

Measuring Students' Learning and Attitude as Exposed to Microscale Laboratory Experiments in Inorganic Chemistry

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Abstract

Microscale chemistry is an approach to conducting chemistry experiments which can help overcome increased concerns about environmental pollution problems as well as rising laboratory costs. It is accomplished by using miniature laboratory glass wares and significantly reduced the amounts of chemicals. The main goal of this study was to explore whether the use of microscale chemistry experiments can increase student's understanding of chemistry concepts and improve attitude towards chemistry practical work. Quasi-experimental design without control group was used to determine from a purposely selected class of 40 freshman students of Bachelor of Secondary Education (BSE). The students worked in groups on eight microscale chemistry experiments in a period of 8 weeks. Pre and post-test were administered before and after the treatment. Results revealed that the microscale approach significantly improved student chemistry academic performance. Students' perception of microscale is positive. Findings showed that the microscale approach can increase understanding of chemistry concepts and can be used as laboratory settings in doing experiments in Inorganic Chemistry.

Keywords: learning, microscale laboratory, students' attitude

1. Introduction

Students may gain more content knowledge as well as knowledge of process skills in chemistry experiments by using active-learning laboratories. Microscale laboratory will provide an alternative approach in providing hands-on activities to students using reduced amounts of chemicals. This laboratory-based approach will aim to improve students' skills in handling apparatus, encourage them to do experiments and to stimulate them to do experiments carefully and patiently.

Hofstein and Mamlok-Naaman (2017) stated that laboratory experiences enhanced students' abilities in scientific practical skills and problem solving. Furthermore, Hofstein (2019) in his undertakings observed that practical works can also promote positive attitudes and develop students' skills regarding cooperation and communication.

In addition, Bradley (2017) reported that laboratory activities should involve active student participation. Taraban (2018) also found that students gained significantly more content knowledge and process skills using hands-on activities and organizing students into collaborative learning groups than in traditional laboratory technique. Bradley (2017) also mentioned in his work that precision and accuracy of experiments is not compromised in using reduced amounts of chemicals and miniature labware and teachers can also use it as a tool to design new laboratory activities.

Furthermore, it was reported that undergraduate students performed microscale experiments with more care and their skills in handling the glass wares were improved after the adoption of this technique in their laboratory (Kelkar & Dhavale, 2018). It is also in line with the Environment Protection Act of 2008 which promotes environmental awareness through

integration of environmental education in all school levels. Implementing microscale chemistry techniques in the undergraduate teaching laboratories reduces the amount of chemicals necessary to perform undergraduate chemistry experiments to a fraction of what was historically used and thus less impact on the environment.

The goal is to ensure safer and sustainable practical works performed through microscale settings. Thus, using a microscale science setting which is considered handy, easy to manipulate and relatively manageable to store could be the possible solution to better conceptual understanding and attitude change towards performance activities in chemistry (du Toit, 2016).

1.1 Objectives of the Study

This study was conducted to investigate whether microscale laboratory experiments in Inorganic Chemistry can increase students' understanding of chemistry concepts and improve attitude towards chemistry experimental work. In particular, the following research questions were posed:

1. Is there a significant difference in the academic performance of students in Chemistry in terms of chemistry achievement after engaging them in a microscale laboratory?
2. What was students' attitude towards chemistry after the use of the microscale laboratory as classroom activities?

2. Literature Review

Microchemistry is considered as a groundbreaking approach and effective teaching tool. This is employed using significantly reduced amounts of chemicals, miniature labware, and safe and easy manipulative techniques. It is also viewed as an alternative approach to resolve problems connected with practical work because it offers hands-on activities and personal experiences for students (Kelkar & Dhavale, 2018)

Chemistry education can take a vital participation in environmental issues, especially through the performance of laboratory experiments because deep understanding can be achieved through actual experiences. Microscale laboratory is suited for such purposes because microscale laboratory is environmentally friendly and can make students be mindful of pollution prevention. In addition, microscale experiments can be done in a very short time. Such time can be available to discuss experimental observations and relate them to environmental issues (Tallmadge et al., 2019).

