AFRICAN JOURNAL OF CHEMICAL EDUCATION

AJCE

Editorial Board

Editor-in-Chief  Temechegn Engida
UNESCO-International Institute for Capacity Building in Africa
ETHIOPIA

Associate Editors  Ahmed Mustefa
Department of Chemistry, Addis Ababa University
ETHIOPIA

Dereje Andargie
Institute of Education, Debre Birhan University
ETHIOPIA

Belina Terfasa
Department of Chemistry, Kotebe College of Teacher Education
ETHIOPIA

Sileshi Yitbarek
Department of Chemistry, Kotebe College of Teacher Education
ETHIOPIA

International Advisory Board

Prof. Peter Mahaffy, King’s University College, CANADA
Prof. John Bradley, University of the Witwatersrand, SOUTH AFRICA
Prof. Ameen F.M. Fahmy, Ain Shams University, EGYPT
Prof. Hassimi Traore, University of Wisconsin – Whitewater, USA
Prof. Hans-Dieter Barke, University of Muenster, GERMANY

© 2015 Federation of African Societies of Chemistry (FASC)

Enquiries and manuscripts should be addressed to the Editor-in-Chief: email eic@faschem.org, PO Box 2305, Addis Ababa, Ethiopia.
CONTENTS

EDITORIAL

ACRICE-2 is coming 1
Temechegn Engida

RESEARCH PAPERS

An investigation of the health hazards of some of the chemical content of powdered juice sold in The Gambia 2
O. Oyelakin, L. Jaiteh, M. A. Salisu and A. Adjivon

How can I improve my students’ ability in doing laboratory practical work on analytical chemistry-I? A case on class N23 at KCTE 13
Tolosa Geleta

Systemic assessment [SA] as a tool to assess student achievements in inorganic chemistry. Part-I: sodium chemistry 44
A.F.M. Fahmy, J. J. Lagowski

Senior secondary students’ performance in selected aspects of quantitative chemistry 69
Macson J. Ahiaikwo

The state of education and outreach activities in Africa in relation to the chemical weapons convention 84
Temechegn Engida

GUIDELINES FOR AUTHORS 94
EDITORIAL

ACRICE-2 IS COMING

Temechegn Engida
Email: temechegn@gmail.com

Dear AJCE Communities,

The African Conference on Research in Chemistry Education (ACRICE) is FASC’s official conference on chemistry education. ACRICE conference is intended as a platform for understanding and enriching education for preparation of African citizens who are able to deal with local and global challenges. To that end, educators and researchers at all levels are invited to share vital knowledge and strategies for teaching and learning in culturally responsive ways.

ACRICE-1 was held in Addis Ababa/Ethiopia in collaboration with the Department of Chemistry of the Addis Ababa University from 5-7 December 2013. The presentations at the Conference were reviewed and published as special issues of AJCE under volume 4, numbers 2 and 3 (http://faschem.org/node/5).

ACRICE-2 is planned to take place at the University of Venda (South Africa) from 29 November to 4 December 2015. As Prof. Liliana Mammino (Chairperson of the Organizing Committee of ACRICE-2) indicated (http://www.ec2e2n.info/news/2014/1506_201412) the conference will consider a wide range of themes crucial for chemical education, spanning through all instruction levels: pre-university (from younger levels to secondary school) and university (from undergraduate courses to the educational components inherent in mentoring post-graduate students). While inviting you to participate in ACRICE-2, we hope you will enjoy reading the 1st issue of AJCE 2015 on various topics in Chemistry Education in Africa.

SJIF IMPACT FACTOR EVALUATION [SJIF 2012 = 3.963]
AN INVESTIGATION OF THE HEALTH HAZARDS OF SOME OF THE CHEMICAL CONTENT OF POWDERED JUICE SOLD IN THE GAMBIA

Oladele Oyelakin1*, Lamin Jaiteh1, 2Muhammad A. Salisu, Anthony Adjivon1
1Division of Physical & Natural Sciences, School of Arts & Sciences, University of The Gambia, Box 3530, Serekunda, The Gambia
2Jigawa Research Institute, P.M.B. 5015, Kazaure, Jigawa State, Nigeria

*Corresponding Email: ooyelakin@utg.edu.gm

ABSTRACT

This short piece takes a limited look at the health hazards of the chemical contents of seven fruit juices sold in The Gambia. All of them have very negative effects on health. The following additives were considered: sweeteners, coloring agents, flavoring agents and acidifiers vis-à-vis established studies. [African Journal of Chemical Education—AJCE 5(1), January 2015]
INTRODUCTION

Powdered fruit juices are sold and consumed all over The Gambia. They are very economical in the sense that from a small sachet of 100 grams, one can dilute the contents with a lot of water and obtain over a liter or more of juice. This makes them to be famous and popular among the population. However, all these contain food additives that are not known by the population. The Gambia has a low literacy rate (51.1%, age 15 years plus) [1] and this may be blamed, in part, for the ignorance of the population vis-à-vis the content of these fruit juices and their effects on health. Further to this, many of these powdered juices are widely advertised using various media within the country.

This study aims to ascertain the bad effects that all the powdered fruit juices sold in The Gambia have on health. The study explored all the synthetic powdered juices sold in The Gambia.

The country is divided into six regions: Region One is the urban area (locally referred to as The Kombos), while the remaining Areas are regarded as the rural areas. All goods sold are imported through the urban area and then distributed to the rest of the country by merchants. With this in mind, the researchers purchased all the powdered fruit juices sold in Region One. The following were purchased: trix, foster clarks, mr cool, luminy, tiara, pop drink and aruzat. These brand substances have the following components:

**Tiara**
Ingredients: Sugar, Acid (E 330), Sweeteners (E 951, E 952, E 950), Natural identical strawberry flavor, Anti-caking agents (E 341, E551), Vitamin C, Acidity regulator (E331), Stabilizers (E 415), Colours (E 171, E 102, E 110).

**Trix**
Ingredients: Sugars, Acidity regulator (citric acid, trisodium citrate), Maltodextrin, Sweeteners (aspartame, acesulfame-K), Anti-caking agents (tricalcium phosphate, silicon dioxide), Antioxidants (vitamin C), Stabilizers (guar gum), Orange flavor, colorants (sunset yellow, titanium dioxide, turmeric).
Mr. Cool
Ingredients: Sugar, Acidifiers (citric acid E 330, trisodium citrate E 331), Ascorbic acid (vitamin C E300), Sweeteners (aspartame E 951, acesulfame-K E950), Natural identical flavor (coconut), Anti-caking agents (tricalcium phosphate E 341), Maltodextrin, Thickening agents (xanthan gum E 415), Colouring agents (tartrazin E 102, sunset yellow E 110).

Aruzat
Ingredients: Sugar, Acidity regulators (citric acid, trisodium citrate), Maltodextrin, Natural identical fruit flavor, Anti-caking agents (tricalcium phosphate, silicon dioxide), Colorants (titanium dioxide, sunset yellow, tartrazin, carmosine), Natural cloudy carboxymethycellulose, Thickening agent (guar gum), Vitamin C, Sweeteners (aspartame, acesulfame-K).

Foster Clark’s
Ingredients: Sugar, Citric acid E 330, Natural identical and artificial berry flavor, sodium citrate E 331, Sweeteners (aspartame, asulfame-K), Colours (E 129, E 133), Calcium phosphate E 341, Vitamin C, Anti-caking agent E 551.

Pop Drink
Ingredients: Sodium cyclamate, Citric acid, Strawberry flavor, Carmoisine.

Luminy
Ingredients: Sugar, Acidity regulator, Citric acid(E 330), Maltodextrin, Sweeteners (aspartame E 951, acesulfame-K E 950), Thickeners (guar gum E 412), Vitamin C (E 300), Natural banana aroma, Colouring agents (tartrazine E 102, sunset yellow E 110), Clot prevention (tricalcium phosphate E 341).

The Gambia is almost completely encircled by Senegal except at the sea where it opens up to the Atlantic Ocean. There are many porous borders and these are used for smuggling virtually anything into and out of the country. Hence, the researchers would not rule out the existence of a powdered juice or more found somewhere in the rural areas and not covered by this study, probably because it is smuggled into the country through unofficial borders. No laboratory work has been conducted in this study; it is purely literature-based.

RESEARCH QUESTION, HYPOTHESES AND METHODOLOGY

This study aims to answer only one question: Are the powdered fruit juices sold in The Gambia injurious to health?

Alternatively, the following hypotheses were formulated:
1. The powdered fruit juices sold in The Gambia are bad for health.

2. The powdered fruit juices sold in The Gambia are responsible to a large extent for a lot of ill-health and death among the populace.

Researchers undertook a tour of all the local shops and supermarkets within the Kombos. Names of all the powdered fruit juices sold in these shops and supermarkets were listed and then they were purchased. Their ingredients were listed and online resources were used to ascertain the effects that they have on health. The information obtained from the internet was based on toxicological studies already carried out by other researchers on the listed chemical ingredients.

RESULTS AND DISCUSSIONS

The food additives found in the synthetic powdered juice were grouped into: acidifier, sweetener, natural identical flavor, anticaking agent, thickening agent, coloring agent and antioxidant. A ‘safe’ food additive is one that has been certified by Food and Drug Administration (FDA) or some other regulatory body for low toxicity, degenerative illness, health benefit etc [2]. Some of the food additives banned by FDA and in some European Union (EU) countries like Norway, Sweden and Switzerland were found in the powdered juice investigated in this study.

The following chemical substances were found in the powdered juices that were purchased; they have been grouped according to their functions:

- Acidifiers: trisodium citrate E-331, citric acid E-330, maltodextrin
- Anticaking agents: tricalcium phosphate E-341
- Antioxidants: ascorbic acid (vitamin C) E-300
- Coloring agents: tartrazin E-102, sunset yellow E-110, carmosin E-122
Natural identical flavors: strawberry flavor, grape flavor, orange flavor, pineapple flavor
Sweeteners: aspartame E-951, acesulfame-K E950, saccharin E-954(i)
Thickening agents: xanthan gum E-415, guar gum E-412

Not all the above-listed additives were looked at by this study.

Health Hazards

Sweeteners: With regard to this study, the researchers consulted existing literature and looked at the effects of aspartame, acesulfame and saccharin. Aspartame raises the amount of phenylalanine in blood and brain [3]. Phenylalanine is an aminoacid used as a building block for proteins. When it is consumed in aspartame it can alter brain function significantly [4].

Acesulfame-K is not metabolized by the body [4]. Large amounts of this substance is clastogenic and genotoxic, this is according to a study carried out by Malaisse W.J. 1998 on mice. It was established that with a certain dose acesulfame interacts with DNA to produce genetic damage [6].

Saccharin is neither absorbed nor metabolized by the body [4]; it is excreted unchanged via the kidneys. As a result of not being metabolized, the FDA considers it to be a safe food additive [4]. There are studies that show positive and negative results, including potential to induce cancer in rats, dogs and humans [7]. These studies involve exposure to the substance at different stages of development of the organism. In the case of rats, exposure to diets containing 5% to 7.5% from time of conception to death showed an increased frequency of urinary bladder, especially in males. In countries like Canada and United States food products containing
saccharin are required to carry a warning label that says: saccharin is a potential cancer causing agent [8]. In The Gambia no such labels were seen by the researchers in this study.

**Color Additives**

Tartrazine is an azobenzene (an artificial yellow). When ingested it is reduced to an aromatic amine which is highly sensitive. Its main metabolite identified till date is sulfanylic acid [9]. This substance produces these reactions in the body: urticarial (skin rash), rhinitis (runny nose), asthma, purpura (purple skin bruising) and systematic anaphylaxis (shock). According to Science [29] these reactions are more common in people with asthma or sensitivity to aspirin.

According to a study carried out on rats by Hassan [10], depending on dosage, age, gender, nutritional status, genetic factor and long term exposure to low doses, the following were observed: chromosomal aberrations.

Sunset yellow: this has other names: orange yellow S and yellow 6. It is synthetic coal tar and azo dye. It is used in fermented foods that must be heat treated. Consumption of this substance in food causes hives, runny nose, nasal congestion, allergies, hyperactivity, abdominal pain, nausea and distaste in food. When ingested in amounts that are higher than would be consumed by humans, it was found that it caused an increase in the incidence of tumors and chromosomal damage [11]. For individuals with sensitivity to aspirin, Zach Harmon [12] showed that sunset yellow causes allergic reactions.

Starting from July 2010 these color additives were banned by the European Union Food Standards Agency from food products: tartrazine, sunset yellow, allura red, brilliant blue, indigo
tine and erythrosine [13]. It is interesting to see that they are still being imported into The Gambia.

**Artificial Flavors**

According to the National Centre for Health Statistics, Hyattsville, USA, artificial flavors contribute to good health. They reduce the risk of heart attacks by preventing blood clots [14]. Artificial flavors contain salicylates; these are chemical cousins of aspirin. Aspirin is known to reduce the risk of heart attacks by preventing blood clots [14]. On the other hand, Keener [15] found that these chemicals are carcinogenic, neurotoxic, are responsible for hyperactivity disorders (attention deficit disorders and attention deficit hyperactivity disorder) and food allergies.

