ADAPTING THE STUDY OF CHEMISTRY IN SENIOR SECONDARY SCHOOLS IN THE GAMBIA TO COST-REDUCING STRATEGIES

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ABSTRACT

In an attempt to elaborate the concept of cost reduction, the researchers tried to explain why the judicious application of expendables and the need to miniaturize experimental models should be introduced in schools, embellishing and drawing examples from relevant literature materials. The researchers further explored, through a survey, the perception of Gambian based teachers on the extent to which their experience and qualification had influenced their judicious use of expendables. And, through an experimental study, the researchers compared the learning outcome derived from student learners who were taught chemistry by the conventional macro model on the one hand with their equivalent counterparts taught the same chemistry concepts by the micro model on the other hand. In the survey design; three research questions were answered and three hypotheses tested while in the experimental design two research questions were answered and one hypothesis tested. By means of multi-stage random sampling techniques, samples of 100 chemistry teachers and 200 senior chemistry students were used for the study. A questionnaire validated and reliably determined with a composition of 27 items was administered to the chemistry teachers, while a standardized test of ten items was also administered to two equivalent groups of 100 chemistry students each taught by the macro and micro models, respectively. At the level of 0.05 probability, qualification and experience, acting independent of each other, were significant factors in adjudging the extent to which chemistry teachers had applied expendables judiciously. At the same level of probability, no significant difference existed between the learning outcomes obtained in the use of the two models, even though the chemistry students taught chemistry by the micro model had a slight edge over their macro model counterparts. Finally, relevant recommendations were made. *[AJCE, 1(2), July 2011]*

INTRODUCTION

The practical orientation of chemistry teaching involves a high consumption of expendables and a considerable amount of glassware casualty. Indeed, a large school consumes a considerable quantity of materials. According to Scott (1992), 6kg of copper II tetraoxosulphate (VI) and 5kg of sodium trioxosulphate (II) are utilized per annum. Such consumption pattern imposes a considerable financial burden on the school concerned especially for schools in sub-Saharan Africa of which The Gambia is one.

There have been economic pressures on the secondary school system of The Gambia: pressures arising from inadequacy in the provision of basic support services and facilities such as electricity, water, telecommunications, etc. There have been pressures arising from the devaluation of the dalasi (the currency in The Gambia, 1USD = D29.50), high cost of textbooks and reference materials, high cost of building construction and maintenance, low purchasing power of parents and students. The scan of approved budgets shows a steady increase during the last five years. This cannot be considered as increased funding if the purchasing power of the dalasi is introduced into the equation. If adjustments were made to reflect current exchange rates, a picture that emerges is one of drastically reduced funding (1). If this is the case, good laboratory management techniques and practices should be prudent to the extent that they are cost reducing.

The concept of cost-reduction cannot be tagged to a definite reference point. According to Mogbo (2) it is a multi-dimensional concept in reagent/apparatus economics which includes improvisation, role-simulation, conscious application of locally available materials, ability to economize the quantity of reagents used in experiments, of recycling procedures, control over potential glassware casualty, ability to minimize the contamination of reagents, repairs and maintenance of equipment, extent at which valuable experimental products are made and stored ready for the market and the ability to use small-scale experiments.

There are many reasons why cost-reducing strategies should be introduced. Cessac (3), Calbraith (4) and Lorch and Lawrence (5) suggested that since the grant-in-aid to schools was not enough, other resources of funds or productivity should be explored and tapped fully by school heads who have the responsibility of ensuring that their schools survive and achieve their goals, times and constraints notwithstanding. Mani (6), Chukwuemeka (7) and Mojekwu (8), while contending that it was too expensive to purchase materials and equipment to go round the students, called on relevant organs to endeavor to provide alternative sources for the teaching of the science curriculum.

