Initial Validation of the Chemistry MicroLab Kit (Chem. µLab Kit) in Facilitating Learning of Selected Chemistry Concepts for K-12 Science

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ABSTRACT The introduction of the Chemistry MicroLab Kit (CµLK) aims to assist student learning of chemistry in a more interactive and practical way. Each kit was designed to address certain topics in chemistry that may otherwise be too abstract to do in a lecture-discussion set up. Among the many topics tackled in secondary school, 13 undergraduate students were hand-picked for this preliminary study. The test subjects for this initial phase of the research both majors and non-majors, were currently enrolled in a Chemistry course. It was also tried-out at the Institute for Teaching and Learning (formerly

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Center for Teaching and Learning) with selected third year students. In this preliminary study, the students found three activities to be interesting and well-balanced: Gas Laws in a Box, Particulate Nature of Matter, and Solution Rules. In assessing the activities, they highly rated the easy language used for understanding the procedures, followed by setup of the experiments and a step-by-step presentation of the procedures. Initial results of the study find it a promising addition to the secondary level chemistry activities because CμLK enhances students' attitudes and motivation toward chemistry laboratory work.

Keywords: Cost effective, Environmental awareness, Microlab, Microscale chemistry

Introduction

Microscale technique, also known as small scale technique, is an environmentally viable option for conducting chemical processes through laboratory experiments using small quantities of starting materials without compromising the quality and standard of chemical applications in education and the industry. In this sense, students who used to work with 10-50 g of reactants and 50-500 g of solvent may now work with only about 10-150 mg of starting materials and 1-10 g of solvent (Buther et al., 1985).

There are several advantages to performing microscale techniques compared to traditional laboratory experiments. For one, they are cost effective because of the reduced cost of chemicals. These techniques allow the introduction of a variety of experiments and the chance to use more specialized chemicals because fewer amounts are required for the laboratory activities. They are also economical in terms of space and equipment requirement because, as an example, many microscale experiments can be done on a standard hotplate with stirrer (www.microlab.org).Another advantage is their environmentally friendly nature since hazardous wastes are reduced and consequently disposed of. Most of the product generated in the laboratory is rarely used outside of the experiment (Szafran, 1989). There poses no apparent waste production when the laboratory requires only a few grams of the product and the procedure requires certain gram quantities. For example, there is no need to make 5 g of a product when only 100 mg is required for analysis and throw away 4.9 g (Breuer, 2004). In a particular study at Arizona State University (US), when microscale techniques were employed, a significant reduction in waste production occured by as much as 80% compared to conventional laboratory experiments (Chloupeck-McGough, 1989).

From a pedagogic point of view, microscale techniques allow for reduced experiment times, while increasing the number of manipulations per laboratory time frame. Students are also able to develop their manipulative skills because of the small amount of starting materials, which as a consequence, do not allow accidental mistakes that could lead to loss of what product is obtained at the end of the experiment (Pickering, 1986).Other advantages cited in converting from conventional experiments to microscale techniques include drastic improvement in the air quality of the laboratories, reduction of storage space for chemicals and equipment, and reduction of contact with potentially toxic chemicals that may also be deemed fire hazards (www.microscale.org).

In contrast, certain issues were raised regarding the feasibility of going microscale in laboratory experiments. One of the biggest points raised lies in its inappropriateness in training for future chemists gearing toward research and industry, if not lack of appreciation for the laboratory experiment due to a small amount of product. There is also the potential of using expensive equipment, which may defeat the purpose of the cost-effective nature of microscale techniques. The students may not be skillful enough in manipulating experiments on a small scale setting.

These issues have been addressed by many universities, one being the University of Strathclyde in Glasgow. In terms of concerns for organic and pharmaceutical researches, many of them do employ microscale experiments, especially in the research and development stages. For issues regarding small amounts of products, only a few grams or milliliters are required to conduct qualitative confirmatory tests such as infrared spectrometry and thin layer chromatography. In the issues regarding students' competence, they can be trained by employing a "semi-micro" setting, which may scale up the experimental requirements from 100 mg to 1-5 g of starting materials.