Artificial flavorings are difficult to study because they are a cocktail of very many chemicals and their recipes are kept as corporate secrets among many food industries; this is according to Harmon [12] and is the reason advanced for the FDA not been able to study them. An instance of this is synthetic strawberry flavor which consists of fifty-nine different ingredients; some flavorings consist of hundreds [12]. Along with this is the fact that there is a lot of uncertainty and risk in creating these artificial flavors and consuming them. If someone is allergic to certain manufactured food, it may be that he is allergic to certain chemical(s) in the flavoring agent added. With this comes the possibility of exposure to new chemicals everyday; and the body may not be used to handling these substances. So it is possible to have two situations: one in which an individual does not react to a natural flavoring and a second one in which the same individual has a reaction to an artificial flavoring.
Acidifiers

Citric acid stands out among all the acidifiers. It is a weak acid found as a natural preservative in acid or sour foods (soft drinks) [16]. The European Union allows citric acid to be added as an acidifier (acid regulator) in fruit juice; 3g per kilogram for fruit juice [17]. Excess consumption of the acid leads to dental corrosion, muscle twitching or cramps, swelling, weight gain, fatigue, mood changes, rapid and shallow breathing [17].

Dickens [25] found that cancerous tissues contain a lot more citric acid in associated body fluids than normal. This acid has also been blamed for modulating pulmonary hypertension, this, according to a study on pulmonary hypertensive chickens orally exposed to the substance for 45 days [18]. Studies on rats [19] showed an increase in enzyme activity, organ weights, especially kidneys and an overall decrease in body weight compared to a control group used in the study.

Modern day use of citric acid is based on 1973 guidelines which considers it be a safe food additive and harmless; this is according to the FDA 2010. In line with this is the unrestricted use of the substance [21]. On the other hand, some countries describe it as ‘the most dangerous cancerous’ additive. They have given it the nickname E poisons in food.

CONCLUSIONS AND RECOMMENDATIONS

All the chemicals listed from the labels are consumed in The Gambia and considering the health hazards discovered by review of scientific literature, one cannot deny the fact that these substances are harming the population in one way or the other. How many avoidable deaths can be ascribed to the consumption of these chemicals? Some, no doubt!
There are no laboratories within the country to analyze for these chemical substances; this may be one reason why they continue to be imported. Even if their presence were detected, is the appropriate government agency aware of the health effects of these substances? Is the awareness of enough concern to ban their importation?

There is thus a need to setup laboratories to analyze these dangerous food additives in imported foods. This should go hand-in-hand with the enforcement of regulation to stop their importation. All the additives that have been banned in the EU and are still being imported should also be banned. If they have already been banned in those countries, there must be a reason for it especially considering the fact these countries have well-equipped laboratories.

The Gambia may not be in a position to understand and validate the reason. Further to this, safer and natural alternatives could be explored. For example, in the use of sweeteners, stevia has been found to be a safer option. According to New York University Medical Center, stevia helps with hypertension and diabetes. This is a better substitute considering the carcinogenic effects of the sweeteners studied in this study.

There is need to enforce the labeling of food products that contain hazardous chemicals, with a warning. For example, as seen earlier: “In countries like Canada and United States food products containing saccharin are required to carry a warning label that says: saccharin is a potential cancer causing agent”. With this kind of labeling in The Gambia the researchers in this study are of the opinion that consumers would be able to make an informed decision.

A safer and less injurious option would be for the government to adopt the use of the contemporary synthetic products in use in the EU. The banned additives must have been replaced by ‘safer’ options; these safer options should be used in The Gambia.
It is the considered opinion of the researchers that if the same synthetic products can be found in other African countries, then one can easily conclude that some medical harm is also being done to the populace, and as such something needs to be done as a matter of urgency.

More importantly, we believe that the young generation should be taught in schools and colleges about the dangers of the use of these chemicals as part of their regular chemical education programs.

REFERENCES

1. http://www.indexmundi.com/the_gambia/literacy.html
How Can I Improve My Students’ Ability in Doing Laboratory Practical Work on Analytical Chemistry-I? A Case on Class N23 at KCTE

Tolosa Geleta
Chemistry Department, In Kamise College of Teachers Education (KCTE), Ethiopia
Email: omarsan.an6@gmail.com

Abstract
From my experience of teaching in KCTE and class N23 (Natural science department, year 2 section 3) in the years of past time, these students were active in class participation and did what was given to them in theoretical approach. However, they were getting confused specially on the concepts requiring applications during practical laboratory activities. They lose their individual confidence of handling and manipulation of apparatus and chemicals. That was why I chose them specially in doing Practical Analytical Chemistry-I (Chem 223) of the semester. This action research was aimed at improving students’ ability in doing the practical laboratory work and exercising of science process skills. This was because these students show lack of experience in specially handling laboratory materials, chemicals and following scientific processes like observation, data record, analysis, measuring and following of appropriate safety rules while working in lab independently or being in groups. In this study, observation, questionnaires and tests were used as tools to gather information about the participants for both pre-and –post interventions. It was seen from the study that students feel more interactive and confident when working in group rather than independently. This has also boomed students’ experiences as it was multi-side interaction between student-student, student-teacher and teachers-teachers as well. This study reveals that students’ achievement improved from 52.37% to 70.21% on questionnaire, 68.06% to 84.44% in test and 69.47% to 72.50% in assessment which covered lab class activity, practical show activity and report writings. In general, it will be better for instructors like me to plan “starting-ongoing-ending” and “cooperative learning” approach while designing the practical lab instruction to enhance students’ learning. [African Journal of Chemical Education—AJCE 5(1), January 2015]
INTRODUCTION

I have been teaching this course since 2009 at least once a year. And from my teaching experiences, I know that this course contains ion analysis, acid-base theories, solubility, redox reaction and complex equilibrium. I have been teaching two courses before and I’m teaching two courses by now for N23 students, of which two courses are laboratory practical work.

The students participate in class, engage themselves in different class activities like asking questions excessively, group works, etc but with low score on individual assessments and show the behavior of confusion while laboratory practical work was implemented. This and other related learning behavior of these students initiated me to conduct this study.

Some studies [1] argue that chemistry is perceived as a very difficult subject by students due to its abstract concepts. This is most often attributed to the challenges that they face to construct the abstract concepts that they frequently encounter in the subject area. In such a way it profoundly influences students’ selection for subject of preference or as area of specialization. Others [2] explained in their study that laboratory applications are of significant importance in chemistry education. However, laboratory applications have generally been neglected in recent educational environments for a variety of reasons.

To me (and to my work colleagues in natural science department of KCTE, I believe) teaching science without practical manipulation in laboratory is teaching an impaired science. It is a science with one sense organ removed. Hence, in order to address the gap, it is important especially by their instructors to pay critical attention for practical laboratory instruction and take the remedial action to minimize this gap, I believe.

Our College (KCTE) being newly established and not well equipped with laboratory materials, it is trivially concluded that most science works are covered theoretically, even though
it should be practical conceptually. Hence, now a day, our College is emerging with on/off access of internet services. And our college uses linkage of practical only work linkage under strict and spoon feeding style with Kamise Town Preparatory School (KTPS). Being one of the teachers of the department, I feel that there is huge gap between the concepts to be thought and the teaching-learning process used in practical work class. Thus, this initiated me to consider this study which mainly focuses on the following questions:

1. What will challenge students’ ability in doing practical lab work?
2. How can I improve students’ ability in doing laboratory practices?
3. What science process skills will students gain as practical method(s) of teaching laboratory intervened?

The main objectives of this study were:
1. To identify major challenges that students face in doing practical laboratory work on Chem 223
2. To device method(s) that help tackle with these problems.
3. To improve students ability in science concept and practical laboratory process skills.

SIGNIFICANCE, ETHICS AND DELIMITATION OF THE STUDY

Science is the base for well being of every world in every aspect like economically, socially and politically. And all these aspects are the field of competition among nations. As stated in previous study [3], the one with better adjustment and most competent from the many is the champion of surviving to continue the competition.

Same concept works to me and my students too, I believe, as long as being part of the population. This study can add certain science concepts, science process skills required specially
for laboratory practical works and safety rules which enable them to work at primary schools in their occupation.

Learning pyramid [4] illustrated educators’ perceptions regarding students learning as they found that: students retain percentage as following ways:

<table>
<thead>
<tr>
<th>Learning behavior</th>
<th>% Retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hear</td>
<td>5</td>
</tr>
<tr>
<td>Read</td>
<td>10</td>
</tr>
<tr>
<td>Demonstration</td>
<td>30</td>
</tr>
<tr>
<td>Discussion</td>
<td>50</td>
</tr>
<tr>
<td>Practice</td>
<td>75</td>
</tr>
<tr>
<td>Apply and teach</td>
<td>90</td>
</tr>
</tbody>
</table>

As mentioned in the table, concepts applied in daily work and involved in practical work will be retained long by students’ mined. Hence, it is practical laboratory which plays a great role in this aspect especially in science teaching as revealed by this study. On the other hand, scholars [5] explained that individuals’ brains will not retain 99% of the information they receive. This has raised a surprising question which was stated as “Consider the vast amount of information that bombards an individual in a single day”, but the students retain only about 1% of all. From this and the table provided above, it is clear that practical and application ways of learning like that of laboratory methods are the leading approach to enhance and meet leaning styles of students besides professional satisfaction.

All sources data for this study were respected, information was quoted, and sources were mentioned exclusively. Participants of the study were communicated and briefed with the objectives of this study. Neither data was collected nor displayed in the absence of common agreement with the participant of the study.

This study was conducted in KCTE being with chemistry major English medium 2nd year students of 2014. These students were attending the course Practical Analytical Chemistry-I.
(Chem 223). Therefore, this study was implemented in Semester-I of the year in the forementioned class by the subject teacher.

Most limiting factors were lack of chemical and apparatus required for the lesson, on/off internet services (access), and lack of virtual chemistry software and insufficient manipulation skill for its application.

**LITERATURE REVIEW**

Learning is a gradual behavioral change. This can be manifested through the way one acts (feeling, expressions, and communications), what one can do and the way one can offer others to act. It develops through different level of ages. The lower level education serves as the development of experience for welcoming of the upper level of learning.

However, studies show that students have difficulties in understanding scientific concepts across all levels of ages. This gets more aggravated in developing countries. Hence it needs science teachers to support students explore the science concepts and process skills. It was argued [6] that in chemistry, being one of the branches of science, teaching its concepts must be designed to incorporate experimentation, observation and other laboratory oriented activities or disciplines. This study also suggested that if we want our students know what and how other chemists (science scholars) do and get them involved in science fun, we have to be able to let them practice science processes activities like observation, measurements, comparisons, classification and evaluation. This is based on the facts that science (chemistry) education is an involvement and understanding of the science processes. Hence the effective use of laboratory is required to make science education successful. In general, laboratory teaching is important in science like that of chemistry as it plays great role in:
• developing science process skills and
• having best experience of what science is.

This implies that even when there is no well equipped and well organized laboratory in schools and higher education institutions like KCTE, it is important to give attention for improvising of laboratory equipments (and chemicals) locally from low cost or no cost available resources. It was forwarded [7] that laboratory practical in their ways of definition and operations means active and interactive approach of teaching-learning process and taken as valuable tools in maximizing the learning experiences of both students and staffs.

1. Benefits of laboratory practices

A previous study [7] has summarized that investigative/inquiry based laboratory practices have potentials to develop students`:

• understanding of concepts
• scientific applications
• scientific attitudes
• practical skills
• problem solving abilities
• scientific habits of mind
• understanding how science and scientists work
• ability to formulate scientific questions
• ability to form hypotheses
• ability to design and conduct investigations
• ability to formulate and revise scientific explanations
• communication skills and/or ability to defend scientific arguments
• interest and motivation
• skills in teamwork
• imagination and creativity
• technical skills in the use of equipments

2. Common challenges of laboratory practice

From experience of teaching in schools and college in the previous years, I found that teaching and learning process of laboratory practical in science was not an easy task. For one thing, the misconceptions of students in science devotes the energy; on the other hand, lack of laboratory experience, exposure and science process skills hinders students from attaining the objectives of laboratory practical designed.

Scholars [7] explained in their study that although laboratory practices enhance the students’ learning experience, it has also been criticized for the fact that it is unproductive and confusing unless clear thought used. It was suggested that cultivation of students’ intellectual skills should be given attention to enhance learning rather than following “cookbook” approach. Hence poorly involved and experienced students developed poor or no experience of laboratory management even for highly expensive chemicals and apparatus. It is common especially in our college that students’ involvement for practical manipulation of these substances is rare in laboratory. This is due to lack of well organized laboratory, large class size, students science background, proximity of practical and theoretical class, availability of standardized laboratory books and poor skills of application of IT for laboratory practical as I confront them in my daily experience of work.
3. Good laboratory practical designs

Some studies conducted previously [8] suggested that when designing or supervising practical/laboratory work, it is recommended that one should leave behind the “cookbook” approach and try to:

i. Foster student independence and growth. It is better to support them in highly challenging situations, encouraging active participation and remove or avoid long time of standing around in an observational capacity.

ii. Enhance students’ learning. Emphasize critical thinking, problem solving, scientific inquiry and other activities that create opportunity for students to think.

iii. Encourage the integrity of the practical classes with the theory and learning thought in other aspects of the courses and classes.

iv. Facilitate, don’t lecture. Avoid telling students the facts but help them to find the answers by questions, experimental designs and the like.

v. Have coordination of practical activity, pre-practical tutorials, report writing methods, practical designs explained for students prior to practical starts.

