USING MICRO SCIENCE EQUIPMENT TO FACILITATE THE STUDY OF QUALITATIVE ANALYSIS – A CASE STUDY IN AN UNDERGRADUATE CLASS

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ABSTRACT

Analytical chemistry is an important aspect of chemistry as it provides a lot of insight into the constituents and measurements of matter in all fields of science and medicine. Thus its study comprises the practice of qualitative and quantitative analysis which allows learners of science to have an experience of analytical work. However, the growing cost of science resources and the increasing numbers of students make the regular practice of such activities difficult. It drains the resources of schools which attempt to expose their students to practical work. In this interpretive study of quality micro analysis, 46 undergraduate teacher trainees participated in the use of microscience equipment in their forth semester for the identification of ions in solutions. Data to assess the feasibility of the intervention was done through observation, a questionnaire and a semi-structured interview. About 86% of the sample intimated that the micro activities were interactive, easy to use, yielded faster results and was fun to work with.

Keywords: Micro science equipment, comboplate, precipitate, analytical.

INTRODUCTION

Analytical work reveals the true nature and measures of constituents of chemical samples. It is applied throughout industry, medicine and all the sciences. Practical analysis increases the conceptual understanding of chemical principles as well as the interactions of matter and its application in our daily lives.

In schools and research laboratories, qualitative analysis is particularly used for selective precipitation so that mixtures of analytes/ions could be separated and identified with ease. Qualitative analysis actually suggests and establishes the chemical identity of species in a sample while quantitative analysis tells about amounts or measures of analytes. A preliminary knowledge of the constituents of a sample of interest could help a chemist make predictions and deductions of further reactions and even come out with relative innovative ideas about matter. However, knowledge about specific reagents and their interactions with some common matter is an asset in qualitative analytical work. An in-depth understanding about the constituents of matter can also help us to explain the occurrence of some events in our environments. From the preamble, it is obvious that exposing students to the study of analytical chemistry, especially qualitative analysis is very important. Nevertheless, due to the rising cost of chemical resources, such activities are hardly engaged in, such that students learn most science concepts and phenomena by rote through lecture methods (Hanson, 2014a). The purpose of this study was to assess the feasibility and response of undergraduate teacher trainees to the use of micro science equipment (MSE) in the concept acquisition of basic qualitative analysis in a tertiary institution.

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LITERATURE REVIEW

Learning concepts and phenomena in abstraction and inefficient ways lead to the formation of alternative concepts (Horton, 2007). Thus low cost, simple and innovative techniques must be devised for chemistry activities so as to move away from the traditional lectures and the more expensive traditional macro activities with their attendant handling problems and high financial cost. Micro science equipment (MSE) thus accommodates budget cuts in institutions and also in line with the current economic crisis (Matei & Vrabie, 2013). The micro science equipment (MSE) is a small lunch-like plastic box which measures 14.5 x 11 x 5.5cm and contains a comboplate, forceps, gas collecting unit, glass rod, glass tube, microburner, pH guide, microspatula, syringes, propettes, and universal indicator. The benefits of practical activities cannot be neglected as they equip learners with process, concept and lab skills. Its use in remote basic schools and universities has been trialled in South Africa (Bradley, 1999). Some schools of thought propose the use of virtual labs in schools as they do not require the use of laboratories, equipment and chemicals (Zakaria, Latip, & Tantayanon, 2012). Walsh (2011) adds that virtual labs protect students from exposure to danger such as explosions. They however, do not expose learners to the acquisition of manipulative skills. Results are instantaneous and create unrealistic situations to students who may find themselves in a real world application without the knowledge to perform. Students are therefore limited in their drive to improve on research in preparation for analytical work when they work in virtual labs. Other methods such as non-participatory demonstrations and use of other multimedia have been found to be ineffective in teaching chemistry- especially to teacher trainees because they do not expose them to adequate acquisition of learning skills .

Some institutions in both developed and developing countries have solved the problems of non-practice of science by resorting to the use of micro science equipment in science classes (Huang, 2007; Hanson, Amedeker, Oppong, & Antwi, 2011; Zakaria, Latip, & Tantayanon, 2012; Abdullah, Mohamed, & Hj Ismail, 2009). The reason for using the micro science equipment is to use microliters of chemicals in low cost, safe, and easy- to- handle plasticware during activities. Less than or at most a gram of solid is often required for such micro activities as against between 5-10 grams with macro equipment. More interestingly, generated waste is minimal and so causes less environmental effects upon disposal. These benefits allow students to work freely in realistic situations without fear of breakages and explosions from ‘unsafe’ or explosive reactions.