One of the leading proponents of microscale techniques is Dr. ZviSzafran, Professor of Chemistry and Vice President for Academic Affairs at Southern Polytechnic State University in Marietta, Georgia. He worked hand in hand with Dr. Mono Mohan Singh, professsor, and Dr. Ronald M. Pike, Professor *Emeritus* both at Merrimack College in North Andover, Massachusetts. He headed the now inactive National Microscale Chemistry Center housed at Merrimack College. All three gave workshops and presentations in various sites and universities around the world. They trained elementary science school teachers, high school chemistry teachers, and college and university faculty and Industrial Chemists in Analytical, General, Organic, and Inorganic Chemistry. The advantages presented by shifting toward microscale techniques are so great that the practice has spread like wildfire, especially in developing countries (Ibanez, 2011). Their website still exists to date, however, no recent information has been posted for post year 2003.

A study on the effect of microscale chemistry on students' attitudes and motivation toward laboratory work in chemistry was conducted by research faculty at Universiti Sains Malaysia (Abdullah, Mohamed & Ismail, 2009). Their initial findings showed that there was no improvement in the students' attitudes and motivation toward practical work in chemistry. They did, however, develop a positive view of practical work and microscale chemistry experimentation wherein students preferred doing the experiments themselves rather than merely observing the teacher demonstrate these activities. In Tanzania, carefully designed and validated curriculum materials pertaining to micro-scale chemistry experimentation (MSCE) developed through adequate procedural specifications are both feasible in A-level chemistry classes and effective in providing positive learning experiences for secondary students (Mafumiko, 2008). Further evidence showed that the MSCE approach was not only easy to use but also made chemistry classes more interactive, interesting, and enjoyable, since students carried out experiments for themselves, collaborated with peers, and communicated with their teachers freely. Besides these affective outcomes, students developed better reasoning skills by engaging in micro-scale hands on and minds on activities.

In response to the K-12 curriculum, this Chemistry microscale kit aims to facilitate more effective instruction and to concretize abstract concepts in chemistry through simple hands-on activities. This kit covers a laboratory manual, a teacher's guide with expected experiment outcomes and alternative laboratory equipment and reagents. Each activity includes using household and other common chemicals to maximize learning experience and develop students' recording, interpreting, analyzing, decision making and laboratory skills despite limited resources in the public secondary school setting.

Hands-on and minds-on activities are important to maximize learning abstract concepts. In Dale's Cones of Experience, people generally remember ninety percent of what they say as they do a thing. Active learning takes place as the students "do the real things." The more sensory channels possible in interacting with a resource, the better the chance the students can learn from it. Experiential learning theory defines learning as the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience (Kolb 1984). A perennial challenge in teaching chemistry is lack of laboratory apparatus and equipment to provide firsthand experience to students and aid them grasp abstract concepts, improve critical and logical thinking and develop manipulative skills and positive scientific attitudes through scientific investigation.

The contents of the kit together with instructional materials were pilot tested and initially validated at PNU-ITL through science student teachers from the Department of Physical Sciences. This was followed by introducing the kit to secondary public schools with successive improvement and revision phase prior to mass production.

The Philippine Normal University, being the National Center for Teacher Education, engages in pursuing research programs to promote quality education, at the same time leading other teaching institutions (3NS) in coming up with innovative instructional approaches and materials that will enhance both content and pedagogical content knowledge. Such vision is aligned to the present university's statement "Nurturing Innovative Teachers," thus this kit reflects novelty by utilizing economical and safer reagents envisioned to help students appreciate underlying chemistry principles using chemicals found around them. It will also encourage teachers to deliver chemistry lessons in a more interactive way–far from traditional teaching strategies. Equally, this project will serve as a prototype for development of more activity-based lessons in chemistry.

Purpose of the Research Study

The study intends to develop a microscale chemistry kit and manual for the least learned concepts and skills in the K-12 curriculum. Specifically, the study addresses the following objectives:

1. Construct manipulative materials/tools/equipment useful in enhancing understanding or acquiring of least learned concepts in Chemistry together with a laboratory manual for the microscale kit;
2. Conduct an initial validation of the manipulative materials/tools/equipment and their manual use by students through a pilot test to be conducted at the PNU-ITL.
3. Perform an initial validation of the manipulative materials/tools/equipment and their laboratory manuals by experts and teachers.