METHODOLOGY

Sample and sampling methods

This study was conducted on year-II chemistry class students. In this class, there were 23 male and 1 female students and all of them were involved on the study. The sample size consists of all the 24 chemistry class students purposively selected. They all take the practical analytical chemistry-I (Chem 223) and were attending their study being in the same class in KCTE. This subject was selected for this study because it contains vast number of experimental works, safety
rules, precautions, and taken by all of these students in this semester. Hence, it was one of the areas where students could apply what they have been learning in the previous courses like Practical General Chemistry-I&II (Chem 103 & Chem 104), respectively. In addition, it creates wide opportunity for me to look through the students’ laboratory skills and learning behaviors.

**Study Variables**

This study uses as a variable on **science concept** and **science process skills** improvement by the participants during the practical work in lab class. The science concepts focus on the application of previous knowledge by the participants on the areas of safety rules, following the scientific method during practical work and scientific report writing. Science process skills, on the other hand, involved the application and utilization of both the basic and integrated science process skills. All these were investigated through study instruments during the whole process of pre-intervention and post-intervention.

**Study instruments**

To collect data, I used different tools like questionnaire, test and observation/assessments. The questionnaire consists of seven items, all explaining the application of science concepts (theories, laws and principles), and science process skills. The test was developed to identify the students’ challenges in doing laboratory practical work using the knowledge that they have learned before. Observations were made through practical class work, home taken work and writing science report. For each and every activity given to them, they were marked and the results were recorded accordingly.
Data analysis methods

All data were organized after collection in the way appropriate for analysis and easy for the reader(s). Hence, I used tables to organize data and explained them within table using numbers and percentages. This was used to compare the results of the collected information(s). Finally, data were displayed in graphs to compare the changes or difference in learning skills and behavior before and after implementation of the remedial action(s).

DATA ORGANIZATION, ANALYSIS AND DISCUSSION

Pre-intervention data

1. Questionnaire

Nine differing practical work were planned to practice by students. Five of them were used for pre-intervention and the rest four were used for the post-intervention practice. Hence after instruction of the five practical works, the question containing seven items was developed and delivered for students to tick against their degree of acceptance for the concepts of each item. Then I counted the total number of students in each item. A scale of 4=strongly agree, 3=agree, 2=disagree and 1=strongly disagree were used as representation for the provided items.

At the head of the last main columns in the table, NAC is used to represent Not Accepted the concepts contained by the items and AC is used to represent Acceptance of the concepts contained by the items listed under focus points.
Table 1 Percentage Acceptance of students for questionnaire items

<table>
<thead>
<tr>
<th>S.N</th>
<th>Focus Points</th>
<th>NAC</th>
<th>AC</th>
<th>%AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Taken the sample and reagents using dropper, Pipette, Burette Or by tilting the Beaker</td>
<td>1</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Registered (recorded) what is seen from experiment as Text, Table, Drawings or own abbreviation during the practical work.</td>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Precipitations (ppt) formed, color changed or Both during the experiment.</td>
<td>1</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>The following properties: Concentration, Volume, Drops, Mass or Temperature of the sample have been measured during the experiment.</td>
<td>11</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Any calculation of the results has been done during lab/ during report writing.</td>
<td>5</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Graphs, tables, or others used to explain what observed from the experiment.</td>
<td>2</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>Working table and all apparatus cleaned before, at the end or both time of the experiment.</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

Where NAC=Not Accepted the items and AC= Accepted the items

Out of the seven items, the highest score was 70.8%, for items 2&3, and the lowest score was 25% for item 4. This implies that students practiced more on the concept of item 2 and 3 while they practiced least on item 4.

2. Test

I have prepared theoretical test and practical test questions which were recorded out of 7% and 8% respectively which comprises a total of 15% evaluation. This was intended for the investigation of the application of science concepts and process skills by the students during the practical work.

Example of practical test questions

Students were individually allowed to respond for the practical work questions after they were instructed on theoretical base in class. The following questions were developed and used for the test.
Q1. Write the chemical formula of bubbles of gas evolved when dilute HCl is added drop wise to the solution containing $HCO_3^-$ ion (2 points).

This question was answered by 5 students as no formation of gas seen, $CO_2(g)$, $Cl_2(g)$ and $Cl(g)$ gases formed while 19 of them answered it as $CO_2$. In this question, it was expected from students to apply the theoretical concepts learned in class before the practical application in laboratory room and relating of pre-requisite knowledge. As it was explained above, some of them yet need support in:

i. Theoretical background revision in order to work on application in practical class.

ii. They need to distinguish the difference among gaseous substances and ionic specious.

Q2. Set up test for Na$^+$ ion (3points).

In doing the practical test for the Na$^+$ ion, majority of them over pass the rinse of the Nichrome wire (substituted by Cu-wire) with HCl. This led them to miss the conclusion that both known sample solution (solution of NaCl) and unknown sample solution (BaSO$_4$ solution) contain the Na$^+$ ion.

In general, the summary of the results from the two tests was organized as the following table using their ID.No instead of indicating their names.

Table.2 Test scores for pre-intervention

<table>
<thead>
<tr>
<th>S.NO</th>
<th>ID.NO</th>
<th>Pre-Int Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>NSR-AL/0118/05</td>
<td>14</td>
</tr>
<tr>
<td>2.</td>
<td>NSR-AL/0119/05</td>
<td>5</td>
</tr>
<tr>
<td>3.</td>
<td>NSR-AL/0122/05</td>
<td>1</td>
</tr>
<tr>
<td>4.</td>
<td>NSR-AL/0123/05</td>
<td>10</td>
</tr>
<tr>
<td>5.</td>
<td>NSR-AL/0130/05</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>NSR-AL/0132/05</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>-------------</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>NSR-AL/0132/05</td>
<td>12</td>
</tr>
<tr>
<td>Average</td>
<td>10.21</td>
<td>Percent</td>
</tr>
</tbody>
</table>

It is trivial to calculate from the table displayed above that students scored 10.21 on average which is approximately 68.06% of the expectation from the test. Finally the students were classified based on their scores for the sake of comparison as Low score (0 to 5), Medium score (6 to 10) and High score (11 to 15) based on their achievement results as follows.
Table 3 Categories of students based on their test achievements.

<table>
<thead>
<tr>
<th></th>
<th>Low score</th>
<th>Medium score</th>
<th>High score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of students</td>
<td>4</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Relative percent (%)</td>
<td>16.67</td>
<td>25</td>
<td>58.33</td>
</tr>
</tbody>
</table>

As could be deduced from the table above, majority of the students (58.33) scored high. But there were students (41.67%) who need support and scored less than pass mark of the point (7.5). These are found at the category of low and medium scorers. This way I have categorized students using their scores on the test coded with their ID No. This helped me to explore who needs support on which concept and process skills for the remedial action to be taken. It also helped me in planning intervention actions. For instance, it directed me to organize my instructional resources, concepts to be reviewed and schedule time and places according to the students need.

3. Observation/Assessment

Observation of students’ different activities during laboratory practical work in lab, home taken activities and lab report writing was evaluated and recorded (Appendix-C) using evaluative rubrics for each of the students work.

I. Practical work observation rubrics

Observation rubrics for practical doing of the lab activity was developed and implemented as the following table and the result was ticked against under the degree of implementation where:

0= Not yet, 1= achieved the standard, 2= competent, and 3=Highly Capable
Table 4 Observation rubrics for practical activities

<table>
<thead>
<tr>
<th>S.N</th>
<th>Focus Points</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Objectives, concepts and what / why to do is understood.</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Test tube&amp; Work instruments cleaned, Table and working space cleaned, Working apparatus and chemicals named</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Procedurally work sample and solutions prepared, Appropriate sample size taken, droppers/spatula used</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Steps followed (lab manual) chemicals and apparatus taken, reagents and samples identified, appropriate amounts mixed.</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Observations, reactions and events recorded ( asked for help etc) as Text, graphs tables or charts</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Appropriate reaction results written or personal abbreviations used</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When students were asked to start the practical work, they lose self confidence and stand a while until their friends begin the task. It seems they get confused with objective of the experiment. Some of them used excess amount of reagents and samples. The others used the same dropper for both the reagents and the sample. It was also seen that some students were trying to use the large sized Brush to wash test tubes which was unfitted. They forgot also to follow the manual instructions and simply added the reagents and the sample together. Three of the students in Group1, for instance, was attending their friends work but not recording what they observed from the experimentations.

II. Lab Report evaluation Rubrics

Table 5 Laboratory report evaluation rubrics

<table>
<thead>
<tr>
<th>S.N</th>
<th>Focus Points</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Basic information, Titles, Objectives and theories written appropriately</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Apparatus, chemicals, Guide manuals(other materials, references) mentioned</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Procedures, safety rules and other precautions focused</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Raw data, Personal abbreviations and IUPAC Symbols/formulas etc used, recorded as either Text, graphs, tables etc</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Analysis- calculations, Drawings, Texts, Observations(effects/changes &amp; results) etc explained well</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Pre-requisites applied, related theories explained, conclusions drawn, etc</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Thirteen of them mentioned the course code as “No.223” instead of Chem.223 on the cover of their report while the other eleven mentioned it as Prac.223. On the other hand, half of the participants did not mention their group numbers on their report paper. Majority of the students did not mention all the apparatus used for the experiments and twelve (50%) of the participants listed the chemicals used without indicating their amounts. All of them did not relate the experiment with previous theories, skills learned was not mentioned and hence what they learned from the experiments was not explained at the end.

III. Example of Home taken activities

It was individually and in groups given home trying question after completion of the practical work in lab room. The result was checked, recorded next and hold for each of them individually. The following question is the sample of the questions used for home work assessment.

Q1. Why do we add HCl to a solution of \( \text{SO}_4^{2-} \) ion before the addition of CaCl\(_2\) reagent?

Even though it was discussed in theoretical classes before, none of them answered it as expected but with the approximate trial, three of them said it as to form of solution of the mixtures of the ions.

The result of the assessment which was used as observation was summarized using tables bellow (see Appendix-C for more).

<table>
<thead>
<tr>
<th>Number of students</th>
<th>Low score (0-5 points)</th>
<th>Medium score (6-10 points)</th>
<th>High score (11-15 points)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>Relative %</td>
<td>0</td>
<td>45.83</td>
<td>54.17</td>
</tr>
</tbody>
</table>
As we can see from the table above, all students scored medium and above. That is 45.83% of them scored 6 to 10 points while 54.17 of them scored 11 to 15 points.

![Figure 1 Observation results for pre-intervention](image)

**Figure 1 Observation results for pre-intervention**

**Major laboratory challenges of students**

It is common expectation that experimentations will help students understand lecture materials as chemistry is one of an experimental science. In the laboratory, they will go over many practical applications of the theories they learned in class. As to some study [9], use of laboratory practical as a study aid helps learners to understand chemistry and even have fun! However, many students did not enjoy laboratory and did not find it helpful because they faced challenges in doing lab work on practical course like chem.223 among which the major ones listed below.

1. **They take a "half journey completed" approach to practical chemistry**

Previous studies [9] called this as “a kook book approach to chemistry.” The students did nothing more than follow the recipe without thinking about what was happening in the test tube and how it was related to what they were studying and to the rest of the world in general. In such
an approach students let to gather information of lab result by mixing what was already prepared by the Lab Instructor. They did nothing in preparing majority of the laboratory samples.

This was what my departmental colleagues and I accustomed to use in laboratory instructions in our College. They were allowed to learn only the half way completed end results. When students took the cookbook approach in doing the practical work, they were going to have a poor experience in the laboratory and an especially hard time completing their laboratory reports [9].

2. Lab experience matters how and what to do

Students lose confidence in handling apparatus and chemicals in laboratory. Taking chemical from stock solution, mixing chemical to conduct reactions and following appropriate safety procedures were the major areas where they felt complicated task during the practical work. Most of them set their mined with fear which was obviously understandable from the behavior what they do, how they act and even tell to me when asked to conduct the activities by themselves. This in turn hindered them from thinking to apply the laboratory safety rules, theories, principles and laws that they have experienced more theoretically and in the previous courses.

Majority of the students prefer to watch what was going on while few group members did practice the activities and collecting their data. Even when I enforced them to practice it, immediately they committed mistakes. For instance, when I asked them to prepare a solution of the solid NaHCO$_3$ from the stock bottle in conducting test for carbonate ion, most of them take the sample solid and add directly to water in beaker without measuring the grams of sample required on beam balance. Some of them try to stir the mixtures using spatula. The other difficulty which they faced during the test for this ion was relating the concept with what they
have learned before. For example, some of them asked me “what is the need of dissolving NaHCO₃ because our objective is to test $\text{HCO}_3^-$? Why we don’t dissolve $\text{HCO}_3^-$ directly?” Others asked me that “why white precipitation is not formed when we add Conc. HCl on solution containing $\text{HCO}_3^-$ ions?” This implies that lack of experience in handling laboratory equipments, chemicals and practice by themselves saturated misconceptions and poor experience in doing practical laboratory works.

