Vol. 5, No. 1, 2019, p. 16-25 p-ISSN 2477-1422 e-ISSN 2477-2038

Simple and Low-Cost Chemical Experiment Kits to Observe the Concept of Gas Laws

(Received 3 October 2018; Revised 24 May 2019; Accepted 26 May 2019)

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DOI: 10.30870/jppi.v5i1.3917

Abstract

This study aimed to develop a simple and low-cost chemical experiment kits to facilitate students in the school which has limited chemistry laboratory facilities. The topic of the experiment was the concepts of gas laws. The research was conducted in a private school in a rural area of Banten, Indonesia using educational research and development method. 10^{th}-grade high school students (n=27) participated in this study. The research result indicated that the experiment kits facilitate the teacher to explain the chemical concepts of gas laws. Learning using the gas laws experiment kits also had positive responses from students. The results showed that the kits were eligible to be applied in the high school chemistry learning.

Keywords: Simple and Low-Cost Kit, Chemical Experiment, Gas Laws.

INTRODUCTION

Chemistry is part of scientific knowledge that is inseparable from their product and process (BNSP, 2006). As a product, chemistry has knowledge of facts, concepts, theories and principles. Whereas as a process, chemistry has a scientific method to proves the theories or concepts. Both can be realized through chemical experiments. Kennepohl (2007) stated that students need experimental activities to develop their laboratory techniques and cognitive abilities. It could include skills such as physical manipulations, observations, problem-solving, data handling, time management, and interpretation of data and results.

The field observations in some private schools in the remote area of Banten, Indonesia region indicated that most of them had limited chemistry laboratory facilities. This is due to the financial limitations of schools unable to provide chemical laboratory materials and equipment. The same constraints were also experienced in several schools in Indonesia (Sundari, 2008). This problem caused many students to lack experiences in practicing chemical experiment. As an alternative solution to support experimental learning, a simple and low-cost chemical experiment kit is needed as a learning medium. For this reason, it is necessary to develop a chemical experiment kit to support school learning.

Research on the development of experimental kits for science learning has also been conducted by several researchers (Saputri & Dewi, 2014; Preliana, 2015; Budiyanto, 2015; Yulianti *et al.*, 2010; Hasbi *et al.*, 2015) to produces feasible experiment kit which has a positive effect on learning outcomes. However, it is necessary to consider the cost of material used to make it affordable for students and school. Therefore, it is required to develop a chemical experiment kit that uses simple and low-cost materials that are feasible to support the learning process.

Some researchers also have an innovation for the development of simple and low-cost learning kits. Kennepohl (2007) has developed a home laboratory kit to teach general chemistry. The laboratory kit was increasing student access and flexibility to the chemical experiment. Moreover, it also brings experiments into a home environment to contextualize learning for the student. The development of affordable laboratory kit innovations has also been conducted on other chemical topics such as polarity of compounds (Zidny *et al.*, 2017), electrochemistry (Chatmont *et al.*, 2015) and polymer chemistry (Bopegedera, 2017).

Based on this background, a study is needed to develop a chemical experiment kit that supports chemical learning on other topics which fits the needs of the school. The subjects of this study were students in remote areas school which has limited chemistry laboratory facilities. The chemistry topic of ideal gas laws was chosen based on need assessment on the curriculum in the school of the participant. The focus of the topic was about the concepts of Gay-Lussac's Law and Charles's Law.

METHOD

This research was a part of mini-research conducted by prospective chemistry teacher students as an effort to improve experiment-based learning in private schools that have limited laboratory equipment. The method used was adapted from the part of Educational Research and Development (Borg & Gall, 1983; Sugiono, 2011). Stages of research encompass (1) need assessment, (2) product design and expert assessment, (3) limited scale trials and assessment by students and teachers. The product was developed in the form of Charles's gas law and Gay-Lussac's gas law experiment kits.

Literature studies and field studies were carried out before the product design process. Need assessment was conducted to determine the type of material that is simple, inexpensive and suitable for use in an experiment kits. Through the design process, a simple prototype kit for Charles's law and Gay-Lussac law for chemistry lessons was made. The prototype was validated by experts. After passing the revision process, the experimental kit was tested on a limited scale to high school students using the demonstration learning method. The learning process was only limited to concepts of Gay Lussac law and Charles' law. The instrument used in this study was a questionnaire assessment of teachers and students. Data obtained during the study were analyzed based on the response of the questionnaire.