Practitioners have indeed, at one time or the other, applied sufficient ingenuity to take care of the expensive nature of science teaching. Carrol and Steward (9), in an attempt to arrest the continuous rise in the cost of equipment and chemicals, established a chemistry kit based on the pegboard method. Students preferred this device to the conventional apparatus. More importantly, this model had certainly reduced the huge financial involvement associated with carrying out these experiments at the conventional macro scale. Farmer (10) in explaining many scientific phenomena based on liquids, air, other gases, mist/fog, extractions *etc* merely scaled down his experimental model to a mere disposable syringe fetched at no cost at all. Wilson (11) introduced a technique whereby the volume size or mass size of chemicals is scaled down, thus ensuring, in the long run, that the quantity of materials employed by a student for a macro-experiment is equivalent to the amount employed by at least ten students for micro-experiment. What is more, the quality of the two experimental results remains the same. Thus small-scale experiments, whereby the adaptive and committed teacher miniaturizes the size, mass and volume of experimental quantities (9-11), such as model and reacting substances, without affecting the experimental procedures and results, when compared with the macro-counterpart and without jeopardizing the overall learning outcome, become salutary.

Apart from scaling down the experimental quantities, it is also necessary that expendables be applied judiciously and economically. This practically-oriented contrivance borne out of good initiative, resourcefulness and training ensures that the chemistry/science teacher should deliberately embark on the economic use of chemicals and other associated consumables such as gas, indicators, water and splints, and thus ensure that through prudent laboratory management technique, the overall learning outcome derivable from such controls is not jeopardized. Evidence abounds. Gupta, Pander and Ameta (12) illustrated how the highly expensive copper turnings, which under normal circumstances constitute a terrible waste during the preliminary test for trioxonitrate (V) ion, could be replaced with filter paper cuttings. As for the filter papers, they are inexpensive and play out their natural role expectation, a waste. Herrickson and Robinson (13) introduced a gravimetric determination substitute for the very expensive silver salt. Adeniyi (14) appeared to have found an inexpensive method of preparing concentrated common salt, Epson salt, alum and local gin.

Adeniyi (14) was also able to provide an answer to tin (II) chloride which often constituted itself into a colossal waste by its self-induced contamination either on long standing, poor storage or the inevitability of an action. He therefore explained how it could be prepared fresh from common tin when needed. Otuka (15) dwelt extensively on the need for prudent laboratory management technique based on the ordering, stocking, storage and safety of equipment.

This study therefore explored the perception of chemistry teachers in The Gambia on the extent to which their experience and qualification have influenced their judicious use of expendables. Furthermore, it compared the learning outcome derived from student learners who are taught chemistry by means of the conventional macro-models on the one hand to their counterparts by the economy small-scale or micro-models on the other.

THE PROBLEM

This study explored two problems in The Gambian context:

1. It intended to find out whether chemistry teachers have been able to apply caution in the use of expendables especially in these days of economic recession when, according to Ogunniyi (16) and Mbaekwe (17), good chemistry teaching is severely threatened by lack of fund, large class size, careless attitude to laboratory materials by chemistry students and apathetic disposition to chemistry by secondary school administrators, many of who did not undergo adequate formal education in science
2. It also intended to compare the overall learning outcome of students taught chemistry, using the economy micro-models with their counterparts taught the same concepts using the conventional macro models.

In order to tackle the above problems, two sets of basic questions and hypotheses were formulated and tested. The first deals with the judicious use of expendables as a cost-reducing strategy in the study of science/chemistry. The following research questions and null hypotheses formed the basis of this first part of the study.

Q_1. To what extent have chemistry teachers applied expendables judiciously?

Q_2. How far has qualification influenced chemistry teachers in their judicious application of expendables?

Q_3. To what extent has experience of chemistry teachers affected their ability to employ expendables judiciously?

Ho_1. Qualification of chemistry teachers is not a significant factor in adjudging the extent they apply expendables judiciously as determined by their mean ratings.

Ho_2. There is no significant difference between experienced and inexperienced teachers in their cautious use of expendables as determined by their mean ratings.

Ho_3 . There is no interactive effect between experience and qualification.

The second set of basic questions and null hypotheses dealt with the small-scale experiments as a cost-reducing strategy in the study of chemistry. Accordingly, the following two research questions and one null hypothesis were tested:

Q_4. To what extent have chemistry students improved their overall learning outcome through the use of conventional macro-models?

Q_5. To what extent have chemistry students improved their overall learning outcome through the use of economy small-scale models?