**Intervention strategies**

1. **Safety rules were reviewed every time students did practical work**

   In any laboratory, safety is paramount [10]. We should take note of the location of safety showers, eye wash stations and fire extinguishers when entering the lab. This implies that the learners should be familiarized with location of the safety materials when doing in lab practice. In addition, students should be instructed what the major types of laboratory accidents can occur, how to manage them, and what care should be taken before they occur. Some studies [11-12] also agree that all students who conduct their research in laboratory should be instructed or take training of the most common chemical safety related with their work.

   Hence, I prepared safety guidelines related with each of the experimental activities planned, delivered the copy of them for my students in figures, texts and discussed on each part with them. Then they were directed to read at home and bring with them every time they came to laboratory.

2. **Scientific theories, laws and principles which imply the science concepts in relation to the (practical) lesson were reviewed before the practical class begins**

   For every practical activity to be conducted there should be revision of related concepts (theories, laws, and principles), procedures and safety rules. This way students` misconception
and confusion could be reduced greatly while self confidence and motivation to work appraised. These also step up the students’ ability in applying science process skills and previous knowledge during practical work.

3. **Students were supplied with appropriate resources like laboratory manuals and safety guide**

   Laboratory manuals provide students with course title (course code), laboratory lessons (practical activities), working procedures, required apparatus and chemicals, report writing formats, pre-lab and post-lab activities and chemical safety. It comprised revision of related concepts; and outlined the outcome of the lesson for each practical activities designed. Hence it was important that students provided with these materials. In addition it saved time for me in such a way that they read it at home and took short notes about what they are going to do in laboratory. This also opened opportunity to discuss on the concept with their friends and read additional references as required. Therefore, it built good background for the learners before starting the experiments.

4. **Students peer work was strengthened in laboratory**

   As a general rule, working alone is not preferred in laboratory. This was one of the chemical safety rules to be followed because it opens opportunity to help each other in case there safety hazards occur. On the other hand, working together was preferred because two minds (intelligence) were more powerful than one. Students can feel more confident and motivated to work when they were with their friends (the one they know more). This helped them share ideas, reduced accidents and let them learn more. Hence, for more effective practical learning, it showed me that it was better if students’ cooperative work encouraged.
5. **Practical work was supported with virtual resources**

Graphs, figures and video clips used to clarify the flow of ideas, working procedures and procedure of data analysis by both students and Laboratory Instructor (LI) in practical work. Hence these were included in lab manuals and guides during the practice. Videos were used to elaborate concepts, process skills and safety procedures in lab work. These resources were adopted from online resources.

**Post-intervention data**

1. **Questionnaire**

Similar questions were delivered to students to investigate if there was any change after intervention regarding each challenge identified. Finally, the following results were summarized as follows (see Appendix-A). This table provides the relative percentage of students that agree with the acceptance (AC) of the practicability of activities outlined from 1 to 7 along with the average of the whole.

Table 7 Triangulation of post-intervention data.

<table>
<thead>
<tr>
<th>Items</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>%AC, Pre-inter.</td>
<td>37.50</td>
<td>70.80</td>
<td>70.80</td>
<td>25.00</td>
<td>41.66</td>
<td>58.30</td>
<td>62.50</td>
<td>52.36</td>
</tr>
<tr>
<td>%AC, Post-inter.</td>
<td>70.80</td>
<td>83.30</td>
<td>70.80</td>
<td>54.16</td>
<td>54.16</td>
<td>75.00</td>
<td>83.30</td>
<td>70.22</td>
</tr>
</tbody>
</table>

From this table it could be inferred that students practiced more on each item. This could also be deduced from their average acceptance for the concept of each item that they have practiced. Hence, the average acceptance for practice was 52.36% for the pre-intervention while it was improved to 70.22% after appropriate action intervened. These imply that they agree with the fact that they have practiced the concepts and process skills planned. It could be illustrated using graphs as done bellow.
Figure 2 Triangulation of questionnaire data

2. Test

Similar kinds of test questions with the pre-intervention one were used to evaluate students’ ability to practice the application of science concepts and process skills after proper intervention was implemented (see Appendix-B). The result was presented as in the following table.

Table 8 Triangulation of post intervention test data

<table>
<thead>
<tr>
<th></th>
<th>Pre-intervention data</th>
<th>Post-intervention data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>68.06</td>
<td>84.44</td>
</tr>
</tbody>
</table>

It could be triangulated using graphs too. The pre-intervention score was 68.06% while the post-intervention value was 84.44% confirming a great improvement.
3. Observation/Assessment

All data was collected during the implementation of the planned intervention strategies. For this purpose, students’ practical class activity, home taken work, and writing report of their work (scientific report writing) was evaluated and the results used to compare their progress (see Appendix-C).

Table 9 Triangulating data for observation of students’ activity

<table>
<thead>
<tr>
<th></th>
<th>Pre-intervention data</th>
<th>Post-intervention data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>10.40</td>
<td>10.88</td>
</tr>
<tr>
<td>Percentage</td>
<td>69.47</td>
<td>72.50</td>
</tr>
</tbody>
</table>

From this table, students’ achievement in doing practical activity was improved from 69.47% at pre-intervention to 72.50% of the post-intervention. Graphically, the results were triangulated in the following way.
RESULTS AND DISCUSSION

Through the conduction of this study, I found my students encouraged more doing the practical activities. Initially, majority of them were waiting for their friends to do any kind of the practical works they were allowed to exercise in lab. Each of them preferred watching and recording what was going on and the final products (resulting data) rather than doing it by themselves.

In general, after implementing the intervention actions planned, the following improvements were achieved.

1. The process skills improved

Observation

Students were able to conduct Observation-Based Logic which enabled them to interconvert different levels of thinking in such a way that their macroscopic-level observations...
were connected to science-based mental models of “what was happening” in submicroscopic-level events (like the interaction of atoms, molecules, reagents and ions) and their symbolic representations (as verbal words, visual pictures, personal abbreviations, chemical symbols & reaction-equations.). This in turn strengthened their thinking skills using Imagination required to interconvert observations (what they hear, see and read from the experimental activities) with mental models. This ability was applied for understanding the concepts of chemistry especially in solving and doing home taken practical questions.

This was improved greatly inter-conversion skills of students between observation and imagination which made mental connections between different levels of thinking (macro, micro, symbolic). These imaginations led them build mental representations of chemistry concepts and provided opportunities for students to observe-and-imagine. This way practicing the lab practical work and conducting attentive observation, they upgraded their observation and representation ability after intervention (see the following samples taken from their work).

Table 10 Students’ observation records

<table>
<thead>
<tr>
<th>Test for</th>
<th>Reagents used</th>
<th>Results observed</th>
<th>Representation/ explanations given by the students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride ion (Cl⁻)</td>
<td>AgNO₃(aq)</td>
<td>White ppt.</td>
<td>Cl(aq)+ AgNO₃(aq) → AgCl(ppt)+ NO₃⁻(aq)</td>
</tr>
<tr>
<td>Sulphate ion (SO₄²⁻)</td>
<td>BaCl₂(aq)</td>
<td>White ppt.</td>
<td>SO₄²⁻(aq)+ BaCl₂(aq) → BaSO₄(ppt) + 2Cl⁻(aq)</td>
</tr>
<tr>
<td>Bicarbonate ion (HCO₃⁻)</td>
<td>Conc. (?) HCl</td>
<td>Bubbles evolved</td>
<td>HCl(l)+ HCO₃⁻(aq) → H₂O + Cl⁻(aq) + CO₂, gas</td>
</tr>
<tr>
<td>Potassium ion (K⁺)</td>
<td>Flame, HCl &amp; Copper wire</td>
<td>Violet colors</td>
<td>Heat + K⁺-ion gives violet color</td>
</tr>
</tbody>
</table>

Some of them used their own way of representing the changes undergone after applying the agents and the others represented using reaction representations for what they observed (see, understand) from the experiments conducted.
Measurements

Students were accustomed to take samples and reagents excessively by eye droppers before intervention. Some of them even tried to take the chemicals by tilting the container holding it. But after intervention, they were able to measure the appropriate sample using measuring cylinder of differing sizes and the reagents drop wise. Beam balance was used to measure solid barium chloride salt to prepare its solution during test for barium ion (Ba\textsuperscript{2+}). In the similar fashion, they counted (measured) 2-3 drops of reagents like Methyl orange, Bromo methyl blue and universal indicators to observe their colors in Acid-Base solutions.

Application

After I revised them the underlying theory, they were able to check for the absence or presence of ions in unknown ion solutions provided for them in lab. For instance the following drawing was taken from the one they exercised to apply.

Table 11 Record from students’ science concept application

<table>
<thead>
<tr>
<th>ExpNo</th>
<th>Result for Known ion test</th>
<th>Result for Unknown ion test</th>
<th>Conclusion drawn for unknown ion solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Red litmus turns Blue</td>
<td>No change</td>
<td>Must be neutral</td>
</tr>
<tr>
<td></td>
<td>Blue litmus no change</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Conc.HCl Evolve bubbles</td>
<td>Evolve bubbles</td>
<td>Probably contain either HC\textsubscript{2}O\textsubscript{4} or CO\textsubscript{3} ions</td>
</tr>
</tbody>
</table>

This implies that students were able to set theories and try to prove/disprove its reality using experimentation methods they discussed in laboratory. Through this they arrived at their own conclusion for the unknown species in the given sample. This was one of the areas where the students developed connection between their science concepts and process skills ability widely.
Compare/contrast

Comparison of properties between known and unknown ion solution was made using the same reagents on each of these samples which led them to arrive at the final conclusion. Hence, they compared and contrast the similarity and difference between the two solutions in property for decision making when known and unknown ion solution was supplied for them in order to test for.

Data record skills

The students used tables, drawing of the experimental set up apparatus, writing symbols and formulas, equations, and personal abbreviations to register their findings and observations from experimental activities in lab.

Safety rules

All students came to lab class with safety guides and lab manuals in hands. They read the procedures, precautions, required theories and objectives of the practical lessons before coming to class as seen from triangulation at every starting phase of practical activity. Available safety materials were worn. In addition, students washed beakers, eye droppers and test tubes all the time before and after each practical work. Apparatus were seen being labeled before chemicals (samples) taken. Work tables cleaned using sponge and apparatus taken to their shelves (original places) at the end of the class. Solid and liquid wastes were kept separately in line with the instruction given on the safety guide.

Writing Report / scientific writing

Students were able to report their work following the scientific procedure which they have learned on Chem 103 courses and which was included on their lab manual. They recorded data appropriately. It was explained qualitatively which was set under recommendation on their
Majority of them were able to relate skills gained with the objects of the lesson because of doing the experiments. When analyzing the data, the underlying theories were used to create connections between the theoretical and practical concepts they learned.

2. Experiences gained

As it was stated under analysis, the data triangulation from Test, Observation and Questionnaire implies that encouragingly students self confidence (ability) and practical work experience on each and every activity implemented showed a great improvement.

RECOMMENDATIONS

It is known that science needs critical thinking, observation, analysis, drawing conclusion, imagination and modeling. Planning and implementation of the following will help our students to exercise these processes and lay better ground to develop background of good science skill experience.

1. Plan “Starting-Ongoing-Ending” Approach

Incorporating pre-lab, during the practical work of lab and at the end of lab practice activities and focus points could help learning and it creates more opportunity to look at different angles on a single activity.

2. Encourage Cooperative Learning

Cooperative work between students, students & teacher and between teachers can boom students’ practical work ability and experience. It also helps easy of teaching-learning process.

