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Green Chemistry Principles: An Alternative Approach to Practice Laboratory Safety and Health

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Abstract. The common problems in Indonesian science laboratory, especially chemistry is ignoring laboratory safety and health. Besides, it is important to protect students and also the environment from dangerous chemical substances and its processes. The aim of this study was to enhance prospective science teachers' knowledge regarding laboratory safety and health through Green chemistry principles. The study used a quasi-experimental design. 38 students of basic chemistry and solution course were purposively selected from this department. Two different instruments for pre and post-test of laboratory safety and health were used to collect the data in the present study. Research findings revealed that there is an adequately increasing in future science teachers' comprehension concerning on laboratory safety and health. This confirmed that the present system was effective to increase the student comprehension. Based on the result, this study implies that Green Chemistry approach could be an alternative approach to practice laboratory safety and health for pre-service science teacher and prepare them not only as qualified science educators but also skilled laboratory personnels.

1. Introduction

In fact, experiment in chemistry is full of risk and danger. So, safety work when doing experiments in the chemistry laboratory must be paid great attention because students will be mostly use hazardous chemical substances and undergo chemical processes directly [1]. Therefore, it is important for all involved in the development of skills and responsibility for laboratory safety as an integral part of every chemistry curriculum [2]. Hence, students can be expected to reduce the potential hazard or accident happened during chemical process.

However, educational institutions have been slower to adopt such safety laboratory works and programs [3]. Laboratory safety and health is rarely to be paid attention by lecturers or teachers as



they still focus on the chemistry content itself. Consequently, students do not recognize it as important parts of the entire chemistry laboratory work process. Knowledge regarding chemical substances and its properties, the function of chemical equipments and its utilization, the chemical accidents and first aid to overcome it are not mastered well by them. Besides, laboratory safety and environmental protection in universities are important to bring up qualified personnel with ability training and doing scientific research [4].

Laboratory safety and health is closely related to Green Chemistry approach. It is one of the approaches proposed by United Nations (UN) and contained in Education for Sustainable (ESD) to achieve a sustainable education [5]. It can be a choice to be applied for creating environmentally friendly, save and health laboratory activities as well [6]. Practically, the approach can be implemented to design a chemical process and product without using and disposing dangerous materials because of its 12 principals [7]. However, only 6 principals has been applied in this study which is relevant to laboratory safety and health, that is less hazardous chemical synthesis, designing safer chemicals, safer solvents and auxiliaries, design for energy efficiency, design for degradation and inherently safer chemistry for accident prevention. Here, the aim of this study was to enhance prospective science teachers' knowledge regarding laboratory safety and health through Green chemistry principles.

2. Methods

This research was a pre-experimental study. The design of research used one group pretest – posttest design which is conducted only on a single group without a comparison group [8]. The group was given a treatment during the study that is Green Chemistry laboratory learning. Furthermore, the effect of that learning toward pre-service science teachers' knowledge of laboratory safety and health was investigated accurately.

This study conducted in Science Education Study Program at Universitas Muhammadiyah Sidoarjo. 38 prospective science teachers was purposively selected being the target of this research. They were 18 students at first year and 20 students at third year of their bachelor program degree who enrolled in the basic chemistry and solution classes.

The first data regarding quality of Green Chemistry Laboratory Learning, researcher used observation sheet of learning activities. That instrument was used by two observers for confirming that all the learning process in Basic Chemistry and Solution course infused by Green Chemistry principles was conducted well and suitable with the lesson plans. The second data were collected by using the test of laboratory safety and health was used twice, in the beginning and end of learning process. It is addressed to ascertain whether prospective science teachers' knowledge of it increasing or not. It consists of three parts; chemical substances and its properties, the function of chemical equipments and its utilization, the chemical accidents and first aid to overcome it. The number of questions in this test is about 18. The data about prospective teachers' knowledge of laboratory safety were analyzed both descriptively and inferentially.