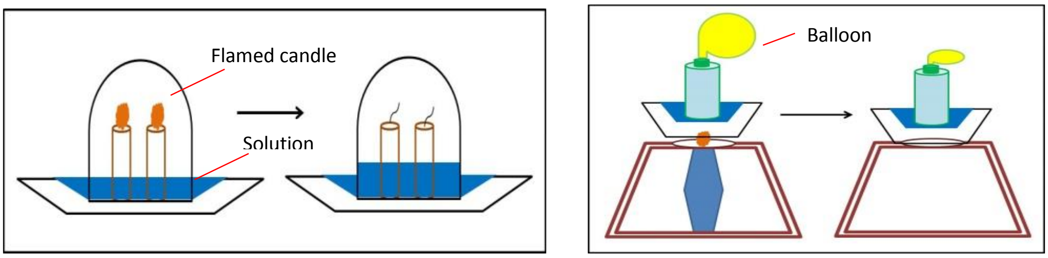
RESULTS AND DISCUSSION

Based on the results of the need assessment and the expert's judgment, a profile of the chemical experiment on the topic of ideal gas laws was created. According to the chemical concepts of gas, an ideal gas is a theoretical gas composed of set randomly moving non-interacting particles under normal conditions. Many gases such as oxygen, hydrogen and some heavier gases like carbon dioxide will behave like an ideal gas. This means they follow the laws of gases such as Gay-Lussac's law and Charles's law. In this study, Gay-Lussac's law chemistry experiment kits were made of materials including candles, colored solutions (natural dyes or food coloring), support pads, glass or transparent glass cover (figure 1a).

Gay-Lussac's law stated that *"the pressure of a given mass of gas varies directly with the absolute temperature of the gas, when the volume is kept constant*" (Libretext, 2019) within a closed system. Gay-Lussac's law is also illustrated as an equation :

$$\frac{P}{T} = k \qquad (1)$$

Where P is the pressure of the gas, T is the temperature of the gas in Kelvin, and k is a non-zero constant. This means that as the temperature increase, the pressure increases and vice versa.



(a) (b)

Figure 1. Chemical experiment kit to observe the concepts of gas laws (Gay-Lussac's gas law (a) Charles's gas law (b)).

The figure 1.a shows the experiment kit in which two flamed candles placed in the top of the colored solution and then it was closed with transparent glass. After a while, the candles' flames will get smaller until they are extinguished, and the water level underneath the glass begins to rise as the candles fade away. The water level will continue to rise for a short time after the candle has been fully extinguished. In this experiment, the glass is filled with gaseous air molecules. The energy from the flames transfers to the air molecules exiting them by raising their temperature. When the air molecules are excited, they are trying to spread further apart. Because the glass will not expand, the volume of space of air molecules can take up is limited. As they are trying to expand in volume, the air molecules press harder against the wall of the glass and the water at its base. The increase in air pressure under the glass causes the water level under it to be pushed lower than water level outside. The higher the temperature or, the more energy the air molecules get, the more pressure will be created under the glass.

As the candle flames burn, they use some of the oxygen contained the beaker for combustion. The products of these reactions are carbon dioxide gas and water vapor. As more hot carbon dioxide gases and water vapor are produced, they fill up the oxygen in the glass that the candles need to burn lower until the candles are extinguished. Once the flame is extinguished, the molecules under the glass begin to cool off. Dropping the temperature and losing their excitement. This causes the amount of pressure of air molecules are exerting on the side of the glass and the water of its base to drop. As the pressure drops the air under the glass wants to be equal to the pressure outside of the glass. This is a need for balance causes a pull on the side of the glass and the water at its base. Because it is easier to pull water into the glass than it is to collapse the sides of the glass, the water in the shallow container is pulled into the glass raising the water level under the glass equalizing its pressure. With the changing of the temperature under the glass, it can be seen that the directly proportional relationship between the temperature and pressure of an ideal gas. This relationship is known as Gay-Lussac Law.