REFERENCES


### Appendix A

**Questionnaire**

**Pre-Intervention**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Focus Points</th>
<th>NAC</th>
<th>AC</th>
<th>%AC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>Taken the sample and reagents using dropper, Pipette, Burette Or Tilting the Beaker</td>
<td>1</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Registered (recorded) what is seen from experiment as Text, Table, Drawings or your own abbreviation during the practical work.</td>
<td>3</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Ppt formed, color changed or Both during the experiment.</td>
<td>1</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>The following properties: Concentration, Volume, Drops, Mass or Temperature of the sample have been measured during the experiment.</td>
<td>11</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Any calculation of the results has been done during lab/ during report writing.</td>
<td>5</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Graphs, tables, or others used to explain what observed from the experiment.</td>
<td>2</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>Working table and all apparatus cleaned before, at the end or both time of the experiment.</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average
Post-Intervention

<table>
<thead>
<tr>
<th>S. No</th>
<th>Focus Points</th>
<th>NAC</th>
<th>AC</th>
<th>%AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Taken the sample and reagents using dropper, Pipette, Burette Or Tilting the Beaker</td>
<td>0</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Registered (recorded) what is seen from experiment as Text, Table, Drawings or your own abbreviation during the practical work.</td>
<td>0</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Ppt formed, color changed or Both during the experiment.</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>The following properties: Concentration, Volume, Drops, Mass or Temperature of the sample have been measured during the experiment.</td>
<td>4</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>Any calculation of the results has been done during lab/ during report writing.</td>
<td>4</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>Graphs, tables, or others used to explain what observed from the experiment.</td>
<td>2</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>7</td>
<td>Working table and all apparatus cleaned before, at the end or both time of the experiment.</td>
<td>0</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

Where NAC=Not Accepted, AC= Accepted the concepts mentioned in focus points

Appendix-B

Test

<table>
<thead>
<tr>
<th>S.NO</th>
<th>ID.NO</th>
<th>Pre-Int</th>
<th>Post-Int</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.</td>
<td>NSR-AL/0118/05</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>26.</td>
<td>NSR-AL/0119/05</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>27.</td>
<td>NSR-AL/0122/05</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>28.</td>
<td>NSR-AL/0123/05</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>29.</td>
<td>NSR-AL/0130/05</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>30.</td>
<td>NSR-AL/0132/05</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>31.</td>
<td>NSR-AL/0135/05</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>32.</td>
<td>NSR-AL/0136/05</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>33.</td>
<td>NSR-AL/0138/05</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>34.</td>
<td>NSR-AL/0141/05</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>35.</td>
<td>NSR-AL/0150/05</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>36.</td>
<td>NSR-AL/0143/05</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>37.</td>
<td>NSR-AL/0128/05</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>38.</td>
<td>NSR-AL/0140/05</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>39.</td>
<td>NSR-AL/0147/05</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>40.</td>
<td>NSR-AL/0151/05</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>41.</td>
<td>NSR-AL/0137/05</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>42.</td>
<td>NSR-AL/0125/05</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>43.</td>
<td>NSR-AL/0121/05</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>44.</td>
<td>NSR-AL/0148/05</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>45.</td>
<td>NSR-AL/0117/05</td>
<td>9</td>
<td>11</td>
</tr>
</tbody>
</table>
46. NSR-AL/0139/05  9   13
47. NSR-AL/0134/05  11  14
48. NSR-AL/0120/05  13  14
Average   10.21  12.67
Percent   68.06  84.44

Appendix-C
Observation/Assessment

<table>
<thead>
<tr>
<th>S.NO</th>
<th>ID.NO</th>
<th>Pre-Int</th>
<th>Post-Int</th>
</tr>
</thead>
<tbody>
<tr>
<td>49.</td>
<td>NSR-AL/0118/05</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>50.</td>
<td>NSR-AL/0119/05</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>51.</td>
<td>NSR-AL/0122/05</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>52.</td>
<td>NSR-AL/0123/05</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>53.</td>
<td>NSR-AL/0130/05</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>54.</td>
<td>NSR-AL/0132/05</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>55.</td>
<td>NSR-AL/0135/05</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>56.</td>
<td>NSR-AL/0136/05</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>57.</td>
<td>NSR-AL/0138/05</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>58.</td>
<td>NSR-AL/0141/05</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>59.</td>
<td>NSR-AL/0150/05</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>60.</td>
<td>NSR-AL/0143/05</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>61.</td>
<td>NSR-AL/0128/05</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>62.</td>
<td>NSR-AL/0140/05</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>63.</td>
<td>NSR-AL/0147/05</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>64.</td>
<td>NSR-AL/0151/05</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>65.</td>
<td>NSR-AL/0137/05</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>66.</td>
<td>NSR-AL/0125/05</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>67.</td>
<td>NSR-AL/0121/05</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>68.</td>
<td>NSR-AL/0148/05</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>69.</td>
<td>NSR-AL/0117/05</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>70.</td>
<td>NSR-AL/0139/05</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>71.</td>
<td>NSR-AL/0134/05</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>72.</td>
<td>NSR-AL/0120/05</td>
<td>11</td>
<td>10</td>
</tr>
</tbody>
</table>
Average   10.40  10.88
Percent   69.47  72.50

Int=Intervention

ACKNOWLEDGMENTS
This study was conducted because of the voluntary and cooperatively involvement of all class N23 in KCTE of year-II in 2013/14 academic year; I would like to thank them as all cooperatively worked with me from the very beginning to the end. My Department colleagues helped me in sharing experiences and my thanks go to them as well. I thank my family so much for their continuous advice and valuing my work all the time.
SYSTEMIC ASSESSMENT [SA] AS A TOOL TO ASSESS STUDENT ACHIEVEMENTS IN INORGANIC CHEMISTRY
PART-I: SODIUM CHEMISTRY

*A.F.M. Fahmy, **J. J. Lagowski
*Department of Chemistry, Faculty of Science, Ain Shams University, Cairo, Egypt
   Email: afmfahmy42@gmail.com
   Web site: www.satlcentral.com
**Department of Chemistry and Biochemistry, the University of Texas at Austin, TX 78712

ABSTRACT
Systemic Assessment (SA) aims at a more effective evaluation of the systemic oriented objectives articulated by SATL model. SA raising the level of student’s academic achievements, increasing students learning outcomes, develops the ability to think systemically, assesses students’ higher-order thinking skills in which students are required to analyze, synthesize, and evaluate, measures the students’ ability to correlate between concepts with reduced working memory load. Systemic Assessment Questions (SAQs) are the building units of the systemic assessment. In this issue we use SA as a tool to assess the student achievement in inorganic chemistry by taking sodium chemistry as a module. We use four types of systemic assessment questions, namely Systemic Synthesis Questions (SSynQs), Systemic Analysis Questions (SAnQs), Systemic Synthetic-Analytic Questions (SSSyn-A Qs), and complete Systemics (SComp Qs). [African Journal of Chemical Education—AJCE 5(1), January 2015]

1 Prof. Lagowski passed away before submission of this article for publication. I lost a good friend and his great support.
INTRODUCTION

Systemic approach to Teaching and Learning Chemistry (SATLC) is a method of arranging concepts in such a way that the relationships between various concepts and issues are made clear. SATL methods have been shown, empirically, to be successful in helping students learn in a variety of settings-pre-college, college, and graduate systems of formal education as well as adult education—in a variety of disciplines such as the sciences (chemistry, biology, physics) [1-4].

A number of statistical studies involving student achievement indicate that students involved with SATL methods taught by teachers trained in those methods achieve at a significantly higher level than those taught by standard linear methods of instruction. However, our studies on Systemic Assessment [SA] [5-8] is an ongoing process of identifying the student learning outcomes, assess the student performance to these outcomes. SA showed that is highly effective in raising the level of students’ academic achievements with reduced working memory load, because even highly complex schema (systemics in SA) can be considered as a single element in working memory [9]. Also develop the ability to think systemically, assess students’ higher-order thinking skills in which students are required to analyze, synthesize and evaluate, measure the students' ability to correlate between concepts, enables the students to discover new relation between concepts. It is more effective evaluation of the systemic oriented objectives in the SATL model Systemic Assessment Questions [SAQ,s]are the building unites of the systemic assessment [7,8,10].
In inorganic chemistry the usual descriptions of inorganic reactions by chemical equations, represents linear separated correlations between reactants, resultants and reaction conditions. The student taught the six general types of chemical reactions, namely, combustion, single displacement, double displacement, synthesis, decomposition, and acid-base reactions.

Although the students know the six types of chemical reactions, they find difficulties in representing chemical changes by correct chemical equations, and in correlation between reactants and resultants. The student while being taught through a linear approach is asked to present the chemical changes by correct chemical equations, without any comprehension or appreciating significance of these relationships representing the chemical reactions. This leads to memorization of the chemical equations and finally to surface and rote learning. Ausubel [11] distinguishes “rote learning” or memorization from meaningful learning. The process called “assimilation” creates personal meaningful knowledge by restructuring the already existing conceptual frameworks that the learner possesses to accommodate to the new concepts being learned.

Our goal in this issue is to develop systemic assessment [SA] strategies and materials can be used by students to assess their learning of chemical changes of elements. Also it might lead to a better understanding of the systemic relations between elements and their related compounds, between compounds of the same element, and most importantly between types of the chemical changes under consideration.
PROPOSED LEARNING MODULE

Domain of learning material

As a material for this study, we take Sodium metal, as an example of metals. Sodium metal is the first member of alkali metals [Group-1.A] of the periodic table. The study includes the extraction of the sodium metal and its chemical properties. Also industrial preparations and chemical properties of some sodium compounds are included. This module is considered as a part of general chemistry for secondary school students and presented by systemic methodology.

Table 1. Domain of teaching material

<table>
<thead>
<tr>
<th>Teaching unit</th>
<th>Teaching themes</th>
<th>Selected contents of defined theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkali Metals [Sodium]</td>
<td>Preparation of Sodium</td>
<td>- Extraction from sodium hydroxide by Electrolysis.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Extraction from sodium chloride by Electrolysis.</td>
</tr>
<tr>
<td></td>
<td>Chemical properties of</td>
<td>- Reactions with oxygen, chlorine, water, acids.</td>
</tr>
<tr>
<td>Sodium</td>
<td>Sodium hydroxide</td>
<td>- Manufacturing of Caustic soda</td>
</tr>
<tr>
<td></td>
<td>[Caustic soda]</td>
<td>- Reactions with acids, acidic oxides, amphoteric oxides, halogens, some salts.</td>
</tr>
<tr>
<td></td>
<td>Chemical properties of</td>
<td>- Preparations of pure sodium chloride.</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>Sodium hydroxide</td>
<td>- Reactions of sodium chloride.</td>
</tr>
<tr>
<td></td>
<td>[Sodium hydroxide]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sodium Chloride</td>
<td>- Preparations of pure sodium chloride.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Reactions of sodium chloride.</td>
</tr>
<tr>
<td></td>
<td>Sodium carbonate and</td>
<td>- Manufacturing of Sodium carbonate, and bicarbonate.</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td></td>
<td>- Chemical reactions.</td>
</tr>
</tbody>
</table>

LINEAR ASSESSMENT VS SYSTEMIC ASSESSMENT

In the linear (Traditional) Assessment [LA], we ask our students to represent the different types of inorganic reactions by chemical equations.

Example from Sodium chemistry: Write equations for the following reactions:

1- Reaction of sodium with water [Displacement reaction].
2- Reaction of sodium hydroxide with hydrochloric acid [Acid-Base reaction].
3- Electrolysis of molten sodium chloride [Electrolytic-Decomposition reaction].

Answer:

Eq. 1: \(2Na + 2 HOH \rightarrow 2 NaOH + H2\)
Eq. 2: \(NaOH + \text{dil. HCl} \rightarrow \text{NaCl} + \text{HOH}\)
Eq. 3: \(\text{NaCl [Molten]} \rightarrow \text{2Na} + \text{Cl2}\) [Cathode] [Anode]
The student can find some difficulties in memorizing the three symbolic chemical equations as above, and he couldn’t correlate between either sodium metal and its related compounds (NaOH, NaCl) or the three chemical processes [Displacement, Acid-Base, and electrolysis] of the above reactions. If the students can memorize these equations, this leads to rote learning. Miller [12] points out that a person can recall seven plus or minus two items or elements of information at a particular moment, because of the working memory limitations and capacity. If students choose to learn these chemical reactions by mechanical memorization, they have to memorize 35 individual elements (items) of information (atoms + any digit indicating the number of atoms or molecules + reaction condition). Note that there are 13 items in the first equation, 12 items in the second +10 items in the third.

According to Miller [12] the memorization of 35 individual items exceeds working memory limitation and provokes working memory overload. The question is how can students overcome working memory overload? Working memory limitation (as well as overload) can be overcome by constructing cognitive schemas; combining simple elements into more complex ones [13]. Cognitive schemas reduce working memory load, because even highly complex schema can be considered as a single element in working memory [9]. This is the basic principle of using SATLC strategy in teaching and learning chemistry based on systemics which is considered as closed schemas. Systemics help students to learn and teachers to assess student’s achievements at higher cognitive levels [1,8] with reduced working memory load.

In the Systemic Assessment [SA] we can ask our students about the same chemical reactions by using four types of systemic assessment questions [SAQ, S] based on systemics.
**Type (1): Systemic Synthesis Questions [SSynQ, s][8]**

Here we ask students to synthesize trigonal systemic represents the chemical relations between [Na- NaOH - NaCl].

In this type of questions we assess our student’s knowledge about relations between (Na, NaOH, and NaCl; 6 items) beside the relations between the three chemical processes [Displacement, Acid-Base, and Electrolysis; 3 items] and reactionns conditions (H2O, HCl, Molten; 6 items). This assesses student learning outcomes in 15 items of information at synthesis level.

**Type (2): Systemic Analysis Questions[SAn Q,s][8]**

In which we give our students the above trigonal systemic (15 items of knowledge) and ask them to analyze to the corresponding chemical equations (35 items). This assesses the student learning outcomes in 35 items of information at analysis level.

1- \(2\text{Na} + 2\text{HOH} \rightarrow 2\text{NaOH} + \text{H2}\)
2- \(\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{HOH}\)
3- \(\text{NaCl [Molten]} \xrightarrow{\text{Electrolysis}} 2\text{Na} + \text{Cl2}\)  
   \(\text{[Cathode]} \quad \text{[Anode]}\)

**Type-3: [SSynQ,s-SAn Q,s] by asking our student to [8]:**

1- Synthesize trigonal sytemic shows the chemical relations between [Na-NaOH-NaCl] in a 15 items of knowledge.
2- **Analyze** the resulted systemic into the corresponding chemical reactions in a 35 items.

Assess student learning outcomes at synthesis followed by analysis level.

**Type-4: Complete the given systemics by adding the missing chemicals [ScompQs]**

Assess student learning outcomes at synthesis level. By using SA we expect to convert our students from surface learning to deep learning of chemical processes in sodium chemistry.

