The effect of using bomb calorimeter in improving science process skills of physics students

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Abstract. The bomb calorimeter is laboratory equipment which serves to calculate the value of combustion heat or heat capacity of a sample in excess oxygen combustion. This study aims to determine the effect of using bomb calorimeter on science process skill of physics students. Influences include the effectiveness of using the equipment and knowing the improvement of students' science process skills before and after using tools. The sample used simple random sampling with one group pretest-posttest research design. The instrument that used is written test that adjusts with science process skills aspect. Analysis of the effectiveness of bomb calorimeter showed useful result 87.88%, while the study of science skill improvement showed n-gain value 0.64 that is the medium category.

1. Introduction

Physics is part of the science that has the nature of a process, product, and values. The quality of learning science is probably not enough to only remember and understand the concept discovered by scientists. However, what is very important is the habituation behavior of scientists in exploring the idea done through trial and scientific research. Subagyo et al. [1] suggested that the process of the invention involves the concept of fundamental skills through scientific experiments can be implemented and enhanced through laboratory activities.

On the subject of learning physics, especially heat, is one of the materials that require laboratory activities. Laboratory activities conducted on the subject of heat is a calorimeter experiment. Calorimeter experiment aimed at implementing Azas Black. The calorimeter is a tool designed to isolate system in it so that the heat out of the body together with the heat into the water and container. The purpose of the trial is to determine the calorimeter combustion heat of an object [2].

Hodosyova et al. [3] examined the development of science process skills in physics education on aspects of formulating hypotheses, interpretation of data, and making a conclusion. The result is factual success knowledge of physics and reached 92%. Akinbolala and Afolabi [4] state that the fundamental process skills in physics are higher than the integrated process skills. The science process skills consist of necessary skills and integrated skills [5]. The essential skills include; observing, aligning the classification, predicting, measuring clicking, conclude and communicating. Integrated skills involve
identifying variables, tabulating the data, present data in graphical form, clicking describe relationships between variables, collect and process data, analyze research, develop hypotheses, operationally defining variables, designing and implementing experimental research.

The enhancement science process skills of students who follow learning model laboratory activity with problem-solving significantly higher than the students who attend the learning model to verify laboratory activities [6]. Kruea-In and Thongperm [7] stated that teachers need to develop what and can use the skills in different contexts of science. The understanding of the concept of learners has increased in the medium category, while the motivation to learn also increased 17.04% after using simple bomb calorimeter [8].

Ruys and Aelterman [9] stated that one of the skills that must develop through learning physics is the science process skills. Science Process Skills (SPS) is a way of thinking and acting that is based on scientific methods to prove or develop the concept of the process of science or science products. Based on research by Çakır [10], science process skills of student teachers is still low, so the SPS is not only given to students at the primary and secondary level but also at universities.

The aspect of science process skills to be observed in this work are keeping, formulating hypotheses, preparing equipment and materials, doing an experiment, interpretation of data, and communicating. Scientific thinking was done one with a bomb calorimeter experiment. Psychomotor abilities of students into ability assessed. Bomb calorimeter experiments, need to be investigated the effect of using a bomb calorimeter. Furthermore, this effect is devoted to the effectiveness of using the bomb calorimeter and improved student learning outcomes science process skills before and after the experiments. This study aims to determine the efficacy of using the bomb calorimeter and improvement of science process skills.

2. Methods
The work method is one group pretest-post-test with 33 students as the sample of Physics Department of Mathematics and Natural Science Faculty, Semarang State University. Science process skill of student assessed by the test that already tried out before. The test consists of the sixth science process skill aspect. Sample took the pretest, then took the experiment with bomb calorimeter and finally took the posttest so it can be known the effect of bomb calorimeter using by doing the test (Figure 1).

**Figure 1. The design pattern one group pretest-Post-test Design**

| O₁ X O₂ |

Where:
X = Treatment, use of lab-developed
O₁ = Value pretestt (before using the lab-developed)
O₂ = Value posttest (before using the lab-developed) [11]

This work is the application of a bomb calorimeter that has been made and tested for accuracy and compatibility from the expert one. Pretest initiated action on a sample of students, and then students are grouped in groups of 3-4 students. Furthermore, students do practical work with the bomb calorimeter laboratory device consisting of a bomb calorimeter tools and manuals book, and then the students got the posttest. Pretest and posttest are designed following aspects of the science process skills.

