Development of basic physics experiments based on science process skills (SPS) to enhance mastery concepts of physics pre-service teachers in Melde’s law

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Abstract. This study aims to develop basic physics experiment (BPE) to improve the mastery concept in the Melde’s law. Research and development (R&D) was conducted by involving physics pre-service teacher as many as 18 students in the first year and 15 students in the second year as the research sample. Experiment were developed through the development of Science Process Skill (SPS)-based student worksheets which has been reviewed and judgment by expert, which included observing, communicating, classifying, measuring, inferring, predicting, identifying variables, constructing hypotheses, operationally defining variables, designing experiment, acquiring and processing data comes to a conclusion. The results of the first-year study showed that student’s SPS had not been trained optimally, students were still having difficulty in observing, determining experiment variables, inferring and hypotheses. This results in a low mastery of the concept in the Melde law material with a mean class score of 55.56. In the second year, the development of experiment activities was carried out by emphasizing the basic practice of SPS in the beginning of the lecture through simple experimental topics to a more complex. Based on the data processing of the second-year research showed an increase in student process science skills (SPS) and there was an increase in mastery of concept with a mean grade of 73.22. Based on the results of the study, it can be said that the development of basic physics experiment based on SPS that have been carried out can improve the mastery of the concept of in Melde's law.

1. Introduction
Experiments are a way of presenting material that students actively experience and prove about what they are learning, students are totally involved in doing, following a process, observing an object, analyzing, proving and drawing their own conclusions about an object, condition or process [1]. Experiment activities are a characteristic and essence of natural science learning that requires students to experience the process of discovery as scientists do [2,3]. Furthermore, experiment activities can be seen as an activity that can train science process skills, scientific attitudes, and a scientist's way of thinking [1,2]. Students can develop various competencies, not only train process skills, but also can increase students' self-confidence in the concepts that they are learning because students not only get theory but also can prove and discover the concept through experimental activities carried out.
Nowadays, experiment activities are generally carried out by using guidelines in the form of worksheets that have been made very detailed, with procedures for data collection, processing and analysis of data and also conclusions (cookbook experiment). Experiments with this method lack the flexibility to think and act in experiment activities, instead of like scientists, in this method students are more likely to be a robot that only carry out what has been written in the experiment manual. This has an impact on science process skills that are not properly trained, as well as mastery of concepts from the material learned in experiment activities. The results of previous studies indicate that science process skills (SPS) of prospective teacher is low, especially in determining the relationship between experiment variables and designing experiment procedures [4-6]. This low SPS can also be seen from students who turn out to have middle to lower science process skills [7], especially in the planning and designing experiments [8]. The low of SPS turned out to have an impact on achieving mastery of the concept of low students [6]. This can be understood because students with good SPS have the ability to absorb information in learning well so they can master the subject matter well. Therefore, efforts to improve SPS and mastery of concepts must be carried out.

Therefore, the development of experiment activities based on science process skills (SPS) is important to provide experience and train skills possessed by scientists in conducting experiments and also to improve the mastery of student concepts. Science process skills are skills that involve cognitive or intellectual, manual, social, mental and physical aspects which function as tools needed for effective learning, problem solving, and individual and community development [9,10]. Furthermore, having science process skills means preparing future scientists who have scientific literacy, namely enabling students to use science in everyday life and helping students to acquire important skills that must be possessed to understand and study the world in which they live (personal, social and global) [11,12]. In addition, SPS is considered important because it underlies a person to practice thinking skills such as building hypotheses, manipulating data, reasoning about data, applying concepts/laws/theories in science, scientific literacy, and can be developed as a provision in learning science through a series of experience methods scientific in the process of discovering and developing new knowledge [13-15]. Based on the description above, it can be said that SPS is a fundamental ability that is needed by each individual in carrying out activities to acquire and develop new knowledge.

Experiments based SPS for students can build a more effective learning atmosphere, provide important experiences, and prove to have a positive impact on students' academic abilities, improve understanding and mastery of concepts and improve scientific skills and science process skills of students [16-18]. Furthermore, studies on teacher training programs illustrate that understanding concepts can be built through SPS and have an impact on the ability to teach science [13]. Science process skills have a relationship with student cognition development [8,19,20].

In the previous study (first year), it was found that the increase in student SPS was not optimal, especially in the ability to make observations, identify experiment variables, inferring and hypotheses, student responses were generally not based on observations but originated from students' initial knowledge. This has an impact on the achievement of mastery concepts that are classified as low with an average value of 55.56 (scale 100) [6]. Based on the results of the analysis, this is because students are not used to observing the physical phenomena that are shown. In the second year, the development of experiment based SPS was carried out by emphasizing the training of basic SPS in the beginning of the lecture through simple experiment topics to a more complex direction. This change is outlined in student worksheets designed using the SPS approach as was done in previous research, but by emphasizing basic skills of SPS, namely in the observation activities section as shown in Figure 1 [21].
2. Methods

The development of experiments based SPS was carried out using the research and development (R&D) method. The study was conducted on pre-service physics teacher students who learn the basic physics experiment I (BPE I), namely as many as 18 students in the first year of the study and 15 students in the second year. The experiment material in this study is Melde's Law experiment with settings as shown in Figure 2.