**DESIGN OF LEARNING MATERIAL**

Learning sheets were prepared in the form of:

1. A diagram of proposed liable bottles of the given element [Sodium] and some of its related compounds,

2. Systemic diagrams representing different types of systemic assessment questions [SAQs] in which the selected chemicals of any reaction were located in the given systemics. [SAQs] have been designed in accordance with the guidelines stated by: Fahmy & Lagowski [5-9] and Tzougraki [10],

3. Then we ask students to choose between sodium and the given compounds to answer the given systemic assessment questions.

You have the following bottles of chemicals:
Answer the following questions:

*Type-I: Systemic Synthesis Questions [SSynQ.s](8)*

[Synthesize systemics from the given chemicals & assess the student learning outcomes at the synthesis level]

*Type-I-A: Synthesize clockwise or anticlockwise systemic from the given chemicals to give the correct possible chemical relations:*

Q1) Use the following triangular diagrams to construct the clockwise systemic chemical relations between the (forgoing) chemicals.
Q2) Use the following quadrilateral diagrams to construct the clockwise Systemic chemical relations between the (forgoing) chemicals.
Q3) Use the following pentagonal diagrams to construct the possible clockwise systemic chemical relations between the (forgoing) chemicals.
Q4) Use the following hexagonal diagram to construct the possible clockwise chemical relations between the (forgoing) chemicals.
Q5) Draw one possible *anticlockwise triangular systemic* chemical relations between three of (forgoing) chemicals.

A5)
Type-I-B: Synthesize systemic from the given chemicals to give Maximum possible chemical relations

Q6) Draw the maximum possible chemical relations between some of the (forgoing) chemicals in quadrilateral systemic diagrams.

A6-A:

Note: There are five possible chemical relations instead of four in the clockwise quadrilateral chemical relations (Q2).

A6-B:

Note: There are six possible chemical relations instead of four in clockwise quadrilateral chemical relations (Q2).
Q7) Draw the maximum possible chemical relations between the (forgoing) chemicals in a pentagonal systemic diagram.

A7-A:

Note: There are eight possible chemical relations instead of five in the clockwise pentagonal chemical relations (Q3).

A7-B:

Note: There are eight possible chemical relations instead of five in the clockwise pentagonal chemical relations (Q3).

Q8) Draw the maximum possible chemical relations between the (forgoing) chemicals in hexagonal systemic diagrams.
A8:

Note: There are eleven possible chemical relations instead of six in the clockwise hexagonal chemical relations (Q4).

Type-II: Systemic Analysis Questions [SAnQ,s][8]

Assess the student learning outcomes at analysis level.

Type-II-A: [Analyze systemics into another systemic]

Q1) Analyze the given systemic diagram from the (forgoing) chemicals to the maximum possible clockwise systemic chemical relations.
A1)

1-Clockwise quadrilateral systemic chemical relations.

![ Quadrilateral Diagram]

2-Clockwise triangular chemical relations.

![ Triangular Diagram]

Q2) Analyze the given systemic diagram from the (forgoing) chemicals to the maximum possible clockwise systemic chemical relations.

A2

1-Clockwise quadrilateral systemic chemical relations.

![ Quadrilateral Diagram 2]

2-Clockwise triangular systemic chemical relations.

![ Triangular Diagram 2]
Q3) Analyze the given systemic diagram from the (forgoing) chemicals to the maximum possible clockwise systemic chemical relations.

1- **Clockwise pentagonal systemic chemical relations.**

\[ \text{Na} \rightarrow \text{NaOH} \rightarrow \text{Na}_2\text{CO}_3 \rightarrow \text{NaHCO}_3 \rightarrow \text{NaCl} \]

2- **Clockwise quadrilateral systemic chemical relations.**

\[ \text{Na} \rightarrow \text{NaOH} \rightarrow \text{Na}_2\text{CO}_3 \rightarrow \text{NaCl} \]

\[ \text{Na} \rightarrow \text{NaOH} \rightarrow \text{NaHCO}_3 \rightarrow \text{NaCl} \]

3- **Clockwise triangular systemic chemical relations.**

\[ \text{Na} \rightarrow \text{NaOH} \rightarrow \text{NaCl} \]

**Type-II-B: Analyze systemics into The Corresponding Chemical Equations:**

Analyze the following systemic diagrams illustrating the systemic chemical relations between sodium and its related compounds into chemical equations:
Q1)

A1)

\[ \text{2Na} + \text{2H}_2\text{O} \rightarrow \text{2NaOH} + \text{H}_2 \]
\[ \text{2NaOH} + \text{CO}_2 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} \]
\[ \text{Na}_2\text{CO}_3 + \text{Dil.2HCl} \rightarrow \text{2NaCl} + \text{CO}_2 + \text{H}_2\text{O} \]
\[ \text{2NaCl} \text{ [Molten]} \rightarrow \text{2Na} + \text{Cl}_2 \]

Q2:

Q3)
Type-III: Complete Systemics Questions [SCompQ.s]

[Complete the given unfilled or partially filled systemic diagrams & assess the student learning outcomes at synthesis level]

Q1) From (forgoing) chemicals complete the following clockwise systemic trigonal chemical relations.

A1)

Q2) From (forgoing) chemicals complete the following quadrilateral clockwise systemic chemical relations.
A2:

Q3) From (forgoing) chemicals complete the following clockwise systemic pentagonal chemical relations.
A3) From (forgoing) chemicals complete the following hexagonal chemical relations.

Q4) From (forgoing) chemicals complete the following hexagonal chemical relations.
Type-IV: Systemic Synthetic- Analytic Questions [SSyn -An Q.s][8]

It is a combination of systemic Synthesis and systemic Analysis questions. So, we assess the student achievements learning outcomes at both the synthesis & analysis levels. We ask our students to synthesize systemic from the given chemicals then ask them to analyze the resulted systemic to the corresponding chemical reactions.

Q1) Use the following triangular systemic diagram to construct the clockwise systemic chemical relations between the (forgoing) chemicals. Then analyze to the corresponding chemical equations

A1-1: Synthesis:


\[
\begin{align*}
2 \text{Na} & \quad + \quad \text{O}_2 & \text{heat/excess [O]} & \quad \rightarrow & \quad \text{Na}_2\text{O}_2 \\
\text{Na}_2\text{O}_2 & \quad + \quad \text{HCl} & \rightarrow & \quad 2\text{NaCl} & \quad + \quad \text{H}_2\text{O}_2 \\
2 \text{NaCl} & \quad \text{[Molten]} & \rightarrow & \quad 2\text{Na} & \quad + \quad \text{Cl}_2 \\
\end{align*}
\]
Q2) Use the following the quadrilateral systemic diagram to construct the clockwise systemic chemical relations between the (forgoing) chemicals. Then analyze to the corresponding chemical equations.

A2-1: Synthesis:

A2-2: Analysis: To four equations.

1) \(2 \text{Na} + \text{O}_2\) \(\text{heat/excess [O]}\) \(\rightarrow\) \(\text{Na}_2\text{O}_2\)

2) \(\text{Na}_2\text{O}_2 + 2\text{H}_2\text{O}\) \(\rightarrow\) \(2\text{NaOH} + 2\text{H}_2\text{O}_2\)

3) \(\text{NaOH} + \text{HCl}\) \(\rightarrow\) \(\text{NaCl} + \text{HOH}\)

4) \(2\text{NaCl [Molten]} \rightarrow\) Electrolysis \(\rightarrow\) \(2\text{Na} + \text{Cl}_2\)

Q3) Use the following the pentagonal systemic diagram to construct the clockwise systemic chemical relations between the (forgoing) chemicals. Then analyze to the corresponding chemical equations.
A3-1: Synthesis:

\[
\begin{align*}
Na_2O & \xrightarrow{\text{heat/air}} \text{NaOH} \\
\text{Na} & \xrightarrow{\text{Electrolysis on (molten)}} \text{NaCl} & \text{HCl} & \xrightarrow{\text{2NaCl [Molten]} \xrightarrow{\text{Electrolysis}}} \text{Na}_2\text{CO}_3 \\
\end{align*}
\]

A3-2: Analysis: To five equations.

1) \(4 \text{Na} + \text{O}_2 \xrightarrow{\text{heat/ Air [O]}} 2 \text{Na}_2\text{O}\)
2) \(\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2 \text{NaOH}\)
3) \(2\text{NaOH} + \text{CO}_2 \rightarrow \text{Na}_2\text{CO}_3 + \text{HOH}\)
4) \(\text{Na}_2\text{CO}_3 + 2 \text{HCl} \rightarrow 2 \text{NaCl} + \text{CO}_2 + \text{HOH}\)
5) \(2\text{NaCl [Molten]} \xrightarrow{\text{Electrolysis}} \text{2Na} + \text{Cl}_2\) [Cathode] [Anode]

REFERENCES


SENIOR SECONDARY STUDENTS’ PERFORMANCE IN SELECTD ASPECTS OF QUANTITATIVE CHEMISTRY

Macson J. Ahiakwo
Faculty of Technical & Science Education
Rivers State University of Science & Technology, Port Harcourt, Nigeria
Email: mcsahia@yahoo.com

ABSTRACT
The purpose of the study was to investigate students’ performance in chemical calculations involving gas equation, mole concept and chemical equations. 100 Senior Secondary (SS) students from 10 schools in Port Harcourt metropolis participated in the study. Twenty-item objective test was the data collecting instrument. Overall findings of the study showed that students performed poorly in chemical calculation. Inability to make out the goals of test items, not being able to recall information from memory, use of wrong units, difficulties in inter-unit conversions, reasoning deficiencies using information from the stem of test items and from their memory were some of the problems of the students. Implications of these findings for chemical education were discussed. [African Journal of Chemical Education—AJCE 5(1), January 2015]
INTRODUCTION

In November/December, 2013 West African Secondary School Certificate Examination Chief Examiners’ report [1] on chemistry observed, among others, the weaknesses of candidates which included poor expression and presentation of facts, poor mathematical skills and inability of students to use appropriate technical terms in definition and explanation of concepts.

The case of the difficulty students’ encounter in learning some aspects of chemistry is not new [2-6]. Mathematical aspects of chemistry, specifically quantitative chemistry, is of concern to secondary chemistry teachers. Quantitative chemistry at the secondary school level involves mainly simple calculations related to ratio, proportion, formula transformation, addition, subtraction, multiplication and division. Studies of Koleosho [7] on calculations involving formulae and equations, Eniayeju [8] on mass and volume relationships in chemical reactions and the stoichiometry, Abijo [9] on calculations on mole concept, Bello [10] on a calculation involving solubility expressed in mole of solute per dm$^3$ of the solution, to mention a few, reveal the various mathematical problems students have. We also know that mathematics and students are not best of friends in that most students dread mathematics. There are clear indications of students’ poor performance in mathematics [11].

For students to tackle quantitative chemistry, their performance in mathematics must appreciate. If students must learn quantitative chemistry, the teacher must carry out the dual role of teaching chemistry as well as teaching mathematics. This is a problem, especially if the teacher is handicapped in mathematics. This problem, notwithstanding we have success stories of chemistry teachers coping with the situation [12-18]. As the teachers are improving in their methods and strategies in assisting the students learn quantitative chemistry, there is that urgent need to continue to assess the performance of the students.
Handy and Johnstone [19] working with white children examined students’ performance in chemistry using objective tests. Their study revealed students’ performance in “reasoning process concordant with those of the question writer (the teacher), by guessing, by merely rejecting all of the distracters, other devious procedures, and factual recall alone”. The use of objective test in assessing students in chemistry is common in Nigeria both in local and national examinations. In fact, Federal Government [20] has long directed practitioners in the educational sector, for all disciplines, including chemistry, that assessment of the students should include among others multiple choice items.

Specifically, through multiple choice items the study investigated students’ performance in some aspects of quantitative chemistry, namely, calculations involving gas equation, mole concept, determination of molecular formula and structure of compounds, and chemical equations. The study, apart from the interest in performance, will further reveal students’ difficulties in chemical calculations, which might lighten the yoke of the teacher.

**METHODOLOGY**

One hundred senior secondary students drawn from ten schools in Port Harcourt, metropolis of Rivers State participated in the study. The instrument used in the study was a twenty-item multiple choice objective test. The test items were drawn from chemistry areas of calculations involving a gas equation, the mole concept, determination of molecular formula and structure of compounds, and chemical equations.

Chemistry teachers of the students validated the test items. Apart from few test construction mistakes which were rectified, the items were found to be within reach of students. They were ready to be used to study the performance of the students in chemistry.
The test was administered to the students in their various schools. Chemistry teachers of the students assisted in the administration of the test after the principal of the schools granted the permission. A day was chosen for the test administration considering schools schedules. Students were requested to bring their pencils and erasers only to their various examination halls. When the students were seated, test item papers were given to them. On the spaces provided, students gave their names, schools and proceeded to answer the questions. The students were allowed thirty minutes for the twenty test items. At the end of the given time, the test papers were retrieved from the participating students.