The data that obtain are observation, documentation, test, and questionnaires. An observation method used to determine the level of science process skill on a series of practical activities. This method is used to get the value of psychomotor students. The observer is taken from the 8th-semester students who already understand the material lab work done. The documentation is gathering of data of respondents from the 2nd basic physics experiment along with the names of students for homogeneity test. The third
method is the method of testing. The tests used are essay test that accordance with science process skills aspects on the subject of temperature and heat. Martin-Raugh et al. [3] stated the function of the test as a measure of the learners on the cognitive domains. The fourth method is the questionnaire that used to determine the student response and practitioner on the device and experiment.

The effectiveness of using bomb calorimeter showed if indicator value post-test is higher than the standard value set on the course subject. The device called effective when post-test > 70 or at least the practitioner gets-right BC value. While the increase science process skills can be analyzed using n-gain test.

\[
(g) = \frac{(S_{post}) - (S_{pre})}{100% - (S_{pre})}
\]

where:

- \( S_{post} \) = the average value of the final test (%)
- \( S_{pre} \) = the average value of the initial test (%)

3. Result and Discussion

Results obtained from the value of the post-test were analyzed in two purposes, there are examining the effectiveness of bomb calorimeter and examine the gains. The value of post-test showed that the bomb was capable of the learning process, with details of 87.88%.

Instruments questions used in science process skills test, previous trials conducted beforehand. Problem tested amounted to 27 issues with the skill composition were measured to observing, making hypotheses, preparing tool and materials, doing experiments, interpretation of data, and communicating.

Results of trials acquired about 12 questions that have been tested validity, different power, level of difficulty, and reliability, with the skill composition were measured to observing, making hypotheses, preparing tool and materials, doing experiments, interpretation of data, and communicating. Distribution aspects of science process skills, validity, different power, and the level of difficulty of questions used by the test results.

Data results obtained from the value of pretest and post-test showed an increase in science process skills with the gain of 0.64 in the medium. Skill’s aspect that observed consists of Data from the gain test every aspect of the science process skills showed medium and high category shown in Table 1.

| No. | Aspect                                      | N-Gain | Category |
|-----|---------------------------------------------|--------|----------|
| 1   | Observing                                   | 0.40   | Medium   |
| 2   | Making Hypothesis                           | 0.50   | Medium   |
| 3   | Preparing Equipment and Materials            | 0.84   | High     |
| 4   | Doing experimenting                         | 0.72   | High     |
| 5   | Interpretation of Data                     | 0.42   | Medium   |
| 6   | Communicating                               | 0.85   | High     |

The test instrument that based on science process skill then calculated the improvement of each aspect. Aspects observed there are two problems, the question number 1 and 2. On this issue, the students experienced significant growth after using a bomb calorimeter. This is following the opinion of Wittmann [12] that when the students get an overview of a topic, then they can develop his thinking toward a more complex understanding. Participants presented different images of the simple phenomenon of everyday life and a particular procedure uses an electrical component, and then observed which method is right. This makes the learners can find everyday phenomena and saw using an electrical component. In the aspect of finding has the lowest percentage is 67.80% compared to the others. This
indicates that the majority of students still do not understand the phenomenon that is served daily. It is also still less scrupulous about the use of an electrical component.

There are two aspects in making hypotheses about the matter that is the number 3 and 4. The hypothesis is a reasonable approximation to explain an event or a particular observation [9]. Before using a bomb calorimeter lab tool, the ability of learners 41.48% and after using practical tools 70.83%. Appears to be rising significantly. In accordance stated Ruys and Aelterman [9], the scientific work of a scientist usually makes hypotheses which are then tested through experimentation. Through the practical tool, learners can gain practical experience in observing the results. Following that expressed by Ionescu [13] that formulate the hypothesis is done by describing the experiences of using the objects observed. The observed object is practical tool bomb calorimeter.

Aspects of preparing equipment and materials, there are two problems, on 5 and 6. The ability of equipment and materials has increased very significantly. At first, the students were unable to identify the tools and materials used in the experiment. After using a bomb calorimeter practical tool for learners to explain the tools and materials used in the bomb calorimeter lab activities. In accordance opinions Ango [14] while studying science knowledge, learners must apply the concepts, ways of working and attitude in daily life. This indicates that the involvement of students in preparing their experiments for setting up the equipment and materials may reflect attitudes in everyday life.

