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Using small scale chemistry equipment for the study of some organic chemistry topics- a case study in an undergraduate class in Ghana

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Abstract

Practical work increases comprehension of scientific concepts and so is advocated as an important factor in the teaching and learning of especially chemistry, where most concepts appear abstract. Yet the growing cost of science materials and increasing numbers of students make the regular and efficient performance of chemistry activities difficult. In this study, small scale equipment was introduced in an undergraduate class to access its feasibility for adoption in all chemistry activities. 110 students participated in the study for a semester. Data to assess the feasibility of the intervention was gathered through a questionnaire and interview schedule. About 79% of the sample agreed that it was feasible, fun and easy to use the small scale equipment. They added that it allowed more time for discussions as activities were accomplished in relatively shorter times.

Keywords: aldehydes, benzoic acid, ketones, organic chemicals, small scale chemistry equipment,

Introduction

Practical chemistry increases the conceptual understanding of chemistry principles as well as in their application in our daily lives. This is because concepts help us to define and explain objects and events in our environment [**1**]. Learning concepts in inadequate and inefficient ways lead to the formation of alternative concepts [**2**]. Studies have shown that alternative concepts are permanent, continuous and act as barriers to the development of scientific concepts. The studies add that such wrong or naïve concepts are difficult to remediate by traditional techniques [**3**]. Often, more innovative or active techniques would be required for such remediation. There is currently a move from the traditional acquisition of knowledge to scientific inquiry [**4**]. Students now have to acquire knowledge through the process of doing and sequential arrangement of facts to arrive at conclusions or solve problems rather than through the lecture and blackboard demonstrations [**5**]. Laboratory practical activities could also to some extent eliminate discrepancies which result from individual differences. In addition, it improves the way students deduce implications, think critically view things scientifically and solve problems [**6**].

Practical activities require special facilities and equipment. Fully equipped laboratories (labs) are essential but not always necessary as small scale equipment could serve the same purpose as large macro glassware for standard laboratories [**7,8**]. The increasing cost of chemicals and equipment require that other forms of equipping students with the necessary science skills be developed. Some institutions have resorted to virtual labs; while some have reduced their number of laboratory activities to cut down cost [**9**]. Cutting down cost through the reduction of activities will lead to compromising the acquisition of science process skills for personal research and future generation. The use of virtual labs and reduction in lab activities will limit students in their drive to improve upon their research and lab skills in preparation for work as analytical chemists and researchers for their countries and the world at large. Some teachers increase the number of theory teaching hours to compensate for the loss in practical hours. Others resort to demonstrations with non-participatory students and often large groups of students. Small scale chemistry equipment is now adopted by some institutions in both developed and developing nations to solve the lack of practical activities in schools [**7, 10, 8, 11**]. Several activities such as qualitative and quantitative analysis, electrolysis, stoichiometry and aspects of the periodic chemistry have been successfully taught with small scale chemistry equipment (SSCE). The concept underlying the use of the small scale chemistry equipment is to use chemicals in drops or microliters to observe reactions and develop science concepts. The use of chemicals require one gram at most or lower, compared to over 5 grams for use with macro equipment. Generated waste is always small and causes less disposal and environmental effects. Chemicals for use with this tiny durable plastic ware are affordable and safe for use at all levels of education. It allows students to work freely without fear of breakages and unwarranted explosions. The small scale chemistry equipment (SSCE) comfortably accommodates budget cuts in schools and at national levels and is in line with the current economic downturn.

Activities involving the use of SSCE are "interactive". Traditional laboratory experiences point students' attention to getting "good results" by following prescribed procedures. They tend to go through laboratory procedures passively without grasping related concepts. The SSCE approach aims at training students to become more careful observers and critical thinkers during practical exercises. In many short, hands-on SSCE exercises to enhance conceptual understanding, students test new ideas as they are being presented on the spot. Such positive experiences have been reported from its practice in all levels of education in countries such as Ethiopia, America, United Kingdom and South Africa [**12, 13, 14**]. Kelkar and Dhavale **[15]** reported that undergraduates performed activities with more care and their skills in handling equipment were markedly improved after adoption of the small scale technique in their laboratory. Teachers can also use it as a tool to design new laboratory activities to enhance deeper concept understanding of chemistry topics [**16**].

The objective of this study was to assess undergraduate students' responses to how small scale chemistry equipment affected their learning of organic chemistry.

Method

A total of 52 small scale chemistry equipment from the centre for Mathematics, Science and Technology Education, South Africa (RADMASTE), were supplied to 110 students who worked in pairs in two batches. Experiments designed for the semester covered topics such as qualitative analysis (test for aldehydes and ketones, test for unsaturated hydrocarbons, tests for identifying and classifying alcohols) preparation of esters, recrystallization (purification of aspirin) and acid-base extraction of benzoic acid from naphthalene.

A mix of close and open ended questions was administered at the end of the exploratory study. In all there were 10 close ended questions and 5 open ended questions which constituted a survey questionnaire. This was followed by an interview to assess the participants' impressions about the feasibility of the small scale chemistry equipment in learning concepts in organic chemistry. The results were analysed by finding simple percentages of the gathered data out of an expected whole.

Results and discussion

Feedback from students on the usefulness of the SSCE to facilitate understanding in the study of organic chemistry was gathered through their opinions about practical activities which they performed in part A of a survey questionnaire. Part B of the questionnaire also assessed their opinions but was more in-depth in that it allowed the students to express themselves freely. The students' responses to Part A of the questionnaire are presented in Table 1.

