The concept and science process skills analysis in bomb calorimeter experiment as a foundation for the development of virtual laboratory of bomb calorimeter

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Abstract. This study aims to analyze the concepts and science process skills in bomb calorimeter experiment as a basis for developing the virtual laboratory of bomb calorimeter. This study employed research and development method (R&D) to gain the answer to the proposed problems. This paper discussed the concepts and process skills analysis. The essential concepts and process skills associated with bomb calorimeter are analyze by optimizing the bomb calorimeter experiment. The concepts analysis found seven fundamental concepts to be concerned in developing the virtual laboratory that are internal energy, burning heat, perfect combustion, incomplete combustion, calorimeter constant, bomb calorimeter, and Black principle. Since the concept of bomb calorimeter, perfect and incomplete combustion created to figure out the real situation and contain controllable variables, in virtual the concepts displayed in the form of simulation. Meanwhile, the last four concepts presented in the form of animation because no variable found to be controlled. The process skills analysis detect four notable skills to be developed that are ability to observe, design experiment, interpretation, and communication skills.

1. Introduction

Practical work is one of the methods in chemistry learning that can give students experience for doing experiment to acquire knowledge and prove learned theory. Doing experiment allows students to gain their own experience of an object so that students will be easier to understand. That is because almost 90% of the information obtained and gained by students through directly performing the learning they learn [1].

Practical work can also be used to build the science process skills. It is supported by the previous research that found a practical work is one of the effective approaches of science learning to improve the science process skills [2]. Furthermore, Harlen defined the science process skills as an adaptation of the skills used by scientists to construct knowledge, discover problems and make a conclusion [3].

One of the factors that support the implementation of chemistry learning by using the practical work method is the availability of the chemical apparatus. Hence if there are no supported chemical apparatus are available, then the practical work certainly could not be implemented [4]. One of the reasons of the unavailability of the instrument is the expensive price, such as bomb calorimeter.

The bomb calorimeter is an instrument used to measure the heat of reaction at a fixed volume and the measured heat which called the change of internal energy (ΔE). In chemistry, the changes of heat of a reaction can be measured at fixed pressure or volume [5]. However, the facts in the field show...
that mostly can be measured at fixed pressure because of the ease in designing the apparatus use in practical work [6,7] and availability apparatus. For instance, the concept of energy involved in reaction should be learned with the support of the laboratory activity.

The high price of some chemical instruments linked to the absence of the required equipment, therefore the integration of technology in education is a strategis options. One of the utilization of technology in education is making a virtual laboratory. Virtual labs can be defined as learning and virtual teaching environments that are designed like real laboratories and can be used by students to practice anytime and anywhere if there is a computer [8]. The result of research in practical work learning using virtual laboratory that has been done shows that virtual lab can improve the readiness for learning activity in laboratory, and strengthen the conceptual knowledge [9-12]. In addition, the virtual lab can also provide an opportunity for students to develop scientific process skills [13-15].

One of the important steps which must be done before making a virtual laboratory is doing concept and science process skills analysis. This needs to be done so that developers know the concepts and science process skills contained in bomb calorimeter experiments so that it can be builded in the virtual lab that will be developed. Based on these descriptions, the aims of this study is to analyze the concepts and science process skills required in bomb calorimeter experiment as a basis for the development of virtual bomb calorimeter.

2. Methods
This study use a Research and Development (R & D). There are ten steps of R & D method according to Borg and Gall (2003) namely 1) research and data collection, 2) planning, 3) product draft development, 4) initial field trials, 5) revise test results, 6) field trial, 7) improvement of product of field test result, 8) test of field implementation; 9) final product refinement, 10) dissemination and implementation. However, in this study only discusses the stage of research and data collection.

3. Result and Discussion
Analysis critical concepts and; skill process of bomb calorimeter was analyzing by optimizing of bomb calorimeter experiments. However, the basic principle of the bomb calorimeter is to measure the heat at a constant volume. The heat that is measured using this apparatus is heat of combustion because the reaction is a combustion reaction. Furthermore, since the heat is measured at a constant volume, in other words the measured heat is the change of internal energy (ΔE = qv).

3.1 Analysis of Concept
In analyzing important concepts based on working procedures and experimental data. The optimize data of bomb calorimeter experiments obtained are temperature data with time shown in the following graph.

Figure 1. Graph temperature vs time
In the analysis of working procedures starting from the sample used in the experiment. The results show the first sample to be used is benzoic acid. The purpose of the use of benzoic acid because the energy of benzoic acid is known so can determine the bomb calorimeter constant. After, knowing the value of bomb calorimeter constant then can measure the heat of combustion for other samples.

Next, an analysis of the amount of O₂ gas pressure used in the experiment. The amount of gas pressure is related to the combustion that occurs such as perfect combustion or incomplete combustion. Perfect combustion occurs when using excessive O₂ gas while incomplete combustion occurs when using limited O₂ gas. This will have an impact on the experimental data obtained, which in incomplete combustion will form a black solid and also the remaining length of the burner wire that cannot be measured. Therefore, in bomb calorimeter experiments must produce perfect combustion.