Ho_4. There is no significant difference between the performance of students taught chemistry by means of the conventional macro models and their counterparts taught the same concept by means of the economy small-scale models as determined by their mean ratings.

METHODOLOGY

In line with the problem and the research questions/hypotheses, two separate research designs were employed, namely, survey and experimental study.

Survey Study

The survey study involved chemistry teachers in The Gambia on their ability to apply expendables judiciously. Specifically the study sought out the effects of experience and qualification on chemistry teachers' ability to apply expendables judiciously. 200 chemistry teachers were selected on the basis of multi-stage random sampling techniques from 50 secondary schools in all the six educational regions in The Gambia. This sample was further stratified into qualification and experience using table of random numbers into 30 highly qualified, 35 moderately qualified and 35 lowly qualified teachers and 25 highly experienced, 35 moderately experienced and 40 lowly experienced teachers.

Only the questionnaire was employed for data collection. The chemistry teachers were expected to respond to two types of questionnaire based on supply type/data blank and select type/checklist. The questionnaire for the latter was based on a four-point Likert-scale, namely: 4 = Optimal use of expendables judiciously, 3 = Moderate use of expendables judiciously, 2 = Sparse use of expendables judiciously, and 1 = No-use of expendables judiciously (for the instrument, see Appendix 1).

In order to ensure the face validity of the questionnaire, draft copies were sent out to four experts: one in curriculum studies, one in the sciences, one in chemistry education, and one in measurement and evaluation. The reliability of the instrument was determined using the Cronbach-Alpha method.

Data involving all three research questions were answered using means and standard deviations. Data involving the three hypotheses Ho_1 and Ho_2 and Ho_3 were tested at $P \leq 0.05$ level of significance using ANOVA. Experience was categorized into three using the following scale: 0 – 5 years = low experience, 6 – 15 years = average experience, and above 15 years = high experience. Qualification was classified into three using the following academic milestones that are common in The Gambia, namely Higher Teacher's Certificate (HTC), Ordinary National Diploma (OND), Nigeria certificate in Education (NCE), and Higher National Diploma (HND): HTC/OND/NCE = low qualification, first degree chemistry or HND science = average qualification and higher degree in science = high qualification. The extent to which expendables are used judiciously was classified as follows: Above 3.50 = judicious use of expendables optimally, 2.50 to 3.50 = judicious use of expendables moderately, 1.50 to 2.49 = judicious use of expendables sparingly and below 1.50 = non-use of expendables.

Experimental Study

The experimental design was employed in executing the second part of the study, that is, comparing the learning outcome derived from students who were taught chemistry by the conventional macro model with their equivalent counterparts taught the same chemistry concepts by the micro model. It involved 10^{th}, 11^{th} and 12^{th} grade secondary school chemistry students from all the six educational regions of The Gambia. Specifically the study attempted to find out the impact of teaching strategy-based model (conventional macro-model versus economy micro-scale) on the overall learning outcome of chemistry students. The sample was composed of 200, 10^{th}, 11^{th} and 12^{th} grade senior chemistry students that were selected on the basis of multi-stage random sampling technique from senior secondary schools within the six educational regions in The Gambia. Of this number of students, based on production of two similar/equivalent groups, 100 students were taught chemistry using the conventional macro-models while the other half of the students were taught the same concepts using the economy micro-models. The two groups were made similar by means of earlier tests in practical volumetric analysis and practical qualitative analysis. Consequent on their performances in these two tests, an attempt was made to match all the two hundred students into two groups. Finally, the odd and even number method was used in order to put the matched groups into two compartments. One compartment, the control group, was made up of students who were taught some named chemical concepts using the conventional macro-model while the other group, the experimental group, was made up of similar or equivalent students who were taught the same chemical concepts using the economy micro-model. The means of each of the two groups in qualitative and quantitative analysis were calculated in each case. The two mean scores were close to 59.10 and 58.99 for macro- and micro- models respectively on qualitative analysis. On quantitative analysis, the means were 59.12 and 59.11, respectively.