METHODOLOGY

MSE which had been purchased from the Centre for Mathematics, Science and Technology Education, Witwatersrand University, South Africa (RADMASTE) were supplied to 46 teacher trainees. Micro science activities from a RADMASTE manual (Durbach, Bell, & Liwanga, 1996) were adapted for use. The adapted activities covered tests for the common cations: silver, lead, aluminium, calcium, zinc and the anions sulphate, nitrates and carbonates in aqueous solutions. These ions were particularly chosen because they are the ions which are commonly tested for (identified) in high school chemistry. A preliminary activity to introduce the MSE and qualitative analysis was organised for the trainees before the start of this study. This is presented in Appendix A. the trainees were also encouraged to work collaboratively so that they could support each other, if the need be, in using the newly introduced equipment and for the purposes of reflective discussions.

An adapted direct-observation schedule (Mafumiko, 2008), was used at regular intervals during practical sessions to assess how trainees responded to the use of the MSE and MSE activities per 30-second intervals. This observation was done in conjunction with a trained colleague, and the inter-rater reliability was found to be 86%. A questionnaire comprising five close-ended questions and five open-ended questions were administered at the end of the study to trainees. This was to get the trainees' individual impressions about the MSE. The questionnaire was followed by a semi-structured interview with ten trainees who were randomly chosen to obtain their in-depth impressions of the feasibility of the MSE in performing qualitative analysis and how it enhanced their learning of associated concepts. The results were analysed by finding simple percentages of gathered data out of an obtained whole.

RESULTS

Results on trainees' response to the MSE and its activities were gathered through observation, interview and MSE practical activities. The observation session involved assessment of trainees' responses and behaviour during MSE activities. The observation results are presented in Table 1. The indicators, ±, + and – (Mafumiko 2008), show how the trainees exhibited 'partial', 'full' or 'no observed' participation respectively in the activities carried out.

Table 1: Pooled results from the MSE cation tests observation sheet

		Weeks			
Item	Behaviour/Response/Activity per week	1	2	3	4
1.	No confusion in understanding of activity procedures	-	±	+	+
2.	Evidence of working with MSE and other materials	-	±	+	+
3.	Work with precision/ accuracy in time	±	±	+	+
4.	Formulate general statement about activity	-	±	+	+
5.	Names, formula & chemical reactivity of reacting components written independently & confidently	±	-	+	+
6.	Coherent discussion and collaboration among trainees	-	±	±	+
7.	Relation of new concepts in other situations	-	-	+	+
8.	Understanding of required scientific terms and language	-	±	+	+

From Table 1, it is observed that majority of the trainees responded positively (+) to the use of the micro science equipment after their second week. There was 100% participation in the fourth week and an apparent exhibition of almost all the desired behaviours and actions. The trainees understood the requirements on their activity sheets and interpreted them efficiently by exhibiting the expected responses. Collaborative activities and interactions were however not evident. It appeared that they preferred to work independently.

Similar observations were made when the trainees carried out tests for the identification of anions. The difference here was that, the trainees did not exhibit their understanding of the necessary concepts for the identification of anions as for the cations. Thus they were not able to formulate general statements as easily and as fast as they did with the cation activities. Their observations are presented in Table 2. (The indicators of +, ± and -, in Table 2 mean the same as in Table 1).

Table 2: Pooled results from the MSE anion test observation sheet

		Weeks			
Item	Behaviour/Response/Activity per week	1	2	3	4
1.	No delay in understanding of activity procedures	±	+	+	+
2.	Evidence of working with MSE and other materials	±	+	+	+
3.	Works with precision/ accuracy in time	-	±	+	+
4.	Formulates general statement about activity	-	±	+	+
5.	Names, formula & chemical reactivity of reacting components written independently & confidently	-	-	+	+
6.	Coherent discussion and collaboration among trainees	-	-	±	+
7.	Relation of new concepts in other situations	-	-	+	+
8.	Understanding of required terms and language	-	-	+	+

Results from Table 2 indicate that the trainees had apparently gained more confidence in the use of the MSE and so interacted affably with it, as well as with their colleagues. However, some trainees showed dissatisfaction with their initial outcomes and so discarded their solutions several times and repeated their activities over and again before they reached a final decision. All of these were however, done within the allotted time.