Furthermore, in Charles's law experiment kit, the materials used were heaters, supports pad, water bath bowls, bottles and balloons (Figure 1.b). According to the concepts of the ideal gas, Charles’s gas law stated that *“the volume of a fixed amount of gas maintained at constant pressure is directly proportional to the absolute temperature of the gas”* (Chang, 2010) within a closed system. Charles’s law is also illustrated as an equation:

$$\frac{V}{T} = k \qquad (2)$$

Where V is the volume of the gas, T is the temperature of the gas (in Kelvin), and k is a non-zero constant. What this means is as temperature increases, volume increases or as temperature decreases, volume decreases. Figure 1.b shows the experiment kit for Charles’s gas laws observation on ideal gas. In this experiment, a balloon is filled with gaseous molecules. When it is placed in a bottle with boiling water, the energy from the higher temperature water and steam molecules are transferred to the lower temperature air molecules inside the balloon and exciting them. When the air molecules inside the balloon are excited by raising their temperature, they spread further and further apart increase in the volume space they take up. The higher the temperature or, the more energy the air molecules get, the larger the balloon will grow, or in other words, the greater the volume of space our gas will take up. If we remove the balloon to cold water, the air molecules inside the balloon will gradually lose the energy. This process is dropping back to room temperature, causing the balloon to shrink in volume (decreasing the volume).

The prototype of chemical experiment kits that produced then assessed by the teacher and students as participants. Analysis of the feasibility of chemical experiment kits was carried out using a questionnaire. The questionnaire consists of 9 categories of student assessment and teacher assessment on educational aspects, technical aspects, and aesthetic aspects.

The results of the student questionnaire analysis on chemical experiment kits of ideal gas laws (Gay-Lussac law and Charles law) were carried out using a Likert scale 1-5 with a rating range: strongly disagree, disagree, neutral, agree, strongly agree. The data is presented in the form of a percentage of student responses, as shown in figure 2.

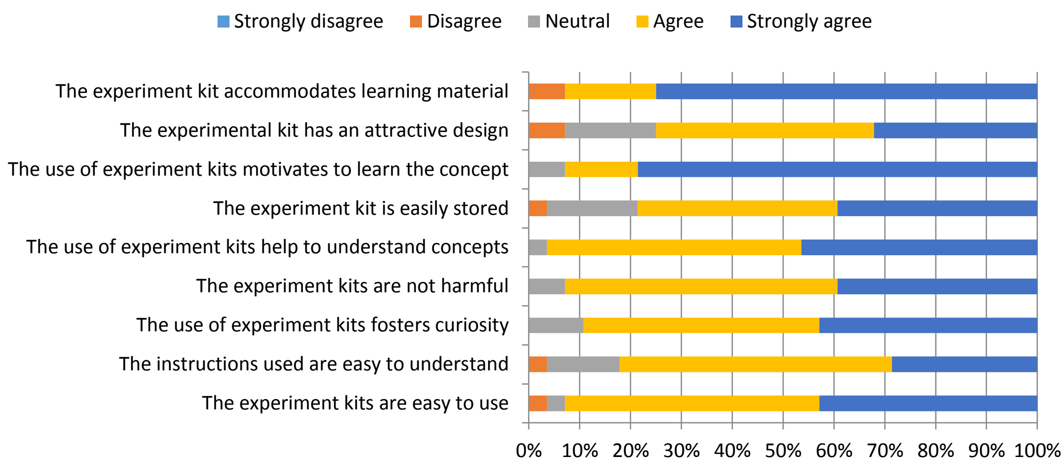


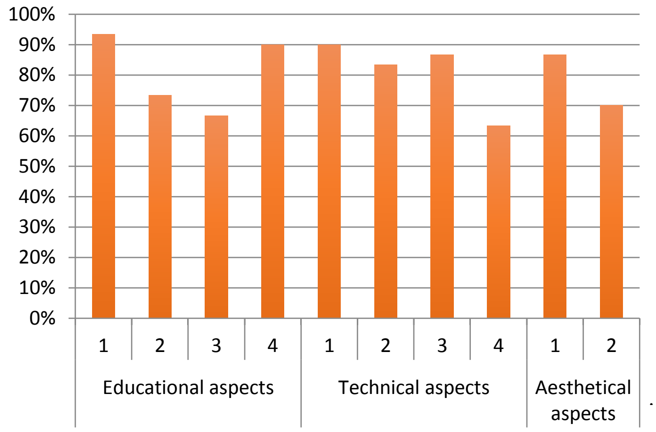
Figure 2. Diagram of the Student's Assessment of Gas Laws Chemical Experiment Kit

In general, more than 70% of students give positive responses to 9 assessment categories. This showed that students shared a very positive response to the ideal gas chemistry experiment kit learning media. Students gave a positive response because they had new experiences that had not been felt before in class. Limited access to chemical laboratory facilities was one of the contributing factors.