Ten test items were developed and standardized by the researchers and used in collecting the pertinent data. For standardization, 25 senior secondary schools were selected from the Greater Banjul Area for a trial run. A table of specification defines the scope and emphasis of the test and relates the objectives of the test to its content. The try-out tests were given to a sample of 10 students drawn from each of the randomly selected schools. After scoring, additional comments from two experts on measurement and evaluation and two experts from chemistry pertaining to the timing and clarity of instructions were sought and noted by the researchers. This enabled the researchers to replace the poor distracters. On administering the test to the 10 students, an item analysis was made to remove more of the poor items. Their item difficulty indices and their discrimination indices were obtained for ten test items.

Based on the test-retest method and allowing for an interval of two weeks between test and retest, the correlation coefficient was calculated to be 0.79 using Pearson. The dichotomous scoring of items based on right and wrong answers were considered through the Kinder-Richardsons's formula 21, which gave 0.81, in which poor performance = 0% - 39%, average performance = 40% – 59%, and good performance = 60% - and above. Research questions Q_4 and Q_5 were answered using means and standard deviations. The null hypothesis Ho_4 was tested using t-test analysis.

Out of a total of four chemistry education majors that were trained for five days at the University of The Gambia, two of them were assigned to teach the controlled group. The other two taught the experimental group. Both groups were subjected to the same topics and constrained to the same time spectrum. The topics consist of i) preparation, properties and reactions of hydrogen sulphide, ii) acid-base titration, iii) identification of common cations, iv) identification of common anions, and v) preparation, physical properties and reactions of ethanol.

The approaches utilized in teaching the concepts listed above can be found in Appendix 2. In other words, Appendix 2 provides the conventional macro-approach versus economy small-scale approach in teaching the same topics to two similar or equivalent groups of students. It also provides the relative cost and advantage of each approach as applied in the context of The Gambian schools.

RESULTS

The data collected through the various instruments and analyzed using the methods of analysis described above were presented in the ensuing pages.

Table I. Influence of qualification on the extent to which chemistry teachers have applied expendables judiciously.

Nature of Qualification	**Mean Scores**	**Std. Deviation**	**N**
Highly Qualified	3.14	0.64	30
Averagely Qualified	2.94	0.80	35
Lowly Qualified	2.56	0.73	35

The results in Table I clearly show that qualification of the teachers has a measure of influence on the judicious use of expendables during the practical class sections. The highly qualified chemistry teachers had the highest mean score with the lowest standard deviation.

Table II. Influence of experience on the extent to which chemistry teachers have applied expendables judiciously

Nature of Experience	**Mean Score**	**Std. Deviation**	**N**
Highly Experienced	3.33	0.31	25
Averagely Experience	2.20	0.60	35
Lowly Experienced	1.99	0.74	40

The most experienced chemistry teachers made the most judicious use of chemical expendables as evidenced by their highest mean score out of the three categories reflected by the above results in Table II.

Table III. ANOVA table for qualification of chemistry teachers and the extent to which they applied expendables judiciously

Source of Variation	**Df**	**Sum of Squares**	**Mean Squares**	**Fcal**	**F table**
Explained	2	38.4	19.20	6.00	3.15
Residual	98	294.2	3.00		
Total	100	332.6			

Significant at 0.05 alpha level

Since the analysis of variance (ANOVA) showed that the observed or calculated F value is higher than the critical F value, the test statistics is in the critical region, and we reject the null hypothesis of no significant factor. Therefore, the chemistry teacher's qualification is quite of a positive significance in adjudging the extent to which expendable have been applied judiciously.

Table IV. ANOVA table for experience of chemistry teachers and the extent to which they applied expendable judiciously

Sources of Variation	**Df**	**Sum of Squares**	**Mean Squares**	**Fcal**	**F table**
Explained	2	36.80	18.40	6.23	3.15
Residual	98	288.60	2.94		
Total	100	325.40			

Signification at 0.05 alpha level

Since the observed or calculated F value is higher than the critical table F value, the test statistics is in the critical region, and we reject the null hypothesis of no significant factor. In other words the chemistry teacher's experience is quite of a positive significance, in adjudging the extent to which expendable have been applied judiciously.