ANALYSIS OF DATA

Item analysis was carried out to find out the distribution of the responses for the various options offered in the test items. The frequency distribution was converted to percentage (in brackets). Reasons given by the students (SS) for the options they ticked were also considered. The analysis is presented for each test item, thus,

Item 1: A certain amount of gas occupies 5.0m$^3$ at 2 atm. and 10°C. Calculate the number of moles present (R = 0.082 atm. dm$^3$K$^{-1}$ mole$^{-1}$)

(a) 0.400 moles (b) 1.521 moles √(c) 0.431 moles (d) 0.34 moles

SS: (45%) (30%) (20%) (5%)

Item 2: 2.0 moles of an ideal gas are at a temperature of -13°C and a pressure of 2 atm. What volume in dm$^3$ will the gas occupy at that temperature?

√(a) 21.32 dm$^3$ (b) 21.23 atm (c) 20.21 dm$^3$ (d) 21.24 dm$^3$

SS: (18%) (23%) (48%) (11%)
Item 3: Under a pressure of 300Nm$^{-2}$, a gas has a volume of 250cm$^3$. What will its volume be, if the pressure is changed to 100 mm Hg at the same temperature? (760mm Hg = 101325Nm$^{-2}$)

(a) 51.50cm$^3$  (b) 56.52cm$^3$  (c) 56.25cm$^3$  (d) 50.25cm$^3$

SS:  (30%)  (29%)  (11%)  (30%)

Item 4: A certain mass of gas has a volume of 241cm$^3$ at 18°C and 753mm Hg pressure. What would its volume be at STP?

(a)203cm$^3$  (b)201cm$^3$  (c) 221cm$^3$  (d) 224cm$^3$

SS:  (30%)  (14%)  (28%)  (28%)

Item 5: A gas has a volume of 500cm$^3$ when a pressure of 1000Nm$^{-2}$ is exerted on it. What will be its volume, if the pressure is changed to 150mm Hg at the same temperature (760mm Hg = 101325Nm$^{-2}$)

(a) 25cm$^3$  (b) 20cm$^3$  (c) 25dm$^3$  (d) 20dm$^3$

SS:  (19%)  (12%)  (56%)  (13%)

Item 6: Calculate the number of moles in 1.58g of Solid potassium tetraoxomanganate (vii)

(a) 0.01mole  (b) 0.001mole  (c) 1.0mole  (d) 0.10mole

SS:  (12%)  (31%)  (45%)  (12%)

Item 7: Calculate the number of atoms of elements in a sample of 18.63g of lead (Pb = 207)

(a) 5.4x10$^{22}$ atoms  (b) 0.5x10$^{22}$ atoms  (c) 5.0x10$^{22}$ atoms  (d) 4.5x10$^{22}$ atom

SS:  (13%)  (36%)  (23%)  (28%)
**Item 8:** How many moles are there in 20g of CaCO\(_3\)? (Ca = 40) C = 12, O = 16)

\(\sqrt{\text{(a) 0.2 moles (b) 0.02 moles (c) 0.21 moles (d) 0.3 moles}}\)

SS:  
(14%) (28%) (28%) (30%)

**Item 9:** If 12g zinc reacts with excess hydrogen chloride acid, calculate the number of moles of hydrogen liberated.

\(\sqrt{\text{(a) 0.32 moles (b) 0.032 moles (c) 0.23 moles (d) 1.231 moles}}\)

SS:  
(18%) (18%) (37%) (27%)

**Item 10:** What is the mass of 3 moles of oxygen molecule? (O = 16)

\(\sqrt{\text{(a) 69g (b) 79g (c) 86g (d) 96g}}\)

SS:  
(26%) (38%) (14%) (22%)

**Item 11:** A compound has a composition C = 93.2%, H = 7.7%. The compound has a relative molecular mass of 78 and burns with a very soothly smell. What is the compound?

\(\sqrt{\text{(a) benzene (b) toluene (c) kerosene (d) fuel}}\)

SS:  
(18%) (24%) (31%) (27%)

**Item 12:** The percentage composition of carbon, hydrogen and oxygen in vitamin C was determined by burning a sample weighing 2.00mg. The masses of carbon (iv) oxide and water formed are 3.00mg and 0.816mg respectively. What is the empirical formula of vitamin C?

\(\sqrt{\text{(a) C}_6\text{H}_6\text{O} (b) C}_3\text{H}_4\text{O}_3 (c) C_2\text{H}_2\text{O}_4 (d) C_2\text{H}_4\text{O}_1}\)

SS:  
(5%) (15%) (33%) (47%)
Item 13: Sample of calcium chloride 1.64g is dissolved in water and silver trioxonitrate (v) solution added. A precipitate of AgCl weighing 4.24g was formed. Determine the simple formula of calcium chloride.

(a) CaClO   (b) Cu₄Cl   (c) CaCl   √(d)CaCl₂
SS:   (18%)   (30%)   (46%)   (6%)

Item 14: A compound contains 84% carbon and 16% hydrogen. Find the empirical formula of the compound.

√(a) CH₂   (b) C₂H₄   (c) CH₄Ca   (d)C₆H₆K₆
SS:   (18%)   (42%)   (10%)   (30%)

Item 15: A mineral contains 14.7% calcium and 67.7% tungsten (W), the reminder is oxygen. Find its empirical formula.

√(a) CaWO₃   (b) CaO₃   (c) CaO   (d) CaW
SS:   (18%)   (33%)   (28%)   (21%)

Item 16: What volume of dry carbon (iv) oxide (CO₂) gas measured at STP will be produced from the decomposition of 3.5g calcium trioxocarbonate (iv)? (Ca = 40, C =12, O = 16)

(a) 1.6dm³   √(b) 0.78dm³   (c)1.06dm³   (d)0.6dm³
SS:   (10%)   (10%)   (28%)   (52%)

Item 17: Calculate the number of moles of calcium chloride (CaCl₂) that can be obtained from 25g of limestone, CaCO₃ in the presence of excess hydrogen chloride (HCl) (Ca = 40, C=12, O=16, H = 1, Cl = 35.5)

√(a) 0.25moles   (b)2.5 moles   (c) 0.52moles   (d) 1.25 moles
SS   (13%)   (28%)   (29%)   (30%)
**Item 18:** What mass of lead (II) trioxonitrate (v), Pb(NO$_2$)$_2$ would be required to yield 9g of lead (II) chloride, PbCl$_2$ on the addition of excess sodium chloride solution, NaCl? (Pb = 207, N = 14, O = 16, Na = 23, Cl = 35.5)

(a) 10.71g  
(b) 10.1g  
√(c) 10.7g  
(d) 1.10g

SS: (30%) (26%) (5%) (39%)

**Item 19:** Determine the mass of carbon (iv) oxide, CO$_2$ produced on burning 104g of ethyne, C$_2$H$_2$ (C = 12, O = 16, H = 1)

(a) 35g  
(b) 325g  
√(c) 352g  
(d) 359g

SS: (20%) (23%) (17%) (40%)

**Item 20:** In the industrial preparation of hydrogen trioxonitrate(v) acid, ammonia gas, NH$_3$ is burned in oxygen, O$_2$ in the presence of catalyst according to the equation:

$$4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 4\text{NO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l})$$

If 260cm$^3$ of NH$_3$ is burnt completely, what volume of NO is produced?

(a) 160cm$^3$  
(b) 261cm$^3$  
(c) 360cm$^3$  
√(d) 260cm$^3$

SS: (36%) (33%) (30%) (2%)

**DISCUSSION OF FINDINGS**

Discussion of findings was done according to the response patterns of the students to the options provided in the solutions of the test items.

(A) Test –Items on Calculations involving Gas Equations

Test-item 1 required the students to find out the number of moles present in 5.0m$^3$ of a gas at 2 atm and 10$^0$C. About 20% of the students got the correct option (c) while the remaining 80% ticked the various distracting options. This question required the application of the formula
PV = nRT. Option (b) 1.521 moles and (d) 0.341 moles were far from option (c) 0.431 moles. However, 45% of the students considered (a) 0.400 moles.

The students seem to have disregarded a whole substantial amount of 0.031 moles of the gas. The students’ thinking may have been that since it is a gas, this amount may not matter much in the experiment. This idea of possible reasoning of not considering the gas amount as not being substantial seem to have also been applied in the students’ choices of answers in items 2 to 5 where the distractive options are closer to the correct options. For instance, in item 3, the correct option is (c) 56.25 cm$^3$ where 11% of the students ticked compared to (a) 51.50 cm$^3$ (30%), (b) 56.52 cm$^3$ (29%), (d) 50.25 cm$^3$ (30%). The reasoning of the students follows the same pattern as in items 2, 4 and 5.

Apart from the students’ choices of wrong options in the test items due to mathematical difficulties associated with chemical calculations, application of the correct units is observed to have been misunderstood by over 12% of the students that attempted the test items. In test item 2, the answers are expressed in dm$^3$ volume. About 23% of the students ticked answer expressed in atmosphere (atm) representing pressure. Similarly, in test item 5, answers are expressed in cm$^3$ (volume). There was still a total of 60% of the students who reasoned that the answer should be expressed in dm$^3$ (higher level of volume). This is also part of the calculation problem associated with lack of understanding of uniformity of units in the relevant equation or formula.

(B) Calculations Involving the Mole Concept

There were five test items related to the mole concept. Solutions of these test items are also connected to those of items 1 to 5. However, these ones required inter-conversion from mass to particles or amount and vice versa. Items 6, 8 and 9 required the student to calculate the
amount in moles. The difficulties the students experienced in items 1 to 5 re-occurred here – the problem of underestimating fractions of the substances just as it was done with the gases. For example, item 6 required the students to calculate the number of moles in 1.58g of solid potassium tetraoxomonaganate (vii). About 12% of the students chose the correct option (a) 0.01 mole. Option (c) 1.0moles where 45% of the students responded is on the far-side of (a) and the remaining distracters (b) 0.001 mole (31%) and (d) 0.10moles (12%).

The students should have reasoned that 1.0moles is a very large amount equal to the molecular mass of the substance. For experiments done at the micro-level, the students may not require that large amount of 1.0mole; rather small amount is needed, of course within the range of 0.001 and 0.1mole. The same reasoning of the students in the choice of answers in item 6, seem to apply to item 8, requiring the estimate of the amount in moles of 20g of calcium trioxocarbonate (iv). Test-item 7 required the estimation of the number of atoms (particles) in 18.63g of lead. This problem involves the knowledge of applying 207g (atomic mass) of lead containing 6.02 x10^{23} atoms (Avogadro’s constant). While only 13% of the student ticked 5.4 x 10^{22} atoms (a), most of the students indicated the distracters (b, c, d). It is thought that the mathematical problem of division and applying the laws of indices would have been responsible for the wrong choices of the options.

On the other hand, in item 10, the problem required conversion from amount in moles to mass. The students should have noted first that what is to be converted is 3moles of oxygen “molecules” not oxygen “atoms”. Only 22% of the students considered (d) 96g while the rest of them took the wrong options. Apart from the chemical calculation problem, lack of understanding of the problem statement affected the reasoning patterns of the students.
(C) Calculations Involving Determination of the Molecular Formula and Structures of Compounds

This section concerns items 11 to 15. In these test items, students are presented with some chemical compositions. Students were required to make out the compounds or figure out their empirical formula or molecular formula. Item 11 was not only to find out the molecular formula, C₆H₆, but also to name the compound. About 72% of the students could not name the compound. On close inspection of the rough works done at the back of the test paper by eighteen students showed that they quickly arrived at C₆H₆ but could not name the compound. It is possible that teachers assume that students are conversant with names of organic compounds, and so do not see the need to match the molecular formula with the names of the compounds.

Arriving at the molecular formula of a compound sometimes may require getting at the empirical formula. The initial step is to divide the compositions by atomic masses of the elements followed by further division with the lowest factor and so on. These are all mathematical algorithms that make demands on the memory capacity of the students. Students are failing to cope means that they cannot calculate empirical formula which leads them to find molecular formula. For test items 12, 13, 14 and 15, over 50% of the students could not calculate empirical formula from the given chemical compositions. What the teacher might do is to identify those aspects of chemical calculation that require mathematical algorithms. First, get the student acquainted with the problems before relating them to the chemical calculations. When that is done, one can now consider the reasoning patterns and further pinpoint where there are problems for remediation.
(D) Calculations Involving Chemical Equations

Test items 16 to 20 are connected with calculations involving chemical equations. It means that in these test items, students should be able to write chemical equations and balance them or determine whether they are balanced or not. From the equations, it is possible to obtain the proportion of the reacting entities which can be equated to standard temperature and pressure (STP). Item 16 required the estimation of volume of dry carbon (iv) oxide (CO$_2$) gas measured at STP from the decomposition of 3.5g of calcium trioxocarbonate (iv).

Only 10% of the students got the correct option, while the rest 90% failed to answer the question. It was observed that students that failed the test could not reason, because they failed to write chemical equations, recall from memory volume of gas occupied at STP. The need to balance equations so as to solve the problem at hand became clearer with item 20. The equation was provided and balanced, but only 2% of the students ticked the correct option. The test required the estimation of the volume of Nitrogen Oxide produced after burning 260cm$^3$ of ammonia. The reasoning was to consider the 1;1 ratio of ammonia used to produce nitrogen oxide. Answers like 160cm$^3$, 260cm$^3$ and 360cm$^3$ do not fall in line. They appear to be guessed as the students could not utilize the information given in the equation. It means that students could also write chemical equations without knowing how to extract information from them.

