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Perspectives on Green Chemistry and the Application of Nvivo 12 Software: A Case Study of Pandemic Period in Chemistry Education

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a b s t r a c t

This case study aims to identify chemistry education students' perspectives on attitudes and implementation of the principles of green chemistry during the COVID-19 pandemic. The participant of this study was 64 chemistry education students who, from the beginning, have conducted online learning, including practicum. The instrument of this research was an online questionnaire to gain the required information. The data were analyzed using NVivo 12 software and presented in percentages based on 12 principles of green chemistry: (1) potential waste generation reduction, (2) efficient use of raw materials, (3) application of environmentally safe production methods, (4) environmentally friendly chemicals, (5) safer additives, (6) minimal use of heat, (7) natural ingredients, (8) reaction products with minimal by-products, (9) the use of effective catalysts, (10) easily biodegradable products for the environment, (11) time management of hazardous products, and (12) anticipation for physical contact with hazardous materials. Moreover, 85% of the students agree that the 12th principle must be well applied. The research findings serve a discourse for lecturers to convince the students to understand and implement the principles of green chemistry in practicum activities, especially during the pandemic.

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1. Introduction

Current learning always tries to achieve sustainability-based education as part of achieving the sustainable development goal (SDG) targets (UNESCO, 2017). In education, the SGDs are reflected in the implementation of the education sustainable development (ESD) (Rieckmann, 2017). ESD in chemistry education is implemented in the principles of green chemistry (Mulyanti et al., 2021). The application of green chemistry in chemistry learning activities is identical to experiments in chemistry laboratories (Mulyanti et al., 2019).

Learning activities in laboratories are the core of chemistry learning (Azhari & Supratman, 2021; Malik et al., 2020) to train the students' skills in using practical tools as well as discover and strengthen theoretical concepts learned in the class (Al-Idrus et al., 2020). Practical activities provide many benefits as well as several obstacles, including the use of quite toxic materials during learning activities in the laboratory. Such a condition challenges the students to minimize materials and activities not oriented to the ESD program (Kolopajlo, 2017). Hazardous chemical activities can be minimized by applying every green chemistry principle during learning activities, such as the preparation and production processes of the practicum (Hawa & Mulyanti, 2021).

Another recent obstacle (during the pandemic period) shows that practicum activities cannot be implemented in the laboratory; thus, the students conduct online practicum (Mulyanti et al., 2021). Consequently, the principles of green chemistry are less effectively implemented as the students do not directly experience practical activities in the laboratory. Therefore, they need information about the implementation of green chemistry principles to work in the laboratory (Mulyanti & Kadarohman, 2021).

This study surveyed students' views on the application of the principles of green chemistry. The result of this survey provides information for chemistry practicum teachers to further convey the principles of green chemistry. Consequently, the students could directly implement these principles during the chemistry practicum in the laboratory.

Nvivo is one of the newest interpretation tools to facilitate research results (Plard & Martineau, 2019). Moreover, this program can map the survey findings in detail, which are then employed in this study (Bandur, 2019). The results of analyzing the 12 principles of green chemistry and research subjects should be clearly interpreted. Therefore, the survey results will provide quite varied statistical data. This research employed NVivo to facilitate the researchers to present each questionnaire result from each subject and questionnaire data from each green chemistry principle; these results and data, so far, have only been interpreted in statistical and graphic forms (Chamidah & Mulyanti, 2021).

2. Method

This research was conducted qualitatively (Bandur, 2019) and obtained the data using Google Form. The survey instruments were 12 principles of green chemistry, including 36 closed questions with answer choices (Mulyanti & Kadarohman, 2021). The research subjects were 65 chemistry education students who have met the criteria of never participating in an offline practicum since the beginning of the lecture. The answers of the research subjects were analyzed qualitatively using a phenomenological design of the NVivo Pro 12 program (Bandur, 2019; Syaodih et al., 2021). The data were interpreted using NVivo 12. The interpretation stages were as follows. First, each principle of green chemistry was labeled as a node on NVivo into 12 nodes. Then, each node was detailed in the form of child nodes to describe the students' responses to the implementation of green chemistry principles. This study gained three child nodes from each node of green chemistry principles (Figure 1). Each response in NVivo was associated with the subject who gave the highest response from the criteria of each child node.