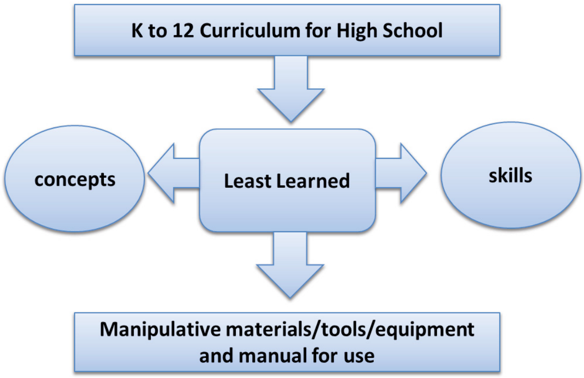

Figure 1. Framework of the Study.

Figure 1 presents the graphical framework of the study. Design of the microlab kit was highly influenced by the competencies specified in the K-12 curriculum from which, a set of least mastered concepts and skills were identified. These served as basis in the design and development of manipulative materials, tools, equipment and the corresponding manual intended to achieve the goal of eventually developing the least mastered skills identified.

Methodology

The study used the material development research design focusing on designing an instructional material in the form of an alternative laboratory kit to facilitate learning of the students' least mastered skills in the secondary level despite limited resources.

Participants

Participants in this study involved students and teachers of Physical Sciences group trained to pilot test the product among students and teachers of selected public schools in Chemistry.

Instrument and Data Gathering Procedure

A rubric was evaluated and used to assess the kit in terms of face and content validity. The effectiveness of the Chemistry µlab in addressing the least learned concepts and skills to high school students was evaluated by administering rubrics to students, student teachers, teachers, and experts of the field. The study was implemented in three phases. Phase 1 focused on developing the kit in accordance to identified least mastered chemistry concepts in high school Chemistry, documented in division offices of schools supervised by the Department of Education. Phase 2 featured the production stage of the prototype kit. Face and descriptive content validation was done to ensure acceptability and suitability as gauged by content experts. Phase 3 had initial testing of the kit at PNU-ITL together with evaluation/assessment of micro-scale kit by experts and/or teachers in the field. In this last phase, each experiment was carried out by a group of five to eight students. The experiments were housed within a kit that contained all the materials needed for the activity as well as a detailed instruction of each. During the treatment, the groups were asked to perform the 13 designed experiments based on their understanding of the instructions and materials given. These experiments have been developed by faculty members of the Department of Physical Sciences based on the least learned concepts and skills in chemistry. After performing the experiments, a questionnaire (Appendix A) was given to evaluate each of the activities. The students were informed that their responses to the questionnaires were strictly confidential. They were also asked to give open-ended comments and suggestions to assess how effective the CμLK conceptualization and preparation was.

Results and Discussions

This research-based project is all about the development of the Chemistry MicroLab Kit (CμLK) intended for the pre-service teachers. The CμLK aims to ease the transport of Chemistry equipment and enhance the learning of chemistry using simple hands-on activities and readily available materials. Students taking up Chemistry subjects with the assistance of their instructors were the test subjects. Initial assessment as to the level of comprehension and competence of the kit was done, with the following hands-on activities:

1. The Particulate Nature of Matter
2. Oh My Electrolytes!

3. Atoms in the Sky (Flame Test)
4. Acid, Base, and Salt
5. Color Me Bad: Chemical Change
6. Subatomi-Coin Particles
7. Magic Transfer
8. Determining the Size of Molecule of Stearic Acid
9. Diminishing Mass
10. Gas Laws in a Box
11. Solution Rules
12. Atoms in the Sky
13. Re-Act Chemically!

Based on preliminary assessment of the students' evaluations, the following data on the evaluation of the CμLK activities are presented.