Researchers also found that the majority of the students perceived that microscale chemistry experiments were fun and easy to handle. It was also noted that by doing this kind of setup, students can learn new skills, increase understanding of concepts and stimulate their interest to do experiments and learn chemistry. The microscale laboratory experiments have been found to stimulate students' interest toward science; thus, understanding can be enhanced (Bradley, 2019).

The benefits of microscale chemistry, among others, are improved safety, cost and time savings, environmental friendliness, pollution prevention, more adaptable equipment and also may enhance chemistry learning. The development of the microchemistry system is based on such equipment which is easy for individual students to use and convenient for teachers to implement (Tobin, 2016).

Microscale activities can be performed in a short period of time and students can still experience systematic way of experiments without the feeling of boredom. This is because the reaction or

the time needed to view the progress involves less time, and because less amount was employed such in effect shorter time will be consumed for the reaction to proceed. Aside from this, once they start, they become engrossed and work actively. It may be because experiments are accompanied by dramatic changes which are quite observable by the senses (Ogino & Ogino, 2014).

Utilization of micro science kits for practical activities in teaching and learning of physics concepts was found to provide the learner with new skills. It was also observed that the students' understanding of concepts increased and further stimulated their interest to perform experiments. Thus, students discovered it was interesting to perform the experiments. Doing observations during the conduct of the activities using these kits can be clear and quickly done, and thus ensuring accurate results if appropriately utilized. Learners were found to be actively participating in the teaching and learning process during laboratory classes, and therefore reducing or eliminating the notion of the students that physics is a difficult subject (Williams & Aderonmu, 2015).

The microscale laboratory apparatuses are small, practically unbreakable and economical, and have been devised to enhance the quality, relevance and accessibility of science and technology education. In addition, the learners are also involved in applying knowledge to real-life situations (Rachmawati, 2013).

Additional findings mentioned that students using the microscale kit showed overwhelmingly positive attitude towards performance of practical work and further reiterated that the students have improved conceptual understanding in science experiments in doing such microscale laboratory settings. Students also perceived that the micro science kits for chemistry experiments were convenient, awe-inspiring and thought-provoking, and also suitable for doing experiments individually or even in a group. It was also reported that undergraduate students performed experiments with more care and their skills in handling the equipment were markedly improved after implementation of this new technique in their laboratory setting (Williams & Aderonmu, 2015).

3. Research Method

This research study utilized the quasi-experimental method with a pretest-posttest design without a control group to determine the learning gained in Inorganic Chemistry through the use of a microscale laboratory in performing practical works. One intact class of students was used as the respondents of the study. The respondents were divided into 10 clusters or groups. Groups can be formed using self-selection, random selection or criterion-based selection. This study exercised self-selection, where students were given the freedom to choose their own group members.

Students worked in groups of 4-5 students in performing the microscale laboratory experiments. Pre and post-test were administered. A chemistry concept test and a questionnaire on attitude towards chemistry laboratory and chemistry learning were administered to evaluate the effectiveness of conducting the chemistry experiments. The classes were handled by the researchers to eliminate another factor that may contribute to the outcome of the study.

One of the instruments utilized was a fifty-item multiple choice type of achievement test in Chemistry consisting of collected items from various standardized tests served as both the pre-test and post-test developed by the researchers and validated by subject specialists. The test covered topics where the practical works were anchored. This test was administered to determine and evaluate the students' learning in Inorganic Chemistry.

To measure the respondents' attitude regarding microscale laboratory a questionnaire was utilized. The questionnaire, entitled Attitude Towards Chemistry Laboratory Work, developed and validated by Hofstein et al. (1997) and modified by Vermaak (2015) was adapted. Some modifications were made regarding the instrument as advised by the evaluator and subjected to validation.