3. Results and discussion

This session focuses on presenting and analyzing the data gained from the implementation of several Green Chemistry principles into Basic Chemistry and Solution laboratory activities. Also, this part elaborates the discussion of research data connected to relevant previous study and literature.

Before explaining the efficacy of Green Chemistry Laboratory Learning toward prospective science teachers' knowledge regarding laboratory safety and health, this session will be described clearly concerning on the quality of learning process. It is the observation result conducted by two observers toward five components of Cooperative learning syntax used in the study during five meetings for Basic Chemistry class and seven meetings for Solution course. First, opening section consists of giving motivation and clarifying learning objectives. Secondly, core section comprises presenting information, organizing pre-service teachers into learning groups, and assisting group to

work and study. Third, closing section covers giving tests and providing recognition. Next, fourth and fifth aspects are observation of learning environment and time management.

The first component observed is opening section. In this section, pre-service science teachers were asked to review the topic which has been discussed in the class and it was relevant to the experiment. It proposed to remind them about the concept as their prior knowledge before using it to analyzing the data gathered when doing experiment. Afterward, the lecturer was stated the learning outcomes. Observers assessed with very good category. It indicates that the first section has been conducted very well and very suitable with the lesson plan.

Next to the second component is core activity. This activity consists of three phases, presenting information, organizing students into learning groups, and assisting teamwork and study. Overall, the first phase of core activity obtained very good criteria of assessment. Pre-service teachers received information regarding chemical tools and its function, chemical materials and its properties used in the experiment. Then, they were introduced by the lecturer laboratory safety and its relation to Green Chemistry principles. Laboratory safety is need to inform adequately and relevantly for identifying sources of danger in the laboratory, its impacts on human life and environment, and also its solution to overcome it [9].

The second phase of core activity is organizing students into learning groups. For this phase, the lecturer was evaluated by observers rather good in guiding the participants to join their groups. They gave suggestion to the lecturer that organizing students into their groups is not conducted in the beginning of the learning process, but it should happen in this phase.

The third phase of core activity is assisting teamwork and study. A very good assessment of this phase cannot be separated from the quality of learning materials used, that is, Module of Basic Chemistry and Solution Experiments based on Green Chemistry principles. In this phase, pre-service chemistry teachers were working collaboratively and communicatively during completing all experiments using Green Chemistry approach as their rule to keep all the process environmentally friendly, save and health. The application of Green Chemistry approach in order to gain a richer experience of the environment and actively participate and contribute in shaping the environment [10].

The fourth and fifth components are time management and learning environment. For time management, observer gave variety scores in range good category. The time allocation should be considered as suggested by the observers. In addition, the lecturer received the suggestions from observers to be more enthusiasm for managing the learning process. However, the teaching and learning process can represent student-centered approach based on observers' assesment.

The data concerning on pre-service teachers' knowledge of laboratory safety will be discussed in this part. It is obtained by using the test of laboratory safety and health. The test was given twice, in the beginning and end of learning process.

Figure 1 shows that laboratory safety and healthy knowledge of pre-service teachers increases after engaging Green Chemistry laboratory learning in Basic Chemistry course. In average, N-gain score obtained is 0,48 (medium category). Hence, the learning process in the laboratory oriented on Green Chemistry approach is adequately effective to strengthening their understanding of laboratory safety and healthy.

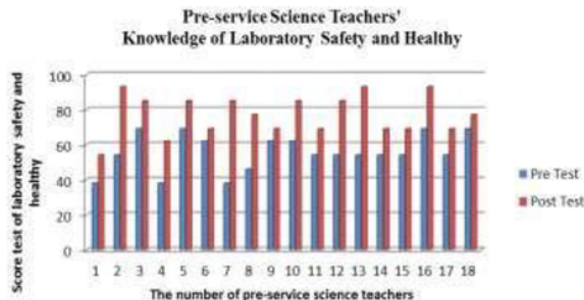


Figure 1. The result of laboratory safety test for Basic Chemistry Course

Six green chemistry principles, which is related to laboratory safety and health, inserted into five basic chemistry experiments in order to give new experience for first-year students of science education program study to conducting safer chemical laboratory activities. Learning the green techniques and principles is best done experimentally in the lab [11]. Therefore, it is prominent to practice and implemented this approach in academic laboratories as training for the future science teachers.