Table 1. Preliminary Assessment of The Particulate Nature of Matter

	ITEM	Mean	SD	Remark[a]
1.	Language used is easy to understand.	4.00	0.000	SA
2.	Identifies all materials used in the experiment.	4.00	0.000	SA
3.	Provides step-by-step description of procedure.	4.00	0.000	SA
4.	Diagrams are clear and accurate.	3.00	0.632	A
5.	The experiment is easy to set-up.	4.00	0.000	SA
6.	Tables for data are provided.	2.20	0.400	D
7.	Formula for calculation are given.	2.20	0.400	D
8.	The experiment enhanced my understanding of the topic.	4.00	0.000	SA
9.	I enjoyed performing the experiment.	3.75	0.433	SA
10.	The experiment increased my interest in Biology/Chemistry/Physics.	3.80	0.400	SA
	Overall	**3.49**	**0.786**	**A**

[a]*Based on Mean*

The average rating for this activity was a 3.49, which fell under the category of "agree." The most common comment that the students had with this activity was that some of the questions were repeated.

Table 2. Preliminary Assessment of Oh My Electrolytes

	ITEM	Mean	SD	Remark[a]
1.	Language used is easy to understand.	3.50	0.764	SA
2.	Identifies all materials used in the experiment.	2.40	1.020	D
3.	Provides step-by-step description of procedure.	2.20	0.980	D
4.	Diagrams are clear and accurate.	1.80	0.748	D
5.	The experiment is easy to set-up.	3.20	0.980	A
6.	Tables for data are provided.	2.00	1.095	D
7.	Formula for calculation are given.	1.50	0.500	D
8.	The experiment enhanced my understanding of the topic.	2.20	1.166	D
9.	I enjoyed performing the experiment.	2.20	1.166	D
10.	The experiment increased my interest in Biology/Chemistry/Physics.	1.50	0.764	D
	Overall	**2.31**	**1.146**	**D**

[a]*Based on Mean*

The average rating for this activity was a 2.31, categorized as "disagree." Some comments from the students include the following: (1) lack of materials and instruction; (2) the conductivity apparatus was not working; (3) consider adding how the solutions were made; and (4) no instruction on how to use the instrument.

Table 3. Initial Assessment of Atoms in the Sky (Flame Test)

	ITEM	Mean	SD	Remark[a]
1.	Language used is easy to understand.	2.00	0.000	D
2.	Identifies all materials used in the experiment.	2.00	0.000	D
3.	Provides step-by-step description of procedure.	2.00	0.000	D

4.	Diagrams are clear and accurate.	2.00	0.000	D
5.	The experiment is easy to set-up.	4.00	0.000	SA
6.	Tables for data are provided.	1.00	0.000	SD
7.	Formula for calculation are given.	1.00	0.000	SD
8.	The experiment enhanced my understanding of the topic.	3.00	0.000	A
9.	I enjoyed performing the experiment.	4.00	0.000	SA
10.	The experiment increased my interest in Biology/Chemistry/Physics.	4.00	0.000	SA
	Overall	**2.50**	**1.118**	**A**

[a]*Based on Mean*

The average rating for this activity was a 2.50, falling under the category of "agree." Only one respondent evaluated this activity and made the following comments: (1) the procedure was not clearly stated; (2) there were no diagrams or pictures presented in the manual; (3) the materials were incomplete; and (4) the nichrome wire could not pick up the solids used for the flame test.

Table 4. Initial Assessment of Acid, Base, and Salt

	ITEM	Mean	SD	Remark[a]
1.	Language used is easy to understand.	3.67	0.471	SA
2.	Identifies all materials used in the experiment.	1.67	0.471	D
3.	Provides step-by-step description of procedure.	3.33	0.471	A
4.	Diagrams are clear and accurate.	1.67	0.471	D
5.	The experiment is easy to set-up.	2.67	0.471	A
6.	Tables for data are provided.	1.67	0.471	D
7.	Formula for calculation are given.	1.67	0.471	D
8.	The experiment enhanced my understanding of the topic.	3.00	0.000	A
9.	I enjoyed performing the experiment.	3.00	0.000	A
10.	The experiment increased my interest in Biology/Chemistry/Physics.	3.00	0.000	A
	Overall	**2.53**	**0.846**	**A**

[a]*Based on Mean*

The average rating for this activity was a 2.53, interpreted as "agree." The students commented that the concentrations of NaOH and HCl were not the same, which led to inaccurate results, as much as insufficient glassware to work with.

