Development of basic physics experiment based on science process skills (SPS) to improve conceptual understanding of the preservice physics teachers on Boyle’s law

D Saepuzaman*, S Utari, M G Nugraha
Department of Physics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

*Corresponding author’s email: dsaepuzaman@upi.edu

Abstract. The study was motivated to develop Basic Physics Experiment (BPE) to improve preservice physics teachers understanding on Boyles law. The method used Research and Development (R&D) and involving preservice physics teachers as many as 18 students in the first year and 11 students in second year. This Study uses Student Worksheet (WS) based on Science Proses Skill (SPS). The conceptual understanding will be evaluated multiple choice tests for concepts Boyle Laws. The Result of the first year showed that student achievement in observation, inferring and hypothesis aspect of SPS not optimally. The result of conceptual understanding 46.67. In the second year, some activity and worksheet of SPS were develop based on the finding in the first year. Based on second year data showed improvement of SPS students and the result of conceptual understanding on Boyle Laws 78.86. Based on the results, it can be conclude that the development of basic physics experiment based on science process skills to improve conceptual understanding of the preservice physics teachers on Boyle’s law.

1. Introduction

The progress of science, information and technology has had an effect on all aspects of life, including science and technology education. Science and technology education plays a key role in preparing the nation's next generation that is competitive. The preparation of citizens so that they can live in their era is a challenge for educational problems in each country, so that some countries change the direction of the curriculum to prepare their citizens [1]. Changes in the direction of education at this time provide provision for scientific literacy competencies and 21st century skills. However, to build competencies and skills that need to be supported by the quality of resources both teachers and students. For example, one of the teacher's failures in inquiry is the lack of teacher knowledge about students' abilities [2]. To build more complex competencies and skills students are expected to have basic abilities. The results showed a positive correlation between science process skills and scientific attitudes [3]. This shows that to develop scientific literacy competence or 21st century skills, some basic skills are needed including science process skills.

Although these skills are considered important, the results of the study show that these skills are still not possessed by the teachers. The results of the study in Jambi showed that 63.44% of teachers had a low understanding of SPS [4]. The difficulties of teachers in carrying out learning using the science process skills approach include presenting observation activities, developing inquiry questions and building experimental activities [5]. Some studies have found that the low level of students' SPSs that are science teachers and junior high school teachers have [6] and teachers rarely use these skills in
their skills [7], so that students' SPSs are difficult to develop. More global research shows the quality of science education in some countries, especially in Indonesia is still categorized as low. Based on the assessment of the Education Development Index (EDI), it indicates that Indonesia is a 64th ranked out of 120 countries [8]. The results of the United Nations Development Program (UNDP) in 2013, the Human Development Index (HDI) covering aspects of manpower, health, and education, were ranked 121 out of 185 countries. Based on the Learning Curve Institute's report on the analysis of education performance, Indonesia is ranked 40 out of 40 countries of education mapping [9]. This finding is the basis for developing the skills that a teacher must have to teach his students. One effort that can be done is that prospective teachers are trained in their process skills so that it also has an impact on mastering the concept. The way to train more real is done during lectures. The Basic Physics Experiment course is one of the subjects that is considered appropriate in facilitating prospective teachers in developing science process skills and mastery of concepts. Technically the development of science process skills based experiments is guided by the development of a SPS-based practical worksheet. In general, the development of skills that build SPS is presented in Figure 1. This diagram provides guidance on the direction of developing experimental instructions, skills of SPS that are written with a smaller letter size stating the basic SPS, and larger letter sizes expressing integrated SPS. The experimental Instruction model developed starts from practicing observation skills, to understand what is observed requires communication skills, measuring skills using tools to help the senses to get better quality data, sometimes in our observations requires classification skills to understand matrices that are used as separators or grouping, inferring skills related to explaining observed things, predictive skills evaluating inferring, predictions developing patterns of trends based on data, these skills are basic SPS. As already known that the SPS training gives prospective teachers experimental experience as scientists, this research intends to develop ways to enhance SPS prospective teachers’ skills through the development of experimental instruction design in the BPE 1 course. Instructional in the form of student worksheets designed using Approach SPS as illustrated in Figure 1 [9].

Figure 1. Diagrams SPS

In developing experimental instructions not all skills must be hurdled, depending on the characteristics of the concept to be built. If the teacher needs to present a phenomenon to facilitate students in determining the independent variables, bound and variables that must be controlled these skills are important skills that underlie the hypothesis and operationalize variables. Skills in designing investigations are based on hypotheses and operationalize variables (how to measure independent variables, bound and attempt to control variables), integrated SPS skills are built before students do data collection (experiments).