Doing experiment aspect, there are two problems, the number 7 and 8. The ability to conduct experiments to increase visible from pretest-post-test of 24.85% to 79.24%. Participants presented a problem influences variable in the experiment as well as how to experiment a bomb calorimeter. Participants can explain the influence of a variable to the results of experiments supported by observational data table on practical instructions.

Interpretation of data aspect is two problems, numbers 9 and 10. Participants are required to interpret and complete a trial data presented. And outlines the equations used in the bomb calorimeter practicum. Data interpretation increased significantly, ie, from 45.29% to 68.01%. This is consistent with that expressed by Ionescu [13] that a person is said to be able to experiment when it managed to identify and control variables in the lab.

There are two aspects to communicating, of the last two numbers 11 and 12. Ruys and Aelterman [9] revealed that the skills to describe what was found is one of the fundamental skills required of scientists. In this aspect, the data presented experimental results were then learners are required to process them in the form of an explanation. Improving the ability to communicate the results of the pretest and post-test

![Figure 2. Graph of Science Process Skills Improvement consist of (1) Observing; (2) Making Hypothesis; (3) Preparing Tool and Material; (4) Doing Experiment; (5) Interpretation of Data; (6) Communicating](image-url)
was 51.33% and 92.61%. It is seen that the increase in this aspect is quite high. This is because the students can search for a relationship sari one variable to another variable based on the data presented.

Based on Figure 2 on improving the science process skills, the most significant improvement seen in the aspect of preparing tool and materials as well as conducting bomb calorimeter experiments. In the graph appears every science process skills criteria have been growing significantly. It's because in these two aspects students observing and identifying practical activities directly. Conversely, the lowest increase contained in observing aspects of 21.82% due to the practitioner was already accustomed having a scientific attitude observed. This is evidenced by the results of the practicum that students are already quite good. The effectiveness of experiment tool calculated by comparing the data result after using bomb calorimeter and standard value set on the course subject, showing in Table 2.

| Criteria  | The number of participants | Percentage (%) |
|----------|----------------------------|----------------|
| Effective | 29                         | 87.88          |
| Ineffective | 4                         | 12.12          |

Based on Table 2 it can be seen that the device practicum consists of laboratory equipment and manuals bomb calorimeter bomb calorimeter effective learning. Indicated by the results of post-test participants can reach even exceed the minimum criteria of the basic physics course that is with an effective percentage of 87.87%, and the percentage of 12.12% is ineffective. The mean results post-test 78.50 which means according to the criteria B, so that we can conclude practical devices effective in improving learning science process skills.

Data obtained from the observation sheets science process skills supporting results post-test obtained on those aspects of science process skills. In practical activities, one can develop its science process skills. Following of Su and Yeh [5] that aims to apply the science process skills so that learners’ direct stimulation with an object of knowledge so that students learn the process and products simultaneously. Its main activity is observed from the observation sheets science process skill (Table 3).

| No. | Aspect                   | Score | Percentage (%) | Criterion |
|-----|--------------------------|-------|----------------|-----------|
| 1   | Observing                | 115   | 87.12          | Very High |
| 2   | Making Hypothesis        | 115   | 87.12          | Very High |
| 3   | Preparing Tools and Materials | 112 | 84.85          | Very High |
| 4   | Doing experiments        | 121   | 91.67          | Very High |
| 5   | Data Interpretation      | 117   | 88.64          | Very High |
| 6   | Communicating            | 111   | 84.09          | Very High |
|     | Score average percentage of |       | 87.25          | Very High |

The result of this process skills of observation and then together with the report made by the students after the lab into the value of psychomotor learners. In addition to cognitive value, psychomotor is also assessed through observation sheet of science process skill and reports done by students. The results show the value of the psychomotor average percentage of 87.25% is very high. Suitable for research of Spekor-Levy et al. [15] that science process skill could be developed by experiments method with lab equipment based on inquiry. Observation sheet consists of four aspects. Aspects of science process skills were observed in the experiment are preparing the tool materials, doing experiments, interpretation of data, and communicating. Aspects of observing and formulating hypotheses can be seen from the report made by each in the lab.
Observing skill is a skill in observing an object directly by using the senses [16]. Skills observe and formulate hypotheses can also be seen from the student's skills in doing experiments. Two of these skills can be observed through the results of a report written by the students. This report is provided in the lab manual so that students are asked to complete the report. Statements in this practical guide have been tailored to the aspect of science process skills. The ability to observe learners include examining practical tool measurement results and writing data obtained properly. The percentage of 87.12% observed aspects including very high criteria.