In lectures, students conduct experiments with a worksheet guide that has been reviewed by experts. Worksheets are designed and developed using the SPS approach, which includes observing, communicating, classifying, measuring, inferring, predicting, identifying variables, constructing hypotheses, defining operational variables, experimental designing, data acquisition and processing, analyzing and conclusion. Student answers to the worksheet were analyzed as profiles of each aspect of student’s SPS in the form of percentage achievement using equation 1 [22].

\[
P (\%) = \frac{\sum \text{student’s correct answer}}{\sum \text{students}} \times 100 \% \quad (1)
\]
The achievement of mastery concept in Melde’s law was measured using a multiple-choice test instrument which was developed based on the standard Test of Force Concept Inventory (FCI). Enhancement of mastery concepts is analyzed using normalized gain values (N-gain) [23].

\[
< g > = \frac{T_f - T_i}{S_I - T_i}
\]

With \(<g> =\) normalized gain, \(T_f =\) posttest score, \(T_i =\) pretest score, and \(S_I =\) ideal score (maximum score).

### 3. Results and Discussion

This research is a development of previous research (first-year research) which found that the achievement of SPS and mastery concept of student was not optimal [6]. The development of experimental design is done by emphasizing the observation skills at the beginning of the experiment by considering the difficulty level of the experiment, which starts from simple observation questions towards more complex. Based on the processing and analysis data on student worksheet answers, the profile of student SPS achievement compared to the first-year research shown in table 1.

| No | SPS Aspect                  | Achievement of SPS |
|----|-----------------------------|---------------------|
|    |                             | 1st year  | 2nd year |
| 1  | Observing                   | 16.67%    | 73.33%   |
| 2  | Communicating               | 27.78%    | 80.00%   |
| 3  | Classifying                 | 100.00%   | 100.00%  |
| 4  | Measuring                   | 77.78%    | 93.33%   |
| 5  | Inferring                   | 55.56%    | 86.67%   |
| 6  | Predicting                  | 72.22%    | 93.33%   |
| 7  | Identifying variable        | 44.44%    | 86.67%   |
| 8  | Constructing hypothesis     | 44.44%    | 80.00%   |
| 9  | Defining variable operationally | 56.56% | 86.67% |
| 10 | Designing experiment        | 44.44%    | 86.67%   |
| 11 | Acquiring and processing data | 77.78% | 93.33% |
| 12 | Analyzing                   | 83.33%    | 93.33%   |
| 13 | Conclusion                  | 100.00%   | 100.00%  |
|    | Average                     | 61.62%    | 88.72%   |

Based on table 1, there is an increase in the achievement of student SPS in the second year, with an average achievement of 88.72%. Furthermore, each aspect of SPS also has increased compared to the first-year research. From the results of this study it can be said that the process of improvement and development of experiments in year 2 succeeded to increase the achievement of student SPS. Emphasis on the initial part of the experiment by basic simple questions and then followed by more complex questions, making students understand the phenomenon being demonstrated better. This can be seen from the aspect of observation that increases very high, which means that students have been able to find and report in detail the physical symptoms of observed physical phenomena. This also supports the improvement of other SPS aspects, such as communicating skills, making hypotheses, identifying and defining experimental variables, designing experimental activities to making conclusions from the analysis of experimental data.

The increase in student SPS was accompanied by the achievement of mastery concepts as shown in table 2.
Table 2. Achievement of mastery concept in Melde’s Law

| Year research | Average of Pretest (scale 100) | Average of Posttest (scale 100) | gain | N-gain |
|---------------|---------------------------------|---------------------------------|------|--------|
| 1st year      | 25.93                           | 55.56                           | 29.63| 0.40   |
| 2nd year      | 31.22                           | 73.22                           | 42.00| 0.61   |

Based on table 2, the achievement of student mastery concept has increased compared to the first-year research with a posttest average of 73.22 and N-gain of 0.61. This is inseparable from the process of experiment activities carried out by students and also the achievement of student SPS as shown in table 1. For example, in an experiment activity one of the student activities is to find the factors that influence the wave velocity on a string. This activity was considered successful, because all students were able to understand and answer the questions relating the string parameters correctly as shown in figure 3.

Based on the questions in figure 3, students are able to understand the changes in the parameters of the string and their consequences for the parameters of the standing waves produced on the string. This finding further confirms that science process skills have a relationship with the formation of student cognition [8,19,20], students with good SPS have the ability to absorb information in learning well so that they can master the subject matter well. Thus, it can be said that the development of experiments based SPS in this second-year research was better than previous studies.

4. Conclusion
The development of Basic physics experiments based on Science Process Skills which begins with observations of physical phenomena by emphasizing basic SPS in the beginning of the lecture through simple experimental topics in a more complex makes students able to develop science process skills. The results showed that the development of experiments based SPS was able to train SPS well and improve student’s mastery concepts.
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