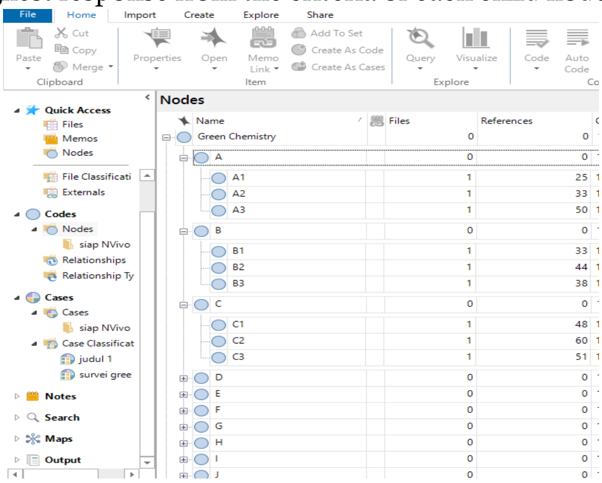


Figure 1. Map of research results on the NVivo 12 Pro program

3. Result and Discussion

Each research subject's responses to the 12 principles of green chemistry on Nvivo 12 are depicted in Figure 1. Each principle is coded alphabetically (AL), from 1 to 12. The 12 principles of green chemistry are as follows.

A. Potential waste generation reduction
B. Efficient use of raw materials
C. Application of environmentally safe production methods
D. Environmentally friendly chemicals
E. Safer additives
F. Minimal use of heat
G. Natural ingredients
H. Reaction products with minimal by-products
I. Effective use of catalysts
J. Easily biodegradable products in the environment
K. Time management of hazardous products
L. Anticipation for physical contact with hazardous materials

This study employed different colors,(especially green and red. Green refers to a principle with the best response from the subject's average opinion on the questionnaire, namely the 12th principle. Meanwhile, red refers to a principle with the lowest response, namely the sixth principle. Coloring only shows the difference because it is the focus of the research results.

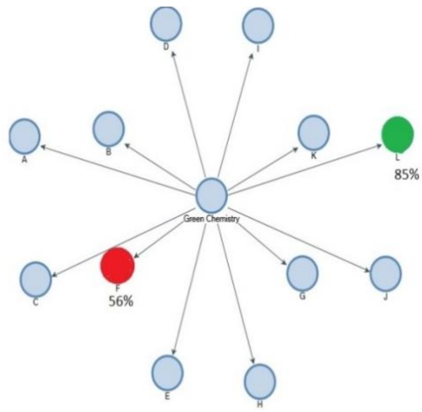
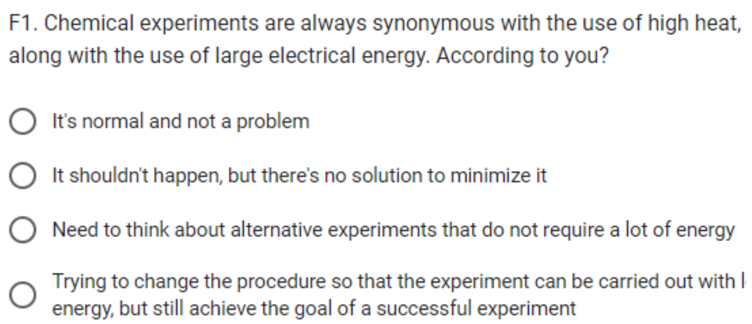


Figure 2. Nodes in NVivo of 12 principles of green chemistry

The lowest response occurs in the sixth principle, which minimizes energy in the chemical reaction process. The first question (Figure 3) receives a 64% of the responses (Figure 4). This finding shows that many students do not want to change the experimental procedure by minimizing the use of heat or energy.


F1. Chemical experiments are always synonymous with the use of high heat, along with the use of large electrical energy. According to you?