Table 5. Initial Assessment of Color Me Bad: Chemical Change

ITEM	Mean	SD	Remark[a]
1. Language used is easy to understand.	3.40	0.490	A
2. Identifies all materials used in the experiment.	3.20	0.400	A
3. Provides step-by-step description of procedure.	3.60	0.490	SA
4. Diagrams are clear and accurate.	3.00	0.894	A
5. The experiment is easy to set-up.	3.40	0.490	A
6. Tables for data are provided.	2.60	1.019	A
7. Formula for calculation are given.	2.40	0.800	D
8. The experiment enhanced my understanding of the topic.	3.00	0.000	A
9. I enjoyed performing the experiment.	3.00	0.000	A
10. The experiment increased my interest in Biology/Chemistry/Physics.	3.00	0.000	A
Overall	**3.06**	**0.676**	**A**

[a]*Based on Mean*

The average rating for this activity was a 3.06, categorized as "agree." Some comments made by the students were the following: (1) the $CuSO_4$ solution should already have been prepared; (2) the baking soda should have been weighed; (3) not enough glassware available; and (4) some instructions were unclear.

Table 6. Initial Assessment of Subatomi-Coin Particles

	ITEM	Mean	SD	Remark[a]
1.	Language used is easy to understand.	3.80	0.400	SA
2.	Identifies all materials used in the experiment.	3.40	0.490	A
3.	Provides step-by-step description of procedure.	3.60	0.490	SA
4.	Diagrams are clear and accurate.	3.20	1.166	A
5.	The experiment is easy to set-up.	3.80	0.400	SA
6.	Tables for data are provided.	3.40	0.490	A
7.	Formula for calculation are given.	3.00	0.000	A
8.	The experiment enhanced my understanding of the topic.	2.60	1.020	A
9.	I enjoyed performing the experiment.	1.80	0.748	D
10.	The experiment increased my interest in Biology/Chemistry/Physics.	2.00	0.632	D
	Overall	**3.06**	**0.947**	**A**

[a]*Based on Mean*

The average rating for this activity was a 3.06, falling under the category of "agree." The students made the following comments: (1) some materials were missing; (2) the instructions were unclear; and (3) the experiment was boring and uninteresting.

Table 7. Initial Assessment of Magic Transfer

	ITEM	Mean	SD	Remark[a]
1.	Language used is easy to understand.	3.75	0.433	SA
2.	Identifies all materials used in the experiment.	3.00	1.000	A
3.	Provides step-by-step description of procedure.	3.25	0.433	A
4.	Diagrams are clear and accurate.	3.00	0.000	A
5.	The experiment is easy to set-up.	3.75	0.433	SA
6.	Tables for data are provided.	2.75	0.433	A
7.	Formula for calculation are given.	2.25	0.829	D
8.	The experiment enhanced my understanding of the topic.	3.25	0.433	A

9.	I enjoyed performing the experiment.	3.75	0.433	SA
10.	The experiment increased my interest in Biology/Chemistry/Physics.	3.50	0.500	SA
	Overall	**3.23**	**0.732**	**A**

[a]*Based on Mean*

The average rating for this activity was a 3.23, with a corresponding rating of "agree." The students made the following comments: (1) the iron nails were missing; (2) the group members should not exceed 5 people; and (3) the experiment was easy to perform.

