | 10                    | 5,1      | 1              | 0,6        |

The third step in the PBL model is guiding the group experience. In this step, students are guided in conducting experiments and trying to analyze problem-solving. The aspects of PPP that can be trained in this step are observing and classifying. The activities carried out by students in this step were observing the vibrations produced by the pendulum and the waves formed from the slinky and ropes. In the PBL class, it is proven that this step is quite effective in practising the skills of observing and classifying, which can be seen from the results of student KPS [23,29]. Examples of student observations can be seen in Figure 2.
The fourth step in the PBL model is to develop and present the work. In this step, students in their groups discuss making graphs based on observation tables. The PPP aspect that can be trained in this step is to communicate. In this step, students are given the breadth of expressing their opinions in presenting the results of the experiment in different forms, and presenting the experimental results directly so that they can develop scientific communication skills in class forums [22,30,31]. This step is quite effective to use to practice communicating skills as evidenced by students’ answers on the worksheets shown in Figure 3.

The final step in the PBL model is to analyze and evaluate the problem-solving process. This stage is the problem-solving stage. The PPP aspect that can be trained in this step is concluding skills. Students are trained by making conclusions from experiments that have been carried out to answer problems that have been raised at the beginning of the meeting. This step proved less effective to train KPS in the concluding aspect because the results achieved in the posttest showed that the average KPS concluding aspect in the inquiry class was higher than the PBL class. It is because, at the first meeting in the PBL class, researchers lacked time so that the learning process could not be completed properly. The conclusions made by students can be seen in Figure 4.

**Figure 2.** Preview of student observation results on PBL Student Worksheets

**Figure 3.** Snippets of Communicating Results of Students on PBL Student Worksheets

**Figure 4.** Summary of results concluding students on PBL Student Worksheets
In the first step of the inquiry learning model, namely orientation, the teacher conditions students so that they are ready to carry out the learning process by showing a simple demonstration of the concept of vibrations and waves as shown in Figure 5a. After that, in the second step, namely formulating the problem, the teacher asks students to understand the real problems that the teacher gives based on the demonstration. When the teacher demonstrated, it was seen that students observed the demonstration given by the teacher and understood the real problem based on the demonstration that was observed. Students observing the teacher demonstration are shown in Figure 5b. In the first and second steps, the science process skill of the students being trained is observing skills.

![Figure 5. a) The teacher demonstrates an example of vibration, b) Students pay attention teacher demonstration](image)

In the third step, namely proposing a hypothesis, students must make a hypothesis or provisional assumptions to provide temporary answers to the formulation of the problem originating from the teacher's demonstration. Based on the analysis of the Inquiry Student Worksheet 1 shown in Figure 6, it is known that students in the inquiry class have been able to propose a hypothesis from the problem formulation, namely "Which ruler has a fast vibration?". From the formulation of the problem, students propose an estimate of something that has not happened based on existing trends. In proposing a hypothesis, the SPS of students who are trained are predictive. It shows that the inquiry learning model is effectively used to practice predictive skills.

![Figure 6. Snippets of Student Hypotheses on Inquiry Worksheets](image)

The fourth and fifth steps are collecting data and testing hypotheses. The hypothesis testing stage is the most important because it aims to prove or test the hypothesis, which is supported by real (empirical) evidence from the experiment. Previously, students must first determine and prepare tools and materials and work procedures. After everything is ready and willing, then students experiment, collect data and end with analyzing the data. The skills of observing and measuring in the inquiry learning model are trained when students measure the variables needed in the experimental process. Observing skills and using tools are also related to measuring skills. If students can observe and use the tools, then the students' measuring skills are also good. Based on the analysis of the Inquiry Student Worksheet in Figure 7, it shows that students have been able to test the hypothesis correctly, which indicates that students' measuring skills are also good. With inquiry activities, students are encouraged to find information about data that supports problem-solving, and the necessary data can be obtained through a
measuring process so that students can test hypotheses. It shows that the inquiry learning model is effective in practising measuring skills.

**F. Testing Hypotheses**

1. It turns out...length of string...affects the period and frequency of vibrations.
   While...deviation...does not affect the period and frequency of vibrations.
2. If the length of the rope, the more vibration frequency will be...smaller...
3. It causes ruler vibration...shorter...faster than a ruler...longer...

**Figure 7.** Sample test the student hypothesis on the inquiry students worksheet

Classifying skills are developed through exercises categorizing objects based on the nature of the objects. Classification is a skill-based on observation skills (observing). If students can observe, it means students are also able to classify [5]. Based on the analysis of the Inquiry Student Worksheet 2 shown in Figure 8, it is known that students in the inquiry class have been able to distinguish types of waves based on their characteristics. It shows that the inquiry learning model is effectively used in training classifying skills.

**Figure 7.** Sample test the student hypothesis on the inquiry students worksheet

**F. Discussion Questions**

1. What are the characteristics of the transverse wave?
   Answer:
   1. Consists of hills and valleys
   2. The direction of the vibration is perpendicular to the direction of the wave propagation

2. What are the characteristics of longitudinal waves?
   Answer:
   1. Consists of compression and expansion
   2. The direction of the vibration is parallel to the direction of the wave propagation

**Figure 8.** Classifying skills preview on the inquiry students worksheet

Communication skills are trained when students can turn tables into graphs. Based on the analysis of the Inquiry Student Worksheet 1 shown in Figure 9, it is known that students in the inquiry class have been able to change the form of tables into graphs.