- It's normal and not a problem
- It shouldn't happen, but there's no solution to minimize it
- Need to think about alternative experiments that do not require a lot of energy
- Trying to change the procedure so that the experiment can be carried out with l energy, but still achieve the goal of a successful experiment

Figure 3. The first survey instrument of the sixth principle of green chemistry

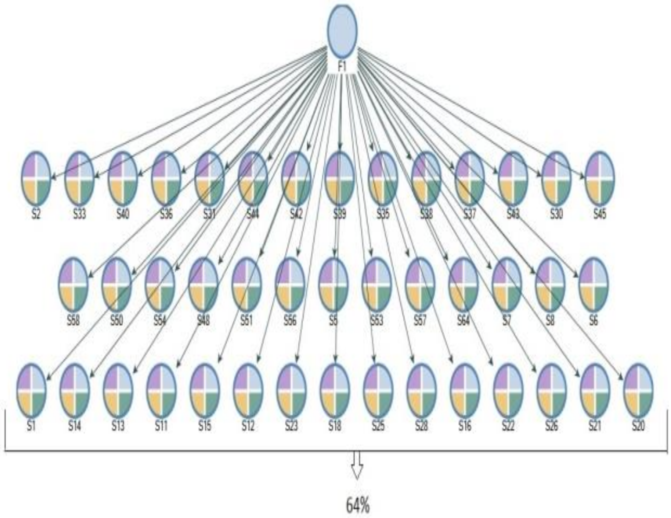
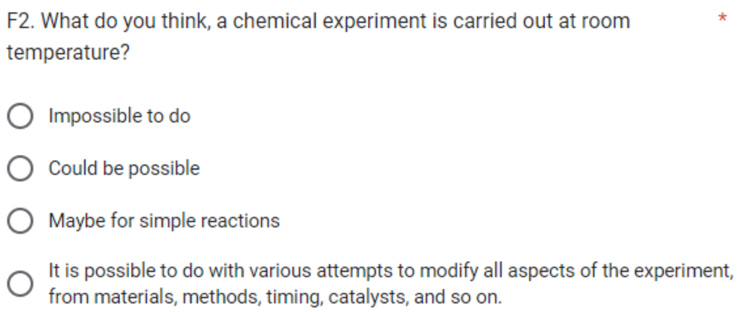


Figure 4. Number of subjects with good responses to the first question of the sixth principle

The lowest response also occurs in the second question of the sixth principle (Figure 5) because 64% of the respondents agree that the modified chemical process is possibly conducted at room temperature (Figure 6). This result is inversely proportional to the number of studies that have successfully implemented at low temperatures in synthesis reactions (Hintermann & Wong, 2017).


F2. What do you think, a chemical experiment is carried out at room temperature? *

- Impossible to do
- Could be possible
- Maybe for simple reactions
- It is possible to do with various attempts to modify all aspects of the experiment, from materials, methods, timing, catalysts, and so on.

Figure 5. The second survey instrument of the sixth principle of green chemistry

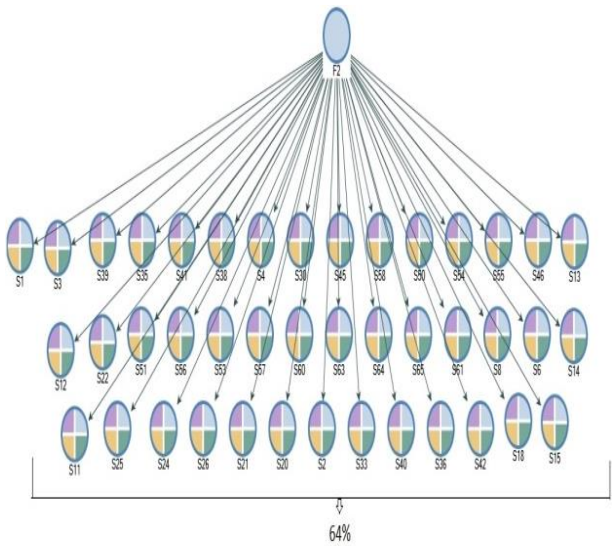
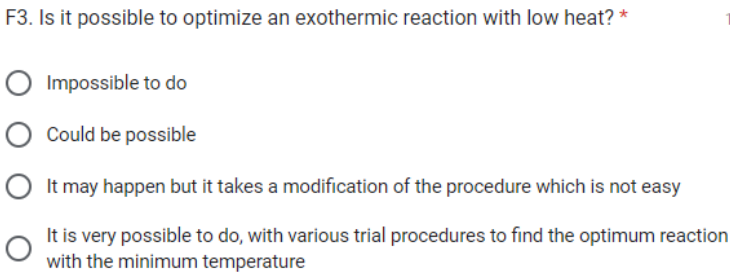