The enthusiasm of students towards the use of experimental kits was also high. These results were shown based on positive statements about the use of experimental kits that can motivate students, with more than 75% of students expressing their strongest agreement. Although the materials used were very simple, it turns out that the assessment of the design of the kits obtained a positive response from the students.

Chemical experiment kits were designed very simple and easy to make. This kit was made using materials that were easily found in everyday life. The students could make it even at home and use it easily. Based on the assessment, 90% of students also agree and strongly agree that the chemical experiment kit was easy to use and has a small risk of harm. Moreover, this experiment kit enables to grow students' curiosity (more than 80% of students agree and strongly agree) and help them understand the concept of ideal gas law (more than 80% of students agree and strongly agree). In addition, most students also stated that the instruction was easy to understand with more than 90% giving statements of agree and strongly agree.

The results of the teacher (n = 6) questionnaire in the chemical experiment kits of ideal gas laws (Gay-Lussac's Laws and Charles's Laws) were obtained by evaluating the educational aspects, technical aspects, and aesthetic aspects. Assessment aspects were obtained based on the percentage of the average evaluation interval: 0% -19.99% = Very Less; 20% -39.99% = Less; 40% -59.99% = Enough; 60% -79.99% = Good; 80% -100% = Very good. The following diagram results from the teacher's assessment can be seen in Figure 3.



The categories of assessment :
Educational aspects:
1. Support ing the learning objectives
2. Motivating students to learn
3. Facilitating students to understand the concept
4. Supporting science process skills

Technical aspects:
1. Safe to use by students
2. Easy to use
3. Easy to made from simple materials
4.The instructions are easy to understand

Aesthetic aspects:
1. Attractive shape design
2. The apropriate color combinations

Figure 3. Diagram of the Teacher's Assessment Result of Gas Laws Chemical Experiment Kit.

The results of the teacher's assessment on the educational aspects obtained over 60% on average with good and very good categories. Thus the experiment kit of gas laws developed in this study can facilitate experimental learning well. The results of the teacher's response as a facilitator in the classroom can be used as a reference because the teacher knows the real situation in the classroom.

The results of the assessment on the technical aspects obtained the percentage of average rating above 60% with good and very good categories. Based on the results of the assessment, it was shown that the experimental gas ideal law kits able to be used well in chemistry learning. So that makes it easier for students to use it and help the teachers to deliver learning material.

The aesthetic aspect was assessed with an average percentage above 70% with good and very good categories. With these results, it can be concluded that this experimental kit has an attractive design in terms of aesthetics so that students and teachers are interested in learning using this kit.

Based on the research result, it can be seen that the experimental kits of ideal gas laws developed in this study is sufficient to be used in the learning process. The use of experimental kits helps students to explore chemical concepts individually and improve their understanding (Abdullah *et al.* 2008). However, it should be noted that these kits were intended for macroscopic observation of the enactment of ideal gas laws. The kits were not intended for quantitative observations of parameters changes in pressure, volume and temperature of the gas. As for proving the concepts in the ideal gas law quantitatively, students must use the appropriate experimental instrument. For instance, the ideal gas laws experiment learning can also be conducted in a laboratory setting to teach glassware scale reading, error analysis, and quantitative analysis (Limpanuparb *et al.*, 2019)

The development of this experimental kit was a case study that has limitations and might be suitable for certain subjects, in this case for students who have not experienced the experience of conducting experimental learning in the laboratory. In accordance with the main objective of developing this experimental kit, it was intended to facilitate students who have limited access to chemical laboratories. The experiments using equipment that are in accordance with the high standards laboratory are recommended for schools that already have complete laboratory facilities.

CONCLUSION

Based on the results of studies conducted with limited scale, it can be concluded that the experimental kits can facilitate teacher to explain the chemical concepts regarding the gas laws. Students also showed a positive perception of the experiment kit, especially in increasing student interest to learn gas laws concepts. The Teacher's assessment of educative, technical, and aesthetic aspects of learning with experimental kits of ideal gas laws showed good criteria.

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