The data changed in graphic form indicates that there are three phenomena/events occurring during the experiment that is before the combustion, the combustion begins, and the steady-state. Phenomena/events that occur prior to combustion is the adaptation of water temperature with environmental temperature. Therefore, it can be concluded that these three phenomena follow the black principle of \( Q_{\text{release}} = Q_{\text{absorb}} \).

Based on the description above, the important concepts contained in bomb calorimeter experiments as many as 7 concept labels that are bomb calorimeter, internal energy, burning heat, perfect combustion, incomplete combustion, calorimeter constant and black principle. In virtual laboratory, concept can be display in form simulation and animation. The concept that can be displayed through simulation if the concept is created by describing the real situation (there are variables that can be controlled), while the concept is displayed through animation if the concept is displayed without any variables being controlled. From seven concept labels obtained, then analyzed which concepts can be displayed on the virtual that will be developed in the form simulation and animation as shown in table 1.

| No | Concept label               | Display in Virtual | Animation | Simulation |
|----|-----------------------------|--------------------|-----------|------------|
| 1  | Bomb calorimeter            | ✓                  |           |            |
| 2  | Change of internal energy   | ✓                  | ✓         |            |
| 3  | Heat of combustion          | ✓                  | ✓         |            |
| 4  | Complete combustion         | ✓                  |           |            |
| 5  | Incomplete combustion       | ✓                  |           |            |
| 6  | Heat Capacity               | ✓                  |           |            |
| 7  | Black Principle             | ✓                  |           |            |

Percentage 42.86% 57.14%

3.2 Sciences Process Skills
In addition to analyzing the related important concepts in bomb calorimeter experiments, in this study also conducted an analysis of the science process skill that can be developed. Science process skills are the physical and mental skills associated with the fundamental abilities possessed, controlled, and applied in a scientific activity, so that scientists are able to discover something new [16]. The same is also stated by [17] that the science process skills are all the skills necessary to acquire, develop, and apply the concepts, principles, laws, and theories, whether in the form of mental skills, physical skills as well as social skills.

There are four reasons why the importance of science process skills needs to be applied in teaching and learning activities [16]. The four reasons are the development of science progresses so fast that it is impossible for teachers to teach all the facts and concepts to the students, students easily understand complicated and abstract concepts when accompanied by concrete examples, the discovery of science...
is not absolutely true, the discovery is relative, and development of the concept cannot be separated from the development of attitudes and values on the other hand must be linked.

The types of science process skills according to [17] are observation, classifying, questioning, predicting, interpreting observations, hypotheses, planning experiments or investigations, using apparatus and materials, applying concept or principle, and communicate. Based on the literature on the science process skills as well as the work procedures of bomb calorimeter experiments, it is determined which science process skills can be developed in virtual bomb calorimeter. Scientific process skills that can be developed are presented in Table 2.

Table 2. Science process skills to be developed

| SPS’s indicators and Sub-indicators | Skill students can have |
|-------------------------------------|-------------------------|
| **Observation**                     |                         |
| • Use as many senses as possible    | Students can observe how to arrange parts of tool components to use bomb calorimeter. |
| **Plan Experiment**                 |                         |
| • Student can determine sample, sample mass, length of wire, O₂ gas pressure and water volume. | Student can determine sample, sample mass, length of wire, O₂ gas pressure and water volume. |
| **Interpreting / Interpreting data**|                         |
| • Conclude                          | Students can deduce the measured heat at a fixed volume of energy changes in. |
| • Students can deduce the purpose of using the first sample of benzoic acid. | Students can deduce the purpose of using the first sample of benzoic acid. |
| • Students can deduce the length of wire that can be used in the experiment. | Students can deduce the length of wire that can be used in the experiment. |
| • Students can deduce water volume limits that can be used in the experiment. | Students can deduce water volume limits that can be used in the experiment. |
| **Communicate**                     |                         |
| • Using empirical data of experimental or observational results with graphs / tables / diagrams. | Using empirical data of experimental or observational results with graphs / tables / diagrams. |
| • Describe the results of experiments or research | Describe the results of experiments or research |
| • Presenting data of observations in the form of graphs and tables. | Presenting data of observations in the form of graphs and tables. |
| • Describe the events that occurred in the experiment based on the graph. | Describe the events that occurred in the experiment based on the graph. |

The result of concept analisys and science process skills are very usefull for the planning developed virtual bomb calorimeter.

4. Conclusion
The concepts analysis show that there are seven concept labels which are important to be concerned in developing the virtual bomb calorimeter. While the analysis related of the concept attribute shows there are 57.14% concept labels that can be displayed through simulation and 42.86% are shown through animation. Meanwhile, the science process skills that can be developed based on the results of
concept analysis are the ability to observe, plan experiments, interpret, and communicate. The result of concept analysis and science process skills are very useful for the planning developed virtual bomb calorimeter. This is because developers can more easily in designing the virtual.

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