Test items 17, 18 and 19 are such problems that rely heavily on the information given in the chemical equation. Less than 17% of the students could provide the correct options to the test items. The teacher will need to teach writing and balancing equations before bringing them into problems like this. Students should understand the reactions so that writing the equations will be meaningful to them. The coefficients of the equations should be made very clear to the students so that they know how they are related to amounts (in moles) and in grams. The coefficients of
the molecules or compounds are very useful in chemical calculations involving chemical
equations. The coefficients can relate to a number of variables in chemistry depending on the
nature of the problem. For example $4\text{NH}_3 (g)$ could means 4moles or parts by volume or 4 parts
by pressure as the case may arise in a problem. Students could not utilize the coefficients in their
reasoning and so obtained distracters as answers.

**IMPLICATIONS OF FINDINGS FOR CHEMICAL EDUCATION**

Chemistry and chemical technology contribute to the quality of life on the planet earth in
many areas: health, nutrition, agriculture, transportation, materials and energy production, and
industrial development. Mathematical contents and operations in these areas are helping in
improving further the quality of life. Concerning the health sector, for example, it has been
suggested by Professor Gabriel Oyibo, a Nigerian-born US mathematical physicist, using his
God Almighty Grand Unified Theorem (GAGUT), that the solution for the dreaded HIV/AIDS
may be found in mathematical manipulations of the virus [21]. It is also suspected that Ebola
Virus Disease (EVD) cure could be sorted out in the same way. Research is ongoing. We cannot
afford to do away with mathematics in the science disciplines including chemistry.

The findings of the study which clearly indicated the poor performance of the students in
chemical calculations need to be treated with the utmost concern. Learning chemicals facts,
concepts, principles and theories with chemical calculations is imperative if we must produce
sound chemists, technologists, engineers, agriculturists and medical doctors, just to name a few.
Teachers’ complaints about chemistry students’ inability to cope with quantitative chemistry is
no longer tenable. Good chemistry teachers are continuously trying out methods and strategies
necessary to combat students’ difficulties in chemical calculations involving gas equation, mole
concept, determination of molecular formula and structure of compounds, and chemical
equations, being mindful that these are in the heart of chemistry curriculum.

Students are not doing well in quantitative chemistry involving gas equation, mole
concept, determination of molecular formula and structure of compounds and chemical
equations. Considering, the relevance of these areas in chemistry and related discipline students
should make frantic efforts to learn them. Chemistry teachers should improve on their
approaches to teaching quantitative chemistry.

REFERENCES
1. Chief Examiners’ Reports (2013). The West African Senior School CertificateExamination (WASSCE) November/December, Nigeria, Lagos, the West
African Examinations Council, Chemistry, 199-220.
ordinary level chemistry syllabus for Nigeria Schools, Journal of Science Teachers
the concept of dynamic equilibrium. STAN National Chemistry Workshop Proceeding,
44-47.
Proceedings, Ilorin, Kwara State.
Science Teachers Association of Nigeria, 26(2), 93-100.
National Chemistry Workshop at the University of Jos, Jos.
outcome in secondary chemistry, Unpublished Doctoral Thesis, University of Ibadan,
Ibadan.
THE STATE OF EDUCATION AND OUTREACH ACTIVITIES IN AFRICA IN RELATION TO THE CHEMICAL WEAPONS CONVENTION\textsuperscript{2}

Temechegn Engida
Immediate Past President of FASC, Addis Ababa, Ethiopia
temechegn@gmail.com

ABSTRACT

This study reports the state of education and outreach activities in Africa with particular reference to the chemical weapons convention (CWC) of the Organization for the Prohibition of Chemical Weapons (OPCW) that was established in 1997 and based in The Hague, The Netherlands. The study employed various approaches like administering tests to chemistry students, secondary school chemistry teachers and chemistry lecturers in a selected university. The findings suggest that a lot has to be done in order to fully and effectively promote the ideals of the CWS among the various stakeholders. [\textit{African Journal of Chemical Education—AJCE} 5(1), January 2015]

\footnote{Versions of this paper were presented at 1) Twelfth Regional Meeting of National Authorities of States Parties in Africa, OPCW, 4 - 6 June 2014, Nairobi, Kenya, 2) OPCW Conference on Education for Peace - New Pathways for Securing Chemical Disarmament, 22-23 September 2014, The Hague, Netherlands, and 3) OPCW’s 16\textsuperscript{th} Annual Meeting of National Authorities, 28 November 2014, The Hague, Netherlands.}
INTRODUCTION

Education and outreach (E&O) refers to activities that support formal or classroom-based education, as well as informal education that occurs outside the classroom. E&O campaigns provide educational experiences for young people in classrooms, libraries, after-school programs, community-based organizations, museums, etc., as well as supporting the professional development of the professionals and paraprofessionals who work with them.

The why of education and outreach in relation to CWC is discussed elsewhere [1] so it is sufficient to say that whereas chemists played a formative role in the development of chemical warfare and the CWC aims to prevent any recurrence of this activity, unfortunately very few chemists know much about the CWC and what it covers, and few chemistry students realize that beneficial substances can be misused to produce chemical weapons.

The issue here is that if chemists and chemistry educators agree that education and outreach in relation to the CWC is a necessary part of their professional obligations, then they need to devise strategies that accomplish these obligations. Existing educational materials for school science and university chemistry students are written mostly for a specialist audience, or have dealt only marginally with the topics central to chemical weapons or the CWC in general. On the other hand, revising or updating the existing chemistry education materials to address and deal with the CWC may not be realistic in the near future, particularly in African countries, mainly because of the financial, institutional and human requirements.

The purposes of this report are there fold: first to validate whether the above claims are still there, to explore the challenges in greater detail in the African context and suggest plausible recommendations as seen from the stakeholders’ perspectives.
METHODOLOGY

Various approaches were used to collect data for this work, some of which were the following. I made a brief look at the Ethiopian secondary school and the undergraduate harmonized Chemistry curricula contents in relation to multiple uses of chemicals and the work of OPCW. I also administered a brief Test on the same issues (prepared by myself) in selected senior secondary schools and a University in Ethiopia. The test consisted of eight questions, some in true-false and others in multiple choice formats. The questions were asking whether a single chemical can be useful or dangerous depending on its use, whether chemists played an influential role in the development of chemical warfare, what CWC stands for, etc. A sample of 52 senior secondary school students, 5 secondary school chemistry teachers (BSc degree Holders) and 11 University Lecturers (MSc degree holders) participated in answering the test. These samples were selected on availability and willingness basis.

I also facilitated, upon request by OPCW, the E&O group at the Twelfth Regional Meeting of National Authorities (NAs) of States Parties (SPs) in Africa, from 4 to 6 June 2014 in Nairobi, Kenya. I posed certain questions and issues to guide them through the discussion process. Some of these were:

- Could professional societies like national chemical societies, continental federations, and international unions be in a position to take the burden? How feasible is this in your country? Why?
- Is there any hope that States Parties in Africa can be the major players in this regard? Do you have specific experiences in your country? What are the challenges and opportunities?
• What are the most feasible strategies to convince education policy makers and curriculum developers to integrate issues related to CWC in already ‘crowded’ curricula in African/your education systems?

• Given the fact that ‘one size fits all’ kind of educational material cannot work here, what are the most plausible and yet cost-effective approaches to address the various stakeholders (science and technology/education policy-makers and shapers-- including politicians and the media, diplomats, senior military personnel, researchers and students of Chemistry/Science)?

That occasion gave me the opportunity to get the views and opinions of representatives of the participating African countries. In particular the participants expressed the challenges they faced in their respective countries in relation to the CWC’s education and outreach activities. They also suggested the way forward.

RESULTS AND DISCUSSION

Ethiopia’s recently developed secondary school chemistry curriculum and the harmonized undergraduate chemistry curriculum do not seem to have been influenced by developments in the area of multiple uses of chemicals. Neither the objectives nor the content areas of the curricula make any reference to the ideals of the CWC. As a consequence, perhaps, the University instructors (MSc holders) attained only as high as 5 out of 8 (only 2 teachers) and as low as 2 out of 8 (5 teachers).

The question here is: Can we assume that these university instructors (the majority of whom scored about 20% on a test prepared for high school students) are ready to teach
secondary school chemistry teachers in relation to the concepts investigated? In fact, some of the secondary school chemistry teachers scored lower than their students in the test.

We can thus safely say that our university instructors, high school chemistry teachers, students and their corresponding curricula are not ready for multiple uses of chemistry concepts or not ready to contribute meaningfully to the ideals of the CWC.

Some of the participants of the 12th regional meeting of the African national authorities (NAs) stated that they already started E&O activities in their respective countries with varied depth and strategies. They have, however, highlighted a number of challenges, some of which are the following:

• Lack of capacity (human, materials and finance). The required added expertise on education and outreach like knowledge of educational/pedagogical principles, and the skills for proper training may not be available at national level within the NAs
• The issue of chemical weapons (CW) not being a priority for African State Parties
• Strategies for engaging various stakeholders with multiple/varied needs
• The burden to conduct large scale training of relevant stakeholders

These challenges in Africa, and perhaps anywhere in the world, tell us that there is a long way to go in relation to educating the various stakeholders by way of making them aware of the ideals and strategies of the CWC. It is good that OPCW started working on E&O as one of its activities. This initiative must continue, as recommended by the temporary working group (TWG) on E&O of OPCW, to reach the wider relevant community through various means.
SUGGESTIONS/RECOMMENDATIONS

The findings require us to do a lot of things at various levels. As expressed by the TWG of OPCE [2] education and outreach is a core component of national implementation of the Convention. Engagement with stakeholders in the chemical industry, the scientific community, academia and the public at large contributes to promoting and expanding a culture of responsible science. More specifically, the following need to be taken into account:

• Convincing key stakeholders like policy makers and university professionals in the value of knowledge and skills about issues related to CWC. Start with issues relevant to them and at the same time related to the CWC, maybe chemical safety and security.
• Use social media with key messages and professional moderators. Capitalize on the availability of mobile (smart) phones in the hands of the African youth.
• In collaboration with IUPAC, consider launching International Day of Chemistry that could help the world to be aware of the use and misuse of chemistry (multiple uses of chemicals)
• At national level encourage NAs to hold Open Day (Competitions) on CWC/OPCW/Multiple Uses of Chemicals
• Target different stakeholders (public, students, teachers, industry professionals, policy makers, parliamentarians, etc)
• Provide intensive training in the form of training of trainers (TOT) so that the approach can be cascaded at national/local level to ensure larger groups are reached, ownership and sustainability ensured
• Use multimedia approach in developing the content to address learning styles/preferences. Some prefer movies, others hardcopy brochures with images and targeted messages, etc.

• Approach sub-regional and regional economic communities of the African Union (AU) by way of conducting side events related to the CWC. Examples are EAC, SADC, COMESSA, ECOWAS, Ministerial Forums on Science, Technology, Education, the African Academy of Sciences, the Federation of African Societies of Chemistry, etc

• OPCW and NAs need to engage the relevant stakeholders starting from the planning stage through implementation and then evaluation. OPCW and NAs could progressively withdraw as the stakeholders own the activities. The planning, Implementation and evaluation (PIE) approach is discussed in the ensuing pages.

• OPCW needs to empower the NAs as they should be the key players. This could be in terms of staffing (numbers), expertise and skills

• To address the issue of CWs not being the priority of African States, the OPCW needs to articulate the benefits to African SPs and develop key message on that to be communicated to the NAs. Perhaps one can start with a more relevant issue like Chemical Safety and Security and then go from that to the target issue

• OPCW needs to stress in its support to sponsored professionals who attend conferences that they do E&O activities as part of their respective presentations/speeches to the science professionals they communicate.

It is my belief that ultimately all these need to rest on one particular issue: INVESTING HEAVILY ON CHEMISTRY TEACHERS DEVELOPMENT (BOTH PRESERVICE AND INSERVICE) IN A SYSTEMATIC WAY! A mere reliance on developing new chemistry
content and making them available for teachers to read could take us nowhere. Similarly, training chemistry teachers in just general pedagogical strategies would not be effective. So what should be done? Address it through the (T)PCK ([technological] pedagogical content knowledge) approach as such an approach integrates the relevant content with the appropriate pedagogy and technology.

I also believe that NAs need to engage themselves on E&O activities in a systematic way. One approach to systematization is the UNESCO’s [3] PIE model (in relation to peace education) discussed and depicted below.

- E&O program development should follow a systematic framework such as the iterative process PIE (planning—implementation—evaluation) to be successful.
- Planning involves identifying goals and objectives, audiences, and educational strategies.
- Implementation concerns the operation of activities.
- Monitoring and evaluation of the results help identify successful activities as well as components in need of improvement.

This iterative process—PIE—leads to an education and outreach program that avoids common problems, such as targeting the wrong audience or using an inappropriate message or medium. The following are PIE-questions to guide the design of an education and outreach program:

**Planning**

- What is the problem or issue you want to address?
- What are your goals and objectives?
- What audiences or stakeholders are involved in the issues to be communicated?
- What are their backgrounds, needs, interests, and actions?
- For each audience, what changes or actions are desired?
- How can audience members be involved in the planning process?
- What constraints and resources are there?
- What messages must be sent?
- What channels and activities will most efficiently result in the desired changes in knowledge