Feedback on the usefulness of the MSE to help conceptual gain in qualitative analysis (identification of ions) was gathered through their opinions in a questionnaire. A 5-point Likert scale with the options 'strongly agree', 'agree', 'disagree', and 'strongly disagree' have been polled as 'agree' and 'disagree'. Neutral and no response items have also been pooled together as 'unsure. The trainees' responses to the close-ended survey questionnaire are presented in Table 3.

Table 3: Part 'A' of the trainees' survey questionnaire (N = 46)

Item		Agree	Disagree	Unsure
1.	MSE was helpful in understanding	35 (76.09%)	4 (8.69%)	7 (15.22%)
2.	MSE activities encouraged critical thinking	26 (56.52%)	3 (6.52%)	17 (36.96%)
3.	Exposure to easier way of identifying ions	38 (82.61%)	1 (2.17%)	7 (15.22%)
4.	Interference of small-sized MSE with observation	5 (10.87%)	41 (89.13%)	0 (0.00%)
5.	Preference of macro equipment over MSE comboplate	4 (8.69%)	38 (82.61%)	4 (8.69%)
6.	Provision of opportunity for active learning	44 (95.65%)	0 (0.00%)	2 (4.35%)
7.	Faster achievement of results	40 (86.96%)	5 (10.87%)	1 (2.17%)
8.	Linked theory with practice	36 (78.26%)	2 (4.35%)	8 (17.39%)
9.	Repetition of activities without loss of time	41 (89.13)	1 (2.17%)	4 (8.69%)
10.	Increased confidence in my results and inferences	39 (84.78%)	3 (6.52%)	4 (8.69%)

Responses from Table 3 indicate that an average of about 82.2 % trainees' answers were in favour of the positive nature of the MSE. Malaysian students who were introduced to the use of similar micro equipment also were highly in favour of its use for chemistry practical activities (Abdullah, Mohamed, & Hj Ismail, 2009). Their attitudes towards practical work increased positively. However, in this current study, an average of 6.10% trainees was not in favour of the use of the MSE for performing qualitative chemistry activities on the identification of ions while 11.74% were indifferent.

The trainees then answered five open-ended questions in a semi-structured focus interview on their impressions about the intervention. The questions were:

1. How different is the micro science equipment and its activities from traditional activities?
2. How true is the assertion that the two types of equipment yield no different results when used?
3. What did you like most about the intervention?
4. What did you like least about the intervention?
5. What suggestions would you want to make about the introduction of the microscience equipment for the study of other chemistry topics in secondary schools?

Some of the trainees' responses were as follows:

- I enjoyed using the already labelled wells of the comboplate because it saved me labelling time. It will be good for secondary students.
- We performed activities without fear of breakages. This time I personally concentrated solely on the activity to be done and so I understood the process and outcomes better than in the past.
- It was interesting to note that one could obtain results with so little chemicals
- The activities helped me to understand most of the solubility rules that we learned by rote. I can now predict the outcomes of chemical reactions because now I know that I simply have to consider the chemical nature of the samples involved as well as the nature of the reagent and see what the outcomes (products) will be. Then, I get an idea for a possible outcome.
- Since we used small volumes of chemicals, the guilt of wasting chemicals through repetition, with the attendant long wait times for results were all eroded. Besides, the chemical waste was also small.
- Reaction times were relatively shorter than for 'regular', traditional activities. Thus more time was availed for group and class discussions and better understanding.

DISCUSSION

A comparative analysis of results presented in Tables 1 and 2 alone, does not show the effect of the MSE as an interventive tool for the trainees behaviours and actions as does the report of their own experiences. From Tables 1 and 2, it is evident that they were able to interpret work procedures, work with the MSE materials and use the expected terms coherently. The improvement in scientific concepts could only be merely ascribed to the MSE but not authenticated as an impact analysis was not done in this particular study. A qualitative analysis of the trainees' responses gathered from the semi-structured interview confirmed most of the assertions that the trainees made in the close-ended questionnaire as presented in Table 3. Here, they intimated that, success was made in their syudy of qualitative analysis because of the only new tool in their usual analytical work- which was the MSE. For example, they said that they enjoyed using the already labelled comboplates as it saved them from improvising labels. In part A of the close-ended questionnaire (Table 3) 82.61% of the trainees preferred the use of comboplates to test tubes (macro equipment) which have no pre-designed labels. They added that it was time saving, which corresponds with their positive choices for questionnaire items 7 and 9 (approximately 87% and 89% respectively). These attestations are similar to what other students said in a study carried out by Hanson (2014b) in a case study on stoichiometric practical activities. Trainees learned to differentiate between