Table 1: Part A of the student survey questionnaire

Item	Agree	Not agree	No response
1.Can be used in the secondary or basic school	93 (84.55%)	7 (6.36%)	10 (9.09%)
2.Easier to use than macro equipment	56 (51%)	50 (45.50%)	4 (3.64%)
3.Unable to see results	28 (25.45%)	82 (74.55%)	0 (0%)
4.Possibility of repeating activity without loss of time	95 (86.36%)	9 (8.18%)	6 (5.45%)
5.Enhance understanding of topic/concept	79 (71.82%)	29 (26.36%)	2 (1.82%)
6.Positively affect interest in learning organic chemistry	99 (90.09%)	11(10%)	0 (0%)
7.Increases confidence in organic practical activity outcome	90 (81.82%)	15 (13.64%)	5 (4.55%)
8.Exposes initial 'wrong' ideas	68 (61.82%)	31(28.18)	11(10%)
9.Provides opportunity for active learning	100 (90.91%)	8 (7.27%)	2 (1.82%)
10.Reduced quantities of chemicals is good for the environment	110 (100%)	0 (0%)	0 (0%)

From students' responses in Part A shown in Table 1, it is observed that about 79.3 % of students answered positively to the benefits they derived from their use of the small scale equipment. 20.7% however did not agree with or were impassionate about the assertion made by a greater number of students. 17.1% did not agree with some of the close ended items while 3.6% did not respond to some of the questionnaire items at all. Responses to part B of the questionnaire sought for further in-depth clarification about students' opinions on the SSCE. The questions asked were:

1. How different is the small scale chemistry equipment different from the traditional equipment?
2. You have to prepare and recrystallize sample A during the last 30 minutes of your practical work. In which of the procedures (SSCE and Traditional) would crystals form faster, with the same given concentrations? Explain.
3. It is asserted that working with the SSCE enables one to understand concepts in organic chemistry better than in the traditional method. How true is this assertion?
4. What did you like least about the introduced SSCE?
5. What suggestions would you want to make to improve the use of SSCE for further/other chemistry topics?

In the open section of the questionnaire students had better opportunity to express their views on the use of the intervention. Analysis of responses to item 1(of part B) of the questionnaire also produced very positive results about the SSCE. Some of the students' comments were:

- Working with the SSCE was fun and interesting. Pairing leads to conservation of chemicals
- Less chemicals were used so reaction times were shorter and results were attained in relatively shorter times (as compared with the traditional macro scale activities)
- Trouble over breakages were eradicated
- Sometimes it is difficult to observe a reaction but in the end it helps to replace wrong ideas with correct ones.
- It enhances one's understanding because you do more activities and see the results for all the different reactions

In response to item 2, respondents unanimously opted for the small scale equipment as being the one which end reaction would be achieved faster to give faster results. Responses obtained to the third open questionnaire item confirmed findings by Zakaria, Latip and Tantayanon **[9]** that small micro equipment has the in-built capacity, if used effectively, to enable students to build their own concepts. This also confirms the result obtained in item 5 of the close-ended questionnaire, where 79 (71.8%) of the students said that their conceptual understanding of topics in organic chemistry had been enhanced. Responses to items 4 and 5 followed a similar pattern as obtained in items 2, 4, 5, 6 and 7 of the close-ended questionnaires. Students said some of the following:

- Gain in confidence in ability to work with small amounts of material
- Hands-on activities provided a lot of opportunities for collaborative learning and gain in confidence
- Ability to accomplish more in a shorter time

Interestingly, students made positive observations about the SSCE approach when they were asked about what they liked least. The researcher expected that an opening had been given for the expression of negative aspects of the SSCE. Some researchers had found out in their studies that their participants had difficulty handling the tiny science equipment [**17, 18**]. Yet the responses of the participants in this study were all vastly positive.

Responses from the semi-structured interview confirmed most of the assertions that students had made in the closed questionnaire. For example a student said that he was now aware that the bromine colour was observed in their reaction with unsaturated hydrocarbons because they added on to the unsaturated molecule. This observation was made after the student had worked with quite a range of saturated and unsaturated compounds and was able to make an informed distinction with scientific reasons. Other students also expressed with interest how they had argued in their group on the formation of a silver mirror and how they performed various activities based upon their original ideas until they finally uncovered the truth through one of the activities they performed. Students intimated that less chemical were used so the school was saving on chemicals and it was good. They added that because low volumes of chemicals were used, less waste was produced and the environment would not be badly damaged if they were per chance disposed of indiscriminately. This was clear that the ethics of resource conservation had been instilled in students through a subtle creation of awareness through the use of the small equipment. They further said that it increased their confidence in performing chemistry activities besides engaging them in active hands-on and mind-on learning. Students' were particularly excited about the reduction in wait time for the appearance of activity results. The SSCE allowed the students to concentrate more on science processes instead of concentrating on breakages with equipment as they do in standard macro labs.

Conclusion

Data gathered from the study indicate that it would be feasible to use small scale chemistry equipment in the study and performance of organic chemistry practical activities at the Chemistry Department of the University of Education. The outcome of the study proved that highly equipped laboratories were good but not necessary for carrying out organic chemistry activities [**10**]. Students said that the SSCE kit was safe, easy to carry around, easy to use and time saving. It also protected the environment from toxic waste. Above all it enabled them to understand some concepts such as that of distinguishing between acid-base extractions and distinguishing between substances within a functional group, which they had been struggling to understand. Students paid less attention to the simple equipment which was not easily possible in the traditional experiments. Thus they were able to concentrate more on science processes and benefited by answering questions more scientifically than they did in their traditional labs.

Recommendation

Laboratory instructors and teachers have to be innovative in their attempts to help students learn or develop science process skills for their future and that of the world at large. Adopting the use of small scale chemistry equipment or downsizing macro activities in topics such as electrolysis and periodic chemistry could go a long way to benefit both students, teachers and educational managers as there would be greater conservation of resources especially in less endowed communities and in these present days of economic downturn.

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