Green chemistry is classified new approach that bring new method in chemistry process to reduce waste and pollution. From the result depicted above, prospective science teachers' knowledge regarding laboratory safety and health is increasing after engaging green chemistry experiments. It indicates that implementing this approach could be an alternative way to raise future science teachers' awareness toward laboratory safety and health. Moreover, they have been embedded environmental value orientation indirectly to shape their positive behavior toward environmental condition, as the result of previous research [12]. They will be used to conduct safer experiments for their students in their future teaching career and practice them laboratory safety and health as well.

The prospective science teachers' understanding of laboratory safety and health in the Solution course is presented in Figure 2. It shows that all of them have higher scores of post test than pre test. Additionally, the result of N-gain score is 0,401 (medium category). This indicates that introducing of several Green Chemistry principles which is connected directly to the laboratory safety and healthy through Solution experiments brings adequately positive effect to strengthening their comprehensive regarding to it.

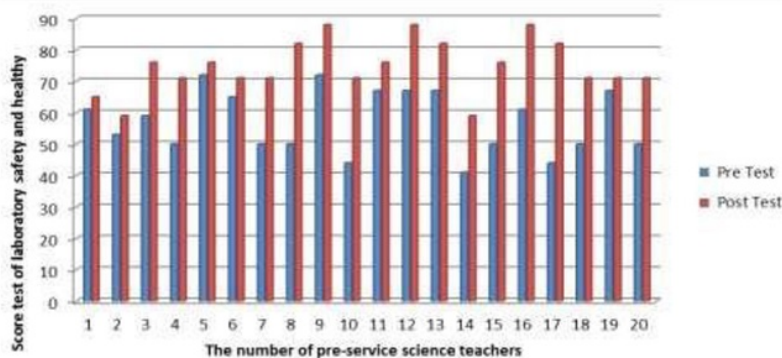


Figure 2. The result of laboratory safety test for Basic Chemistry Course

Several experiments in solution course were chosen for incorporating green chemistry principles because of many hazardous chemical substances used within. For instance, acid and base solution, organic solvents. The most common organic solvents are carbon-based such as toluene, chloroform, acetone, acetonitrile, ethyl acetate and various ethers and alcohols. None of these chemicals should be poured down a sink because they are mostly water-insoluble, toxic, flammable and unlawful [9]. Thus, it needs to apply green techniques by changing from hydrophobic to hydrophilic chemical solvents used in the Solution experiments. The use of hydrophilic chemical solvents means that water as the main solvent. Water is a convenient solvent since it is inexpensive, nonflammable and it is easy to dispose of by just pouring it down the sink [13].

The explanation above is one of example green initiatives which is introduced to future science teachers in the third year of their program through solution experiments. It is necessary for preparing them when deal with the apprenticeship program in the next semester. They set up not only proficient science teachers but also trained laboratory personnels who experienced in terms of designing green and save experiments for senior high school students. Indeed, this kind of effort hopefully yields abundant beneficial for the sustainable environment. Since, it also indirectly persuades young generation to concern on environmental condition start from chemistry laboratory.

4. Conclusion

According to the whole description regarding research findings, it can be concluded that the infusing Green Chemistry principals into learning process in laboratory of basic chemistry and solution course was conducted properly by the lecturer. It represented from the result of the quality of learning process. Therefore, it could bring positive effect sufficiently on the increasing of pre-service science teachers' understanding relating to laboratory safety and health. Furthermore, it is expected to shape their skill as science teacher who conducts environmentally friendly, save and health experiments in the laboratory for future students in their teaching career. Indeed, it is also important to raise their positive behavior toward environment as young generation who are supposed to be agent of change in order to solve environmental problems.

Acknowledgements

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