Table V. ANOVA of mean scores of interactions between qualification and experience in adjudging the extent to which expendables have been applied judiciously

Source of Variation	Sum of Square	Df	Mean Squares	Fcal	F table	Decision
Main Effects	32.470	2	16.235	0.773	3.150	NS
Qualification	380.76	2	190.38	9.060	3.150	S
Experience	256.50	2	1228.25	6.13	3.150	S
2-way interactions						
Qualification/Experience	1228.70	1	128.70	6.125	4.000	S
Explained	1653.50	5	330.70	15.738		
Residual	1996.20	95	21.013			
Total	3649.70	100	36.797			

S= Significant at P<0.05 and N.S=not Significant at P<0.05

Table VI. Mean scores of chemistry students taught chemistry concepts through the macro and micro models.

N	Mean Score	S.D	group
50	0.52	2.75	Macro model
50	0.54	2.41	Micro model

Since both mean scores are very close, also the respective standard deviation, this indicates that there is no significant difference between the performance of students taught chemistry by means of the conventional macro models and their counterparts taught the same concept by means of the (economy small-scale) micro model.

Table VII. t-test in the mean scores of two groups of students taught separately by the micro and macro models

Group	N	Mean Score	SD	tcal	T table
Macro model	50	0.52	2.75	0.0385	1.980
Micro model	50	0.54	2.41		

Not significant at 0.5 probability level.

The t statistics or t calculated does not fall into the critical region, rather it is lower than the t table or t critical, therefore the hypothesis was accepted, that no significant difference exists in the mean achievement scores of two groups of students taught separately by the micro and macro models.

Based on the data in the above tables and the corresponding interpretations, we can summarize the main findings as follows:

I. Highly Qualified teachers and their averagely and lowly qualified counter parts employed the judicious use of expendables moderately. The highly qualified teachers employed them more judiciously than the others while the lowly qualified teachers brought up the rear employing them least judiciously.

II. While highly experienced teachers employed judicious use of expendables moderately, the averagely experienced teachers and their lowly experienced counterparts judiciously employed them sparingly, with the averagely experienced employing them better.

III. Qualification of chemistry teachers was significant at 0.05 level of probability in adjudging the extent to which the Chemistry teachers had applied expendables judiciously.

IV. Experience of chemistry teachers was significant at 0.05 level of probability in adjudging the extent to which the Chemistry teachers had applied expendables judiciously.

V. Both groups of students who were taught prescribed chemistry concepts by macro and micro models performed averagely with the latter having a slight edge over the former.

VI. At 0.05 level of probability, no significant difference existed between the learning outcomes in the use of the two models.

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

The findings on 'experience' are hardly surprising. Human resource conditions have to be adequately provided if meaningful judicious uses of expendables are to be embarked upon. It is hardly expedient to expect a lowly experienced chemistry teacher to inculcate, let alone, internalize these strategies. Therefore in terms of experience, highly experienced chemistry teachers are likely to provide the most needed cutting edge to judicious use of expendables. These observations are in agreement with Mogbo and Jonsyn-Ellis (18).

In the case of qualification, its relevance to judicious use of expendables cannot therefore be overemphasized. Thus, from the findings, a highly qualified chemistry teacher would appear to have employed expendables more judiciously than the moderately and lowly qualified chemistry teacher. Again, the quality and extent of good chemistry teacher will always depend on the extent the teacher is helped to improve his/her skills, knowledge and competence along innovative line based essentially on modern teaching techniques. This observation conforms to Mogbo (19) who posited that qualification was a significant factor in the judicious use of expendables. Implicit in and derivable from this is the fact that chemistry teachers could enrich their judicious use of expendables by acquiring the necessary experience. Furthermore, the more chemistry teachers take advantage of the essence of higher qualification, the more they are likely to acquire greater skills, competencies and proficiencies in the application of expendables judiciously.

Generally, low judicious use was made of expendables on the use of improvised materials, small scale experiments, encouraging the utilization of low concentration of reagents, use of group experiments, and on issues that touch on the avoidance of contamination. Cautious application to expendables demands a lot of planning, co-ordination, persuasion and evaluation. It demands time, expertise, dedication and patience. It has a lot to do with management of scarce resources. Laboratories may never anticipate a revisiting of economic buoyancy when the principal of a school was allotted a huge sum of money as budget for chemistry. Those were the days when indistinct labels to reagent bottles were ignored without a fight to re-identify them and whole contents of Winchester bottles poured down the drain without batting an eye-lid. In the words of Mogbo (19), the teacher must be able to commit his/her professional, creative, technical and ingenious talents if expendables have to be judiciously applied.