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chalky and gelatinous precipitates quite clearly after performing a few activities involving calcium, zinc and aluminium ions. They showed adequate understanding of the underlying chemistry concepts of precipitation as well as how aqueous ions interacted and so could easily rationalise which precipitates would persist in the face of excess reagents and those which would dissolve, with logical reasons. They intimated that they had gained more confidence in carrying out such analytical activities which agreed with responses for questionnaire items 1, 2, 3, and 10 in Table 3. Many of the trainees were now able to understand through hands-on activities, some of the chemical theories that they had learned in high schools with little understanding. Some of them were particularly excited about the fact that so little waste was generated with the micro equipment as compared to the macro equipment (open-ended response bullet 5). By this response, the trainees were in a way expressed some measure of awareness of environmental conservation and protection. They were also happy that results were obtained in relatively shorter times as observed from questionnaire items 7 and 9 (in Table 3). They didn't have to label the already labelled wells for easy identification as they did with test tubes. The fact that the comboplate was made of plastic was an added assert for the trainees. With this knowledge, they could concentrate on their learning process without fear of breakages. They particularly liked the idea of working like scientist who observe, analyse and draw conclusions which conformed to theoretical facts they had learned with difficulty in theory class. In other words, they enjoyed the active learning environments which were inherent in the MSE activities.

The MSE activities involved the identification of ions through selective precipitation and the parameters which governed their reactions. This enabled the trainees to understand the chemical reactivities better, write correct chemical equations and decipher or deduce the ions that would precipitate out and those that would be in solution. The trainees discovered from practice that if aqueous HCl was added to a mixture of Na^+, Ag^+, Pb^{2+}, Zn^{2+} and Al^{3+}, in solutions for example, only Pb^{2+} and Ag^+ would precipitate out as insoluble chlorides, while all the others would be soluble and remain in solution. They went on to explain that adding more acid would not dissolve the precipitates as Cl^- ions have virtually no affinity for H^+ ions in aqueous solutions. In a way, the trainees implicitly learned about equilibrium. They further learned that group 2 cations formed insoluble carbonates and so could be precipitated out of solutions by adding solutions of carbonates to them. An example of an extension (application) activity where trainees in the study had to use knowledge gained to separate cations in an aqueous solution containing $Pb(NO_3)_2$, $Ba(NO_3)_2$ and $Ni(NO_3)_2$ is shown in Appendix B.

CONCLUSION

The results of the study indicated that, using microscience equipment in the study of qualitative analysis in schools could be fun, easy, at low-cost, time saving and easily understandable for teacher trainees of UEW, and possibly, other learners of analytical chemistry. As observed from results obtained from this study, trainees attested to the safety and quick outcome of results with the use of micro equipment. They added that it was environmentally friendly. More importantly, it helped them to understand the underlying chemical principles needed to perform successful analytical work. To substantiate this assertion, the trainees provided more conceptual answers to application questions, where they had to apply their knowledge gained through the practical activities to other related situations. Introducing MSE into deprived communities for the study of chemistry would go a long way to make the learning of science a fun for students as well as enhance their conceptual understanding of chemical principles. In this study, the trainees were able to apply learned principles to write equations, devise schematic diagrams of analytical activities and make correct inferences.

RECOMMENDATION

Teachers could adopt the MSE to teach basic chemical concepts such as the reactivity of metals with water and acids as well as chemical stoichiometric titrations before the introduction of the use of macro scale equipment and activities. This would enable learners gain the necessary process, concept and lab skills in an easy and joyful way. Besides, they would develop the required precision and accuracy required for analytical work.

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Appendix A: An example of a preliminary exercise

Dispense 5 drops of samples A (aq), B (aq) and C (aq) into wells D[1] to D[3]. Now add three drops each of NaOH (aq) to wells D[1] to D[3]. Did the colours of the solutions in the wells D[1] to D[3] change?
What are the observed colours if any?
Which wells had precipitates?
What was the nature of the precipitate?
Explain your answer with chemical equations.
Now add excess NaOH (aq), record your observations and write the necessary supporting ionic equations for your observation

Appendix B: A sample of an application question for qualitative analysis

In a laboratory exercise, you are required to separate the cations in an aqueous solution containing $Pb(NO_3)_2$, $Ba(NO_3)_2$ and $Ni(NO_3)_2$. Write ionic equations for your separation process and show a schematic diagram of the activity. Trainees' scheme for the separation of the cations is presented. (A double vertical line implies that an/a ion/salt precipitates out of solution).