Skills formulate hypotheses contained in the lab manual. The process of formulating this hypothesis led to several questions related to allegations of lab results. The percentage obtained by 87.12% including very high criteria. That is the hypothesis skills of learners high when using a bomb calorimeter practicum. Hodosyova [17] illustrates that formulate the hypothesis is one of the most important aspects of science process skills because these aspects can help learners determine what is important and can follow his experiments based on information obtained in advance in accordance hypothesis.

Skills equipment and materials, this skill is observed by the observer through the observation sheets science process skills. These skills will be fulfilled if the learners can prepare equipment and materials neatly, correctly and functioning properly. The percentage of skill equipment and materials reached 84.85% with very high criteria. This is supported by the manuals already described therein all about lab activities. It might also indicate that learners using the fine manual provided. Hodosyova [17] concluded that skills better learners if they are involved in designing their experiments.

Skills experiment reaches the percentage of 91.67% with very high criteria. This aspect has the highest percentage among other aspects. Indicators of this aspect is an experiment performed three repetitions of the mass of a sample as an independent variable, and variable measurement is done properly. Aspects of this experiment also supported by the manual as a companion tool practicum.

Skills interpretation data obtained a score of 88.64% with very high criteria. This percentage includes quite high, and this is because the learners are already trained and familiar with the analysis of data on subjects majoring in physics. Practical instructions are provided also contained tables of data analysis to facilitate learners.

Communicating skills. These skills are observed through observation sheets science process skills, and the percentage is 84.09% including very high criteria. Written communication can be seen from the report while verbal communication can be seen from the observation sheets science process skills according to the indicators that learners verbally communicate the results of the experiment with bold, correct, and complete.

Student responses about experiment tools consist of 10 statements and have criteria score 1 until 4. The student can complete the response sheet with a score that suitable in student opinion, detail shown in Table 4.

The amount of the average score of questionnaire responses is 87.65% in the very high category. The student questionnaire responses also contain practical advice on the device for the next practical improvements. Feedback from students is then summarized and used for the improvement of bomb calorimeter and manuals book. Repair bomb calorimeter contained in aesthetic aspects which display less attractive, as well as practical aspects of the tool. While the repair manual book in the material aspect of practical guidance. The results of student responses to the bomb calorimeter laboratory devices are presented in Table 4.

Sequential learning through reconstruction sciences a technique facilitates mastery concept [18]. Learning science with process skills approach is important to apply as it involves students to be active and to improve student learning outcomes following the demands of the curriculum developed. Students in the study also had the opportunity to communicate the results of experiments have been conducted in laboratory activities.
Table 4. Student responses to bomb calorimeter lab equipment

| No | Research Aspect                                                                 | Score | Percentage (%) | Criterion       |
|----|----------------------------------------------------------------------------------|-------|----------------|-----------------|
| 1  | Lab tool is very useful in learning physics                                      | 3.88  | 96.97          | Very High       |
| 2  | Forms practical tool looks interesting views                                     | 3.27  | 81.82          | Very High       |
| 3  | Easy lab equipment used in the process of practical implementation                | 3.42  | 85.61          | Very High       |
| 4  | Accuracy conceptual of practical tools structures complete contents of the manual, coherently and tidy | 3.48  | 87.12          | Very High       |
| 5  | The information given in the manual make more efficient practicum                 | 3.45  | 86.36          | Very High       |
| 6  | Statement and sentence in the manual is easy to understand                        | 3.52  | 87.88          | Very High       |
| 7  | Size and models of letters used in the manual visible and easily understood       | 3.58  | 89.39          | Very High       |
| 8  | Fill material included in the manuals easily understood by the user of experiment do not deviate from the concept | 3.52  | 87.88          | of Very High     |
| 9  | Procedures and action steps presented in a systematic and coherent               | 3.64  | 90.91          | Very High       |
|    | Total score                                                                      | 1157  | 87.65          |                 |

4. Conclusion

The bomb calorimeter is effective in learning the material temperature and heat. Criteria for improvement of science process skills are medium and psychomotor abilities including high category. It also can provide a learning experience directly to the practitioner through using of a bomb calorimeter according to aspects of science process skills. Suggestions can be formulated from this study with practical learning can be used as an alternative to be implemented because it can improve science process skills through test value the students.

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