Table 8. Initial Assessment of Determining the Size of Molecule of Stearic Acid

	ITEM	Mean	SD	Remark[a]
1.	Language used is easy to understand.	3.40	0.490	A
2.	Identifies all materials used in the experiment.	3.00	0.894	A
3.	Provides step-by-step description of procedure.	3.00	0.632	A
4.	Diagrams are clear and accurate.	1.80	0.748	D
5.	The experiment is easy to set-up.	2.80	0.400	A
6.	Tables for data are provided.	2.00	1.095	D
7.	Formula for calculation are given.	1.60	0.490	D
8.	The experiment enhanced my understanding of the topic.	3.40	0.490	A
9.	I enjoyed performing the experiment.	3.40	0.490	A
10.	The experiment increased my interest in Biology/Chemistry/Physics.	3.80	0.400	SA
	Overall	**2.82**	**0.973**	**A**

[a]*Based on Mean*

The average rating for this activity was a 2.82, categorized as "agree." The following comments were made by the students: (1) tables and diagrams should have been present for writing down the data; (2) formulas of the chemicals should have been given; (3) materials should have been complete; and (4) the experiment was interesting.

Table 9. Initial Assessment of Diminishing Mass

	ITEM	Mean	SD	Remark[a]
1.	Language used is easy to understand.	4.00	0.000	SA
2.	Identifies all materials used in the experiment.	3.00	0.000	A
3.	Provides step-by-step description of procedure.	3.00	0.000	A
4.	Diagrams are clear and accurate.			
5.	The experiment is easy to set-up.	4.00	0.000	SA
6.	Tables for data are provided.	1.00	0.000	SD
7.	Formula for calculation are given.			
8.	The experiment enhanced my understanding of the topic.	4.00	0.000	SA
9.	I enjoyed performing the experiment.	4.00	0.000	SA
10.	The experiment increased my interest in Biology/Chemistry/Physics.	4.00	0.000	SA
	Overall	**3.38**	**0.992**	**A**

[a]*Based on Mean*

The average rating for this activity was a 3.38, falling under the category of "agree." The students commented that the experiment guided them to learn chemical reaction in a fun and easy way and that the tables for data gathering and additional substances should have been provided.

Table 10. Initial Assessment of Gas Laws in a Box

	ITEM	Mean	SD	Remark[a]
1.	Language used is easy to understand.	4.00	0.000	SA
2.	Identifies all materials used in the experiment.	4.00	0.000	SA
3.	Provides step-by-step description of procedure.	4.00	0.000	SA
4.	Diagrams are clear and accurate.	3.00	0.000	A
5.	The experiment is easy to set-up.	4.00	0.000	SA
6.	Tables for data are provided.	3.00	0.000	A
7.	Formula for calculation are given.	3.00	0.000	A

8.	The experiment enhanced my understanding of the topic.	4.00	0.000	SA
9.	I enjoyed performing the experiment.	4.00	0.000	SA
10.	The experiment increased my interest in Biology/Chemistry/Physics.	4.00	0.000	SA
	Overall	**3.70**	**0.458**	**SA**

[a]*Based on Mean*

The average rating for this activity was a 3.70, categorized as "strongly agree." The students found the activities really interesting and described the applications of the gas laws in an easy way.

Table 11. Initial Assessment of Solution Rules

	ITEM	**Mean**	**SD**	**Remark[a]**
1.	Language used is easy to understand.	3.40	0.490	A
2.	Identifies all materials used in the experiment.	3.00	0.632	A
3.	Provides step-by-step description of procedure.	3.20	0.748	A
4.	Diagrams are clear and accurate.	3.00	0.632	A
5.	The experiment is easy to set-up.	3.40	0.490	A
6.	Tables for data are provided.	3.20	0.748	A
7.	Formula for calculation are given.	2.40	0.800	D
8.	The experiment enhanced my understanding of the topic.	3.40	0.490	A
9.	I enjoyed performing the experiment.	3.80	0.400	SA
10.	The experiment increased my interest in Biology/Chemistry/Physics.	3.80	0.400	SA
	Overall	**3.26**	**0.716**	**A**

[a]*Based on Mean*

The average rating for this activity was a 3.26, with a corresponding rating of "agree." The students made the following comments: (1) the procedures on Part B were unclear; (2) there were not enough glassware; and (3) it was an effective experiment in describing the solubility of the substance.

