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Small-Scale Chemistry (SSC): Its Effect on the Grade 11 Stem Students' Conceptual Understanding of Acid and Base

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***Abstract*—** *Many schools have limited access to laboratories, and some cannot provide students with laboratory experiences. This is even though practical work is vital in the field of science. This study aims to address the lack of science laboratory work by developing a module on acid and base, small-scale chemistry (SSC) activities, and small-scale chemistry (SSC) kit. The study also determined the conceptual understanding of the students before and after the implementation, and evaluate their perception of the SSC approach. This study used a mixed methods to analyze and gather data, The respondents were 50 Grade 11 STEM students. Findings showed that the module, SSC activities, and SSC kit received a positive evaluation from experts who were in-service chemistry teachers. Furthermore, the post-test scores of the students significantly improved, indicating an improved conceptual understanding of acid and base concepts after the intervention. This implies that the SSC approach was as effective as the traditional laboratory.*

***Keywords*—** *Conceptual understanding, Perception, Small-scale chemistry.*

I. INTRODUCTION

Science and technology are the forces driving the world to change rapidly. This change profoundly shapes the skills needed to participate and contribute to society (Stewart, 2010). According to the National Science Teachers Association (2011), science education has a significant role in providing students with skills relevant to the 21st century, enabling them to be better equipped for life. In line with this, Abdullah et al. (2007) pointed out that one of the distinctive aspects of effective science education is the science laboratory. However, it often requires specialized materials, which are rarely available in some countries (Musar, 1993). In the Philippines, science teachers often struggle to provide science laboratory activities due to a lack of equipment or apparatus (Tupas & Matsuura, 2020). Some science teachers are improvising materials to meet the required competencies provided by the Department of Education (DepEd) (Pacala & Cabrales, 2023). However, sometimes, there are not enough options, so teachers make tough decisions by skipping laboratory activities. This further hinders the student's ability to develop (Hadji Abas & Marasigan, 2020). Musar (1993) stated that properly equipped science laboratories are not always necessary. Low-cost approach, like small-scale chemistry (SSC), can be an alternative to the traditional laboratory approach. Mafumiko (2008) defines SSC as conducting experiments on a smaller scale, with fewer chemicals, and switching from glassware to plastic materials. This study specifically aims to develop a module, SSC activities, and an SSC kit focusing on acids and bases, determine their conceptual understanding after the intervention, and evaluate their perception of the SSC approach.

II. METHODS

The study was conducted in Iligan City East National High School- Sta. Filomena. The participants of the study were Grade 11 STEM students enrolled during the academic year 2023-2024. Quantitative analysis method was used to determine the significant difference between pre-test and post-test of students. The module's content was based on the Deped MELCS (Most Essential Learning Competencies). It covers the Brønsted-Lowry acid and base concept, acid-base properties of water, and pH. The activities include identifying acids and bases and conductivity experiments. The kit was designed to ensure portability, cost-effectiveness, and accessibility. The instruments were validated by five (5) in-service chemistry teachers. To determine the conceptual understanding of the students a 20-item multiple-choice test was developed. It was administered as a pre-test and post-test. TOS was also used to guide the development of the questionnaire. The study utilized the two-phase version of the Successive Approximations Model (SAM) to guide the data gathering process, which consisted of a preparation or background phase and an interleaved iterative design, development, and review phase. Moreover, the adopted and modified perception questionnaire based on the study of Tesfamariam et al. (2015) was used.

III. RESULTS

This section presents the results and the analysis of the data gathered.

TABLE 1.

Paired Samples Test of Pre-test and Post-test					
	Mean	**MD**	**SD**	**t-value**	**p-value**
Pre-test	8.64		2.632		
Post-test	15.00	-6.360	2.330	-18.696	<0.001

Based on the result, it presents the difference between the pre-test and the post-test. First, there is a significant increase or improvement in the scores of the students based on the mean difference between the pre-test and post-test, which is 6.36. Another important value is the p-value, <0.001, significantly lower than the chosen significance level of $\alpha = 0.05$. It indicates that there is a significant difference between the pre-test and post-test. This finding is supported by the study of Cooper et al. (1995), stating that SSC can improve the students' performance. Moreover, Yoo et al. (2006) and Abdullah et al. (2007) also noted that students exposed to SSC have better performance than those students who were not.

TABLE 2. Perception Ratings of Students

Perceptions	Mean Ratings	Description
1. I felt actively involved during the small-scale chemistry activities.	3.92	Strongly Agree
2. I found the small-scale chemistry activities interesting.	3.92	Strongly Agree
3. The small-scale chemistry activities helped me understand the concepts better.	3.74	Strongly Agree
4. I feel more confident in my understanding of acid and base concepts after the small-scale activities.	3.84	Strongly Agree
5. The small-scale chemistry activities encouraged teamwork and cooperation.	3.96	Strongly Agree
6. Working with my peers during the small-scale activities helped me understand the concepts better.	3.96	Strongly Agree
7. I found it valuable to discuss and share ideas with my peers during the small-scale activities.	3.90	Strongly Agree
8. I prefer small-scale chemistry activities over the traditional laboratory approach.	3.88	Strongly Agree
9. I believe my peers would find small-scale chemistry activities valuable for their learning.	3.76	Strongly Agree
10. I would recommend small-scale chemistry activities to my peers.	3.90	Strongly Agree
11. The Small-scale chemistry kit was easy to use and handle.	3.96	Strongly Agree
12. I believe the Small-scale chemistry kit was a cost-effective solution for learning chemistry.	3.80	Strongly Agree
13. I felt confident and safe while conducting experiments with the Small-scale chemistry kit.	3.96	Strongly Agree
14. The instructions provided with the Small-scale chemistry kit were clear and easy to follow.	3.74	Strongly Agree
15. The disposing of chemicals was easy.	3.94	Strongly Agree

The result of the student's perception of the SSC approach indicates that there is a unanimous answer. All the students strongly agreed with the statements based on the rating value of the mean scores. The findings showed that the students were actively involved during the activities. They also found it interesting, and it helped them understand the acid and base concepts. Since teamwork in the SSC activities is encouraged, the students had the opportunity to share their ideas with their peers, leading to interactive activities. Most students strongly agreed that the SSC approach is as effective as the traditional approach in the laboratory. They also found the SSC kit easy to use, cost-effective, and safe for them. This finding is consistent with the study conducted by Tesfamariam et al. (2015), stating that the students had a positive response to the SSC as an effective approach for chemistry courses. They also perceived it as easy to use, safe, efficient, and engaging. The result was also further supported by Hofstein and Lunetta (1982), Okebukola (1986), and Thompson and Soyibo (2002), which emphasized that laboratory work positively influenced the student's interest in science education.

IV. Conclusion

The developed module, SSC activities, and SSC kit helped the students improve their conceptual understanding based on the result which revealed that the pre-test scores were significantly lower than the post-test scores, with a significance level of $\alpha = 0.05$. This suggests that participants performed better on the post-test compared to the pre-test. Lastly, the result of the perception of the students revealed positive feedback fand emphasizing the students' favorable experiences with small-scale chemistry activities.

V. Recommendations

Based on the study's findings, the researchers propose the following recommendations: (1) Explore different topics in chemistry across various grade levels. (2) Further enhance the existing module, small-scale chemistry kit, and activities. (3) Employ an experimental design that includes both experimental and control groups. (4) Explore and create new experiments, demonstrations, and hands-on activities that align with the principles of small-scale chemistry.

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