2. Methods
The method used Research and Development (R&D) and involving preservice physics teachers as many as 18 students in the first year and 11 students in second year. This Study uses Student
Worksheet (WS) based on Science Proses Skill (SPS). The conceptual understanding will be evaluated multiple choice tests for concepts Boyle Laws. Students in groups (2 students) have conducted experiments on standing waves with the aim of discovering the quantitative relation between pressure (P) and volume (V) system of gasses as found by Boyle who was guided using a SPS-based worksheet. Boyle’s Law experimental setting is shown in Figure 2.

![Boyle’s Law experiment apparatus](image)

**Figure 2.** Boyle’s Law experiment apparatus

### 3. Results and Discussion

The Result of the first year showed that student achievement in observation, inferring and hypothesis aspect of SPS not optimally. The result of conceptual understanding in the first year 46.67 (maximum score 100). In the second year, some activity and worksheet of SPS were develop based on the finding in the first year. Based on second year data showed improvement of SPS students and the result of conceptual understanding on Boyle Laws 78.86.

| Test                        | First Year Average Score (100 scale) | Second Year Average Score (100 scale) | N-gain |
|-----------------------------|--------------------------------------|--------------------------------------|--------|
| Understanding of Boyle’s Law Concept | 46.67                               | 78.86                                | 0.53   |

Further analysis during the learning process can be found from the responses of students to the SPS worksheet of Boyle's Law. Findings for several aspects presented in table 2.
Table 2. The profile of students’ learning achievement based on their answered worksheets

| SPS aspect               | Findings                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Observation              | 88.89 % of students can observe the relationship between pressure and volume qualitatively. Only 11.45% were able to explain the measurement of the volume and pressure levels operationally, both direct measurements and calculations from the measurement results. 83.33 % able to describe the relationship between pressure in a closed system based on the basic legal concepts of hydrostatic both equations and graphs Pressure function difference in mercury height and Explain the relationship between the volume of gas in a closed space and its absolute pressure. 83.33 % of students are able to express independent, dependent and control variables. Further analysis, found several different reviews for the control variable. For example in determining the value of pressure and volume of system closed (gas) revealed several control variables including temperature, density, outside air pressure and gravity. 94.4 % of the hypotheses formulated, generally the expression of a hypothesis that refers to the relationship between pressure and volume for a closed gas system. There is also a hypothesis formulation that starts from the relationship between the height difference of mercury with pressure, and pressure with volume. |
| Prediction               | 88.89 % were able to express the operational way of measuring independent, dependent and control variables.                                                                                                                                                                                                                                                                                                                                                                                     |
| Identifying Variables    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Constructing Hypothesis  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Defining Variables       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Operationally            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Designing Experiment     | In general 88.89% of students are able to design experiments and ways of determining measurable quantities until the determination of the final physics quantity to be determined.                                                                                                                                                                                                                                                                                                      |
| Processing Data          | 83.33% can determine P₁ with P₁ = P₀ + ρgh and large volumes of radius using a sliding microscope, calculate the air volume of a closed tube using the formulation V = πr²t, r radius of tube, t is height of gas in closed system, calculate the high difference from high mercury in closed and open tubes, calculate the pressure and volume of air for each change in tube height and difference in mercury height, then do the same thing then compare the values of P₁V₁ and P₂V₂. Processing is done by statistical methods. From the results of student processing, the value of the comparison between the multiplication of PV is relatively constant, although not exactly the same. 100% data analysis focuses on the results of PV multiplication for several measurements, the results of data processing show almost the same value (relatively constant). Further analysis of the students stated that the results obtained were in accordance with Boyle's law, although not absolute. The temperature factor cannot be fully controlled because temperature is a quantity that is constantly changing. |
| Analyzing Data           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Conclusion               | In general, all students conclude that the pressure (P) of gas in a closed space is inversely proportional to the volume (V) with the PV multiplication value = constant.                                                                                                                                                                                                                                                                                                                                      |

Based on these findings, improvements were made to student worksheets for SPS-based Law Botle experiments for example, shown in Figure 3.
This worksheet is a development from previous study. The development carried out based on previous findings showing the achievement of student SPS is still low. In general, the development carried out on the questions and guidance contained in the worksheet. Improvement efforts were carried out then applied in this study so as to obtain better results.

4. Conclusion
Based on the results, it can be conclude that the development of basic physics experiment based on science process skills to improve conceptual understanding of the preservice physics teachers on Boyles law

5. References
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