Figure 6. Number of subjects with good responses to the second question of the sixth principle

The lowest response also occurs in the third question of the sixth principle (Figure 7) because 41% of the respondents agreed to apply the modified chemical process at low temperatures (Figure 8). This finding shows that many respondents still disagree with the exposure to the questionnaire to optimize the reaction at low temperatures.


F3. Is it possible to optimize an exothermic reaction with low heat? * 1

Impossible to do

Could be possible

It may happen but it takes a modification of the procedure which is not easy

It is very possible to do, with various trial procedures to find the optimum reaction with the minimum temperature

Figure 7. The third survey instrument of the sixth principle of green chemistry

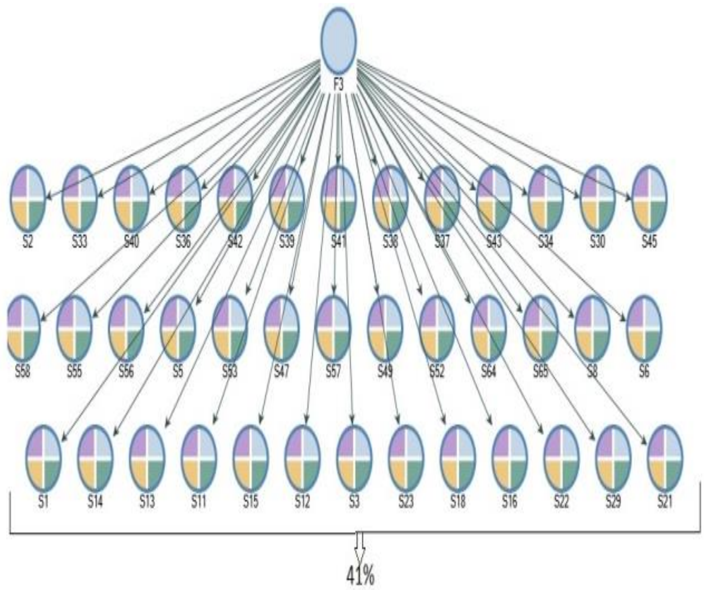


Figure 8. Number of subjects with good responses to the third question of the sixth principle

The survey results show that most students agree with the 12th principle, which is about safety in the laboratory. This survey obtained data from the respondents who have never experienced direct experiments since becoming university students. This means that the students have good initial knowledge of wearing personal protective equipment (PPE) while working in the laboratory; this good knowledge is obtained from online lectures at the university and previous learning at the high school level (O'Neil et al., 2020; Wargniez et al., 2012).

The survey results show that the students are not confident about minimizing the use of energy during reactions in the laboratory. This finding disagrees with various studies that have successfully conducted experiments, such as on reactions and synthesis of organic compounds, at room temperature even without heating (Luu et al., 2020; Xiao & Fu, 2019; Zhi et al., 2020). The findings of this recent study provide pivotal information for chemistry education lecturers to understand and implement the principles of green chemistry in laboratory experiments (Azhari & Supratman, 2021) through practical and theoretical examples. Moreover, the principles of green chemistry should be implemented in learning activities (Karpudewan et al., 2016; Mulyanti et al., 2019; Wahyuningsih, et al., 2017).

4. Conclusion

This study has found that 85% of the students agree that the 12th principle, preventing physical contact with hazardous materials, must be implemented significantly. The lowest result is obtained in the sixth principle, namely the minimal use of heat in chemical experiments because only 56% of the students agree with the sixth principle and could implement it. The findings of this research become a discourse for lecturers to convince students to understand and implement the principles of green chemistry in online practicum activities, especially in daily life and during the pandemic.

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