An attempt should be made at ensuring that the minimum amount of expendables required for sustaining the analytical need of each pupil be ordered and employed. While placing an order an attempt should equally be made at combining minimally all the cations and anions within a salt marked for investigation while playing down on unnecessary duplication. It is unnecessary to subject expensive salts to investigation. Where it becomes desirous to investigate, for instance the nitrate in a salt, sodium nitrate, a relatively cheap salt would be preferred to the highly expensive silver one.

Students should be convinced that any investigative reagent should be sparingly used. In addition, hand pipettes and spatulas should not be dipped directly into reagents as this could engender contamination with its inescapable problem of stultifying good results. In any case, once contaminated, the reagent becomes a liability, a waste and once discarded it increases cost because it has to be replenished with money.

When a multiplicity of wet tests is desired, it is cheaper for the teacher to dissolve samples of the salt in copious volumes of water, a fact that will inestimably reduce cost. Thus, the use of solutions is less expensive than the use of solids. In experiments involving volumetric analysis, efforts should be made to reduce to a reasonable minimum the actual molarity of the salt to be determined. Group and demonstration experiments should be encouraged as an occasional measure to obviate the huge expenditure involving large classes.

From the results the use of improvised materials was not popular with chemistry teachers. This unfortunate practice would appear to negate the views of Otitoji (20) and Balogun (21) who had variously declared that chemistry teachers should adopt them in order to inculcate the virtue of self-reliance which could make them sufficiently imaginative to combat shortage of materials in all their ramifications. Thus Adeniyi (14) suggested a wide range of materials and techniques for improvisation borne out of his personal experience.

Idris (22) practicalized the view that the solution to problems of scarcity for teaching lay in the ability to improvise from local available materials while Ehiemere (23) had demonstrated how simple materials for science teaching could be obtained from supermarket, departmental, hardware and chemist shops as well as from local dumps. Alonge (24) enumerated the relevance of some local materials to the teaching of chemistry, positing further that some of them could be found as house-hold materials. Okwu (25) in his own contribution had directed the attention of chemists to certain traditional activities based on chemical principles. They include iron smelting and forging, fermentation and distillation of palm oil, extraction of medicinal plant products and dyeing.

Even though from the results no significant difference existed in the learning outcomes obtained from the students taught the prescribed chemistry concepts by the use of micro and macro- models, it is pertinent to note that the former achieved slightly better than the latter. This result is similar to the results obtained by Mogbo (26).

The reasons are obvious. The use of small-scale models exposed pupils more to visible and tactile experiences considering the ease of replication of small-scale models to virtually all the students in contradistinction to the prohibitive cost of the macro-equivalent which invariably constrained students to the use of fewer numbers of so-called sophisticated equipment with such 'estrangement' occluding the internalization of scientific processes and skills (27). More than this the micro-model operations are about ten times cheaper than their macro-counterpart.

This study has therefore attempted to show how the chemistry teacher can emphasize cheaper but adequate experimental designs; reflect on the current and true mood of nations within the sub-region; inculcate simple but correct laboratory skills; imbue worthwhile virtues manifested by self-reliance, self-sufficiency, prudent spending and a maintenance culture; integrate the environment with learning; fashion out materials from cheap sources and demonstrate creativity in order to circumvent obstacles.

Finally, we recommend, based on our findings that:

- Chemistry teachers must be urged to upgrade their knowledge, skills and expertise in quest for higher qualification.

- Lowly qualified chemistry teachers should be encouraged to benefit from pre-service training programmes.
- All categories, irrespective of rank or experience, must be encouraged by the various educational organs to attend in-service training programmes deliberately targeted to cost-reduction.
- Chemistry teachers on their own are urged to become more resourceful.