Table 12. Initial Assessment of Re-Act Chemically

ITEM		Mean	SD	Remark[a]
1.	Language used is easy to understand.	4.00	0.000	SA
2.	Identifies all materials used in the experiment.	3.00	0.000	SA
3.	Provides step-by-step description of procedure.	4.00	0.000	SA
4.	Diagrams are clear and accurate.	3.00	0.000	SA
5.	The experiment is easy to set-up.	4.00	0.000	SA
6.	Tables for data are provided.			
7.	Formula for calculation are given.			
8.	The experiment enhanced my understanding of the topic.	4.00	0.000	SA
9.	I enjoyed performing the experiment.	4.00	0.000	SA
10.	The experiment increased my interest in Biology/Chemistry/Physics.	4.00	0.000	SA
Overall		**3.75**	**0.433**	**SA**

[a]*Based on Mean*

The average rating for this activity was a 3.75, categorized as "strongly agree." The activity had only one respondent who commented that there were not enough materials available and that Part C of the experiment was successful because it showed proof of a chemical reaction.

Table 13. Summary of Rating and Corresponding Remarks

ITEM		Mean	SD	Remark[a]
1.	The Particulate Nature of Matter	3.49	0.786	A
2.	Oh My Electrolytes!	2.31	1.146	D
3.	Atoms in the Sky (Flame Test)	2.50	1.118	A
4.	Acid, Base and Salt	2.53	0.846	A
5.	Color Me Bad: Chemical Change	3.06	0.676	A
6.	Subatomi-Coin Particles	3.06	0.947	A
7.	Magic Transfer	3.23	0.732	A
8.	Determining the Size of Molecule of Stearic Acid	2.82	0.973	A
9.	Diminishing Mass	3.38	0.992	A

10.	Gas Law in a Box	3.70	0.458	SA
11.	Solution Rules	3.26	0.716	A
12.	Re-Act Chemically!	3.75	0.433	SA
	Composite	**3.09**	**0.451**	**A**

[a]*Based on Mean*

Overall, activities in the kit were given a remark of "agree" corresponding to a mean of 3.09. Two of the most appreciated activities were Gas Law in a Box and Re-Act Chemically, while only a single activity received the "disagree" remark, specifically item number 2. From the questionnaire, the item with the highest mean score of 3.61 and a rating of 'strongly agree' was item 1, "Language used is easy to understand." This was followed by item 5, "The experiment is easy to set-up," with a mean score of 3.46 and a rating of 'agree.' Third highest mean of 3.22 with a rating of 'agree' was given for item 3, "Provides step-by-step description of procedure."

Three items obtained a rating of 'disagree.' Third lowest, with a mean score of 2.48 was item 4, "Diagrams are clear and accurate." Following this was item 6 with a mean score of 2.37, "Tables for data are provided." Finally, item 7, "Formulae for calculation are given" got the lowest mean score of 2.12.

Experts' Validation of the Chemistry MicroLab Kit

The chemistry microlab kit underwent expert validation. Five validators who are all chemistry teachers assessed the kit in terms of format, language, reproducibility and equipment. The chemistry microlab kit underwent the five experts' validation in terms of format, language, reproducibility and the equipment. Table 14 shows the summary of the experts' validation.

Table 14. Summary of the experts' validation of the chemistry microlab kit

SUMMARY	MEAN	SD	% AGREEMENT^	REMARK*
Format	3.76	0.436	76.0	MSA
Language	3.76	0.447	76.0	MSA
Reproducibility	3.52	0.714	76.0	MSA
Equipment	3.52	0.510	84.0	H
Overall	**3.64**	**0.542**	**86.0**	**H**

Table 14 shows that the overall % agreement among the five experts who evaluated the chemistry microlab kit is 86.0% to mean that the five evaluators had highly agreed on four areas of the microlab kit. Among the four areas, it is noted that equipment has the highest percent agreement equivalent to 84.0% while the other three areas: format, language and reproducibility share the same percentage of 76.0% with marked substantial agreement among the five evaluators.

Table 15. Experts' evaluation about the format of the kit

FORMAT	MEAN	SD	REMARK
1	4.00	0.000	SA
2	3.40	0.548	A
3	4.00	0.000	SA
4	3.40	0.548	A
5	4.00	0.000	SA
COMPOSITE	**3.76**	**0.436**	**SA**

In terms of the format of the chemistry microscale laboratory kit, all five evaluators strongly agreed that the said lab kit is logically sequenced, establishes the scientific concept of the experiment and sections are distinct from each other. This finding is further reflected in Table 15.