**Table 1.2**

| Length of string (cm) | Number of vibrations | Time (s) | Frequency (Hz) | Period (s) |
|-----------------------|----------------------|----------|----------------|------------|
| 15                    | 10                   | 6.01     | 1.43           | 0.62       |
| 30                    | 10                   | 9.21     | 1.01           | 0.92       |
| 45                    | 10                   | 10.52    | 0.95           | 1.05       |

c. Graph the relationship between length of string (L) to period (T) based on experimental data in Table 1.2!

**Figure 9.** Snapshot of communicating skills on the inquiry student worksheet
In the sixth step, which is a conclusion, based on the results of the data that has been analyzed, students can interpret the results of this study. The activity of interpreting data based on empirical evidence is called the activity of making conclusions. Conclusions are made to prove the truth of the hypothesis. States that the skills needed in the concluding stage are the skills concluded [32]. Based on the analysis of the Inquiry Student Worksheet shown in Figure 10, it is known that students in the experimental class have been able to deduce.

**Figure 10.** Conclusion skill trailer on the inquiry students worksheet

Between students who are given learning with PBL learning models and inquiry are more skilled at communicating because in communicating first students must be able to observe, measure, predict and classify. So that also affects the communication skills of students. It shows that the PBL learning model and inquiry are effective in practising communication skills. It is also no different from the research conducted by Purba, F. J, who in his journal stated that problem-based learning could improve KPS, where problem-based learning students are more actively participating in solving problems [33]. KPS taught by the PBL model is also influenced by concept understanding, whereas students' understanding of concepts does not influence KPS students who are taught with the conventional model. It is also in line with Liniarti's study, which states that the guided inquiry model is effective in improving students' SPS [34].

The results of inferential statistical tests to determine the difference in student SPS taught by the problem-based learning model with KPS students taught by inquiry learning model begins with the analysis prerequisite test that is normality test and homogeneity test. The results of the analysis prerequisite test are presented in Table 4 and Table 5.

**Table 4.** Research data normality test results

| Data            | Berdasarkan | Kolmogorov – Smirnov | Signifikansi |
|-----------------|-------------|-----------------------|--------------|
| Science process | Model PBL   | 0,180                 | 30           |
| skills          | Model Inkuiri| 0,148                | 32           |

**Table 5.** Homogeneity test results of research data

| Dependent List  | Levene Test | Signifikansi |
|-----------------|-------------|--------------|
| Science process | 1,813       | 1            |

Table 4 and Table 5 show that the data is normally distributed and comes from a homogeneous population so that the hypothesis test uses the two-tailed t-test. Hypothesis testing was carried out with the help of the SPSS version 20 program. The results of hypothesis testing obtained a significance value of 0.619. Because the calculated significance value is greater than the research significance level (0.05), the null hypothesis is accepted, which means that there is no difference in the SPS of students who are given learning using a problem-based learning model with the SPS of students who are given learning with the inquiry model in vibration and wave matter. It can be concluded that learning with problem-based and inquiry-based models can both develop students' SPS [35,36]. Inquiry learning can affect things including 1) Process skills (observing, organizing data; identifying and controlling variables; formulating and testing hypotheses and explaining; concluding), 2) Student activity ( learning
independently), 3) Skills in expressing opinions verbally, 4) The nature of tolerance for diversity of opinions and perseverance, 5) Having the logic of thinking, 6) The awareness that knowledge is tentative [37]. The problem-based learning model and the inquiry model are learning models that use a scientific approach, because in both models require students to observe (to identify things they want to know), formulate questions (and formulate hypotheses), try/collect data (information) with various techniques, associating/analyzing/processing data (information) and making a conclusion and communicating the results consisting of conclusions to obtain knowledge, skills and attitudes. It is very appropriate to improve students’ SPS, both basic SPS and integrated SPS [38]. According to Ebert & Ebert [39], there are various skills in process skills; these skills consist of basic skills (basic skills) and skills integrated (integrated skills). Basic skills consist of six skills, namely: observing, classifying, predicting, measuring, inferring, and communicating. While integrated skills consist of: identifying variables, tabulating data, presenting data in graphical form, describing relationships between variables, collecting and processing data, analyzing data, analyzing research, developing hypotheses, defining variables operationally, designing research, and carry out experiments. SPS are very important in teaching ways to achieve knowledge and are an important goal in science learning [40]. It is not only important to help students receive information but also to understand learning information.

4. Conclusions

Inquiry and problem-based learning models can develop students' science process skills. The aspects of measuring, concluding, and communicating skills can be developed more by applying a problem-based learning model, while the aspects of predicting, classifying can be developed by applying an inquiry learning model.

Students' science process skills in wave vibration material are classified as good criteria after being taught with the problem-based learning model and the inquiry model so that this model can be an alternative learning model used by teachers to improve SPS on other materials. For teachers who want to apply this inquiry learning model, it should pay attention to the characteristics of the material. The material applied must be able to explore the ability of students to make observations, so that they can explore the ability of students to predict, observe, classify, measure, communicate and conclude.

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