The microscale laboratory activities were also validated by experts. It was mentioned by the evaluators that the activities presented were suitable for freshman students who would take up basic chemistry subjects. Guide questions helped students in the gradual and profound understanding of concepts being tackled. It was also mentioned that the questions designed stimulated higher order thinking skills.

To find out if there is a significant difference in the performance of the respondents in Inorganic Chemistry after the exposure to a microscale laboratory setting, an achievement test was given. In addition, the test provided the means of checking the baseline or prior knowledge in Chemistry of the respondents. The achievement test was administered again after the onset of the experimentation in order to determine the students' learning in Inorganic Chemistry.

3.1 Data Analysis

Appropriate statistical treatment was utilized to analyze data. For this research, means and standard deviation were employed as the descriptive statistical tool. There were computed in order to categorize the students' achievement test and self-rating scores for attitude towards chemistry. The t-test for correlated means (paired samples) was also employed as a statistical tool since one of the interests of the study was to find out whether the calculated difference between the pretest and posttest was significant or not. Data being gathered from the research instrument were presented in tabular forms. The tabulated data serve as the basis of presenting the results of the analysis. The researcher used statistical software in processing these data.

For the scoring of students' attitude per item, a 5-point scale was used.

- 5- strongly agree
- 4- agree
- 3- not sure
- 2- disagree
- 1- strongly disagree

For the scoring of students' attitude based from the computed means, ranges were used:

- 4.51-5.00 – strongly agree (SA)
- 3.51-4.50 – agree (A)
- 2.51-3.50 – not sure (NS)
- 1.51-2.50 – disagree (D)
- 1.00-1.50 – strongly disagree (SD)

4. Findings and Discussions

4.1 Students interest in doing experiments in chemistry

Table 3 shows the results of the students' responses to all items which were categorized into five factors. In terms of interest in doing chemistry experiments (Factor 1), most of the students were in agreement that performing experiments can increase their interests and perceived that without practical works, learning chemistry was uninteresting. These findings were also supported by several researchers who reported that laboratory work is an important medium for promoting students' interest in chemistry studies and also enhancing their attitude towards learning in chemistry laboratory. The extend of the participation of the students in the performance of the activities also improved their interests in doing practical works. (Hofstein & Lunetta, 2015; Okebukola, 2018; Thompson & Soyibo, 2018).

4.2 Pure attitudinal factor demonstrates the pupil's enjoyment of performing experiments, handling equipment and chemicals

Second factor comprises pure attitudinal factors demonstrating the students' enjoyment of performing experiments, handling equipment and chemicals, seeing things for themselves and looking forward to experiments. The data showed that students enjoy handling equipment and chemicals and seeing things during practical work since the responses for both items ranged between 4.10 to 4.58. This is a good indication that somehow students' interest in doing practical works were enhanced and they found the microscale set-up enticing in engaging with chemical reactions. In fact, the students were not in agreement that chemistry experiments are too complicated and unorganized. These findings are supported by Tobin (2016) who suggested that meaningful learning is possible in the laboratory if students are given opportunities to manipulate equipment and materials in order to be able to construct their knowledge of phenomena and related scientific concepts. This shows the importance of letting the students handle and manipulate the experimental set up, allowing them to discover on their hands-on activity the concept being tested rather than demonstrating the activity because of scarcity of glass wares and unavailability of chemicals due to its high cost.

4.3 Some practical aspects of lab work

Responses for practical aspects in lab work showed that the students thought that more time should be devoted to experiment but were uncertain that doing experiments individually would improve their performance in their final exams since the responses were close to '3' for both the pretest and posttest. The data also indicated that they did not agree that performing experiments was a waste of money and time and perceived that doing experiments individually is better than viewing the experiments on video or on television. Actual participation in the conduct of the experiment made them more engaged and cultivating more of their interest to participate every time they will be working in the laboratory. Such participation allows the students to perform in small groups will give them opportunity to investigate and observe more carefully as the experiment progresses. Another advantage of having small groups is that allowing each to be responsible in the conduct, not depending only to the active or performing students to do solely the activity. Delegating the works encouraged the students to be responsible on the performance of their assignment.