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APPENDIX I

Questionnaire on the judicious use of expendables as a cost-reducing strategy in the study of Chemistry

Item	***Strategy***
1	*Use of Improvised material when conventional material is not available*
2	*Ability to quantify and record the amount of expendables committed to an experiment*
3	*Use of small-scale experiments when the expendables are not within reach of each student*
4	*Priority placement of expendables considered indispensable while making a purchase*
5	*Ensuring that the delivery note accompanying an order is identical with the expendables ordered*
6	*Ensuring that correct numbers arrive*
7	*Ensuring that chemicals that react together are not stored together*
8	*Ensuring that chemicals that are susceptible to photochemical disintegration are stored in colored bottles*
9	*Ensuring that the expendables on delivery perform the roles expected of them*
10	*Encouraging the utilization of low concentration of reagents*
11	*Use of group experiments when the expendables are not within the reach of each student*
12	*Teacher or Laboratory assistant or both of them personally or collectively dole out solid salt solution to students thus controlling waste and contamination*
13	*Teacher or laboratory assistant keeps tag of the in-coming and out-going expendables as they are replenished or used up*
14	*Teacher exercises great care over the preparation of stock solutions especially when carried out by the laboratory assistant*

15	*Teacher ensures that only bench reagents are made available to students*
16	*Teacher ensures that students replace stoppers to reagent bottles after use*
17	*All spatulas/ hand pipettes should be properly washed and dried before they are dipped into solid salts or salt solution*
18	*Reagents brought out of parent bottles should not returned to the same bottles*
19	*Stoppers to reagent bottles should not be allowed to lie horizontally on benches*
20	*Each student should own his own spatula or hand pipette*
21	*Only the Teacher and his laboratory assistant have access to Winchester bottles, stock solutions and other storage facilities*
22	*All solutions should be prepared with distilled water, if aqueous solutions are needed*
23	*Reagent bottles are properly washed before they are committed as containers to other reagents*
24	*When the Teacher is not sure of the identity of a chemical, he should either discard it or test it for re-identification*
25	*Reagent bottles are labeled boldly and properly*
26	*Through spot tests or even through more rigorous tests all reagents are inspected on a regular basis*
27	*Storing materials suspect to a high degree of pilferage in securely locked cupboards*
28	*Carrying out a proper investigation of all losses and taking appropriate action after investigation*
29	*Use of fire-warning labels on flammable materials*

APPENDIX 2

Conventional macro-approach versus economy small-scale approach in teaching the same topic to two similar or equivalent groups of students (1 USD = D29.50)

Topic	***Macro-Approach***	***Small-scale approach***
1. Preparation, physical properties and reactions of hydrogen sulphide	*Kipp's Apparatus at an unaffordable cost to most institution*	*Disused plastic wash-bottle fitted with a cork through which a disused coca cola straw will pass*
Cost per kit	*D10, 000. 00*	*D5.00*
Relative Advantage	*Sophisticated*	*Cheap. Every student will most likely work on his own*
2.Acid-base titration	*Conventional molarities in accordance with textbook prescriptions are put to use. Conventional apparatus is also put to use. (made of glass)*	*Molarities scaled down to (1/10) of the molarities used for Macro-approach capacities of materials scaled out and improvised from plastic bottles and tubes and clips*
Cost per a set of apparatus plus a set of chemicals for one student	*D200. 00*	*D10.00*
Relative Advantage	*Sophisticated*	*Cheap and within reach of every student*
3. Identification of cations and anions	*Mass of a solid to be doled out to each student is between 0.5g and 1gm and for the volume it is between 15cm3 and 30cm3. All apparatus to be used is large and conventional*	*Mass of solid to be doled out to each student is between 0.01g and 0.05g while for the volume, it is between 1cm3 and 3cm3. All apparatus will be improvised from waste materials scavenged from dumps and homes*

Cost per practical period per student	*D300.00*	*D25.00*
Relative Advantage	*Sophisticated*	*Available, cheap*
4. Preparation, physical properties and reactions of ethanol	*Quick fit apparatus*	*A cut and nail distillation model to be built by a local welder*
Cost per set of apparatus	*D300.00*	*D40.00*
Relative Advantage	*Sophisticated*	*Each student can provide a set for himself*
Total cost for all kits for one student for four or five experiments	*D13, 500.00*	*D80.00*