As to the language used in the microlab kit, all the five experts have strongly agreed on the area of language to imply that the language used is appropriate, consistent and the words are simple and easy to understand as shown in Table 16.

Table 16. Experts' validation on the language of the kit

LANGUAGE	Mean	SD	Remark
1	4.00	0.000	SA
2	4.00	0.000	SA
3	3.20	0.447	A
4	3.80	0.447	SA
5	3.80	0.447	SA
COMPOSITE	**3.76**	**0.447**	**SA**

The five experts have strongly agreed on the item, reproducibility to imply that the chemistry microlab kit identifies all materials used in the experiment, provides concise, step-by-step description of the procedure and gives clear and accurate diagrams. The strong agreement of the five evaluators is reflected in Table 17.

Table 17. Experts' validation on reproducibility of the kit

REPRODUCIBILITY	Mean	SD	Remark
1	4.00	0.000	SA
2	3.60	0.894	SA
3	3.00	0.707	A
4	4.00	0.000	SA
5	3.00	0.707	A
COMPOSITE	**3.52**	**0.714**	**SA**

Lastly, the equipment or contents of the microlab kit is described attractive, durable, non-hazardous and easy to set up, based on the strong agreement among the five expert evaluators, as shown in Table 18.

Table 18. Experts' validation on the equipment of the kit

EQUIPMENT	Mean	SD	Remark
1	3.00	0.000	A
2	3.00	0.000	A
3	3.80	0.447	SA
4	4.00	0.000	SA
5	3.80	0.447	SA
COMPOSITE	**3.52**	**0.510**	**SA**

Conclusion and Recommendations

The study was able to design a validated microlab kit in chemistry for high school students. Based on the finding, the students were interested in the activity with the most concrete procedure and materials, namely Gas Laws in a Box, Particulate Nature of Matter, and Solution Rules. In contrast, the CμLK activities with missing materials and incomplete procedures got the lowest mean scores, namely Acid, Base, and Salt, Flame Test, and Oh My Electrolytes. Accordingly, students assess the experiments to have very little issue with the language used in writing the procedures which means that the students easily understood them. Some procedures did not have clear and accurate diagrams, missing tables for writing down their data, and missing formulae with which to calculate some of their values from. The experts strongly agreed that the chemistry microlab kit conforms to the criteria in terms of format, language, reproducibility and equipment.

With an overall positive response of the students toward the introduction of the CμLK, this material may be able to deduce their positive attitude towards the subject matter, eventually leading to better student achievement addressing the identified least mastered concepts and skills.

This finding agrees with the popular research findings of several studies (Nasr and Soltani, 2011; Narmadha and Chamundeswari, 2013). Validation and evaluation of the products are promising in terms of the feasibility of introducing the CμLK to secondary students. Most of the items garnered a rating of 'agree,' since the students generally understood the procedure and were sharp enough to point out what was lacking. The items with a rating of disagree can be remedied by rewriting the procedure or including the missing materials in succeeding tests. Possibly, the designed package concretely shows various capabilities attributed to several learning theories that are usually instrumental to the development of concepts and skills such as experiential learning, cooperative learning, hands-on-minds-on approach, inquiry based learning and constructivist theory all incidental learning theories in the development of the k-12 science curriculum which define the bases for the design of such products. With this loop, a promising success in student achievement maybe at hand with the use of these microlab kits in teaching chemistry concepts.

Based on the conclusions arrived at for this research, the researchers recommend that: 1) The CμLK be presented for pilot testing to secondary level students for evaluation; 2) The CμLK be assessed thoroughly for missing items for smoother evaluation by students; 3) Each test be documented with photographs and video evidences for filing; 4) More experiments need to be introduced to facilitate learning of the various topics tackled in secondary school chemistry; and 5) Involve more respondents for every activity which could be done on the next phase of the study.

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