4.4 How students consider lab work as a way of learning

On the aspect of how students consider lab work as a way of learning, students' responses for

the items ranged between 3.55 to 4.13 (positive items) and 1.75 to 2.32 (negative items). This indicates that students considered lab work as a way of learning. They preferred doing experiments compared to watching demonstrations and perceived that they could learn more and understand the basic concepts better by doing experiments individually. During the treatment in this study, the microscale experiments provided the students opportunities to do experiments in small groups. Bradley (2019) claimed that practical work should involve active student participation. Students become more engaged if they are personally involved and responsible for the performance of the assigned activities. In addition, students paid more attention if they were held accountable for the outcomes. Since each member of the group will be assigned to perform a certain task, they feel more excited and participated knowing the importance of doing practical work to enhance their learning on the subject matter. Students realizing the importance of doing practical works for better understanding of the concepts will also resort to better engagement on the subject matter and they will also be able to easily connect their learnings in lecture class. Avoiding the students to have fragmented knowledge regarding the lessons, and encouraging students to be engaged in doing practical works is the platform for scientific consciousness. Chemistry will remain abstract to the learners so long as they are not exposed to its real application in daily life. Such the use of appropriate laboratory equipment or apparatus so that learners can establish connection on particular concepts and principles.

4.5 Environmental value of chemistry experiment

In terms of environmental values, the students slightly agreed that practical work is relevant to their life and in solving problems since their responses were closer to 3.5 to 4. In fact, the mean score for item 1 that focused on whether practical work was relevant to their daily life increased in the posttest.

Tallmadge et al. (2019) stated that the application of microscale chemistry experiments provides the opportunity to raise awareness of the values of environmental awareness into pre-college students regardless of the field in which their interests lie. Since education is critical for promoting the improvement of the capacity of the students to address environmental issues. Chemistry education can play a vital role in addressing environmental issues and problems especially through performance of laboratory activities and it was found out that microscale laboratory is environmentally nonthreatening and can make students be sensitive to pollution deterrence. It is very important that the students will develop awareness on how they should not contribute any further harm to the environment and be sensitive on their production and disposal of wastes.

Table1. Mean Rating of Student Responses to Chemistry Attitude Survey

Attitudes	Pretest		Posttest		Descriptive Rating
	Mean	Standard deviation	Mean	Standard deviation	
A. Students interest in doing experiments in chemistry					
1. Performing experiments in chemistry increases my interest in the subject.	4.02	0.47	4.04	0.49	A
2. Learning chemistry without experiments is uninteresting.	4.09	0.51	4.0	0.50	A
3. Chemistry experiment is very tiring.	1.69	0.44	1.77	0.50	D
4. The more time I spend on chemistry experiment the greater my interest.	3.78	0.30	3.80	0.46	A
B. Pure attitudinal factor, demonstrates the pupil's enjoyment of performing experiments, handling equipment and chemicals					
1. Experiment in chemistry is boring and routinely.	1.75	0.62	1.96	0.59	D
2. I enjoy seeing things for myself during experiments.	4.58	0.48	4.47	0.36	SA
3. I enjoy handling equipment and chemicals.	4.10	0.40	4.22	0.42	A
4. Performing chemistry experiments is too complicated for me.	2.11	0.65	2.09	0.53	D
5. I am looking forward to the next chemistry experiment.	3.95	0.43	3.98	0.50	A
6. I prefer lessons given by the teacher because experiment is unorganized.	2.56	0.32	2.30	0.65	D
7. I do not like chemistry experiments because the observations are never exact.	1.85	0.40	1.98	0.43	D

8. With the help of experiment, chemistry come alive.	4.10	0.36	4.05	0.40	A
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C. Some practical aspects of lab work

1. Performing experiments in chemistry is a waste of money.	1.53	0.43	1.65	0.38	D
2. More time should be devoted to chemistry experiment.	3.38	0.51	3.39	0.45	A
3. If I do many experiments myself, I will better in the final exam.	2.98	0.38	2.85	0.38	NS
4. Periods for experiments are a waste of time.	1.58	0.40	1.63	0.52	D
5. Viewing videos or television which show experiments being performed is better than doing the experiment myself.	2.21	0.49	2.05	0.45	D
6. There is no sense of redoing experiments that scientists have done in the past.	1.80	0.32	1.93	0.40	D

D. How students consider lab work as a way of learning

1. I prefer doing experiments myself to watching the teacher demonstrate them.	3.60	0.41	3.80	0.47	A
2. I learn more when I do the experiment myself.	3.74	0.37	3.55	0.40	A
3. I prefer reading my chemistry book to doing experiments.	2.22	0.43	2.32	0.49	D
4. Chemistry can be learnt and understood without experiments.	1.75	0.38	1.89	0.50	D
5. I understand basic concepts better when I perform the experiment myself.	3.64	0.63	3.56	0.38	A
6. Performing experiments help me understand the theoretical material better.	4.13	0.50	4.07	0.48	A

E. Environmental value of chemistry experiment

1. Chemistry practical work too relevant with my daily life.	3.47	0.30	3.55	0.43	A
2. Doing chemistry practical work can apply chemistry knowledge in solving problems.	3.90	0.48	3.78	0.40	A

Legend:

Range	Description	Descriptive Rating
4.51 – 5.00	strongly agree	(SA)
3.51 – 4.50	agree	(A)
2.51 – 3.50	not sure	(NS)
1.51 – 2.50	disagree	(D)
1.00 – 1.50	strongly disagree	(SD)

4.6 Student Achievement in Chemistry

In the study, students' test score gains in the pre-test and post-test in the achievement test in chemistry measured the students' chemistry achievement as shown in Table 2. As revealed from the table, microscale experiments as classroom activities provided statistically significant differences in students' performance in chemistry. The posttest mean result is 41.53 compared to the pretest mean result of 26.68. It may suggest that the students perform well in the achievement after the conduct of activities using microscale laboratory apparatuses. It may be contributed to the fact that since the students conduct the experiment in small groups this gives opportunities to everyone to participate and be able to have a hands-on experience, the knowledge gained becomes more deeper and as a result the students understand better the concept behind the performed activities. Such, students' interest and understanding of concepts were enhanced. It can also be deduced from the table how evident the difference of the mean results of the pretest and posttest, the results evidently showed a significant difference on the performance of the respondents from their pretest and posttest ($p=0.008$ at $p=0.05$) results. This may imply that performing microscale laboratory experiments may enhance students' learning in Inorganic Chemistry.

Table 2. Comparing the pre and post-test (paired difference t-test)- achievement in Chemistry

	Pretest	posttest
Mean	22.68	43.53
Standard deviation	3.14	3.43
p value = 0.008 < $p = 0.05$ significant		

5. Conclusion

Students involved in this study viewed laboratory work and microscale chemistry experimentation positively. The students received significant gains in their understanding of the chemistry concepts. The mean values for all the items for pre and posttest indicated that the students preferred doing experiments instead of watching teacher demonstrations. They enjoyed handling equipment and chemicals and also comprehended basic concepts better when they performed experiments individually. They also suggested that more time should be given to laboratory work and perceived that chemistry was relevant to daily life. Bearing also in mind the benefits of microscale experimentation in terms of safety, economy, and environmental benefits. Further, the cost for using miniature instruments and chemical reagents were both economically and environmentally effective thus learning may take place without harming the nature such, less chemical wastes produced in the process. The results of the study may also imply the potential use of microscale setting in doing practical works in chemistry. Students seemed to be engaged more for the challenges post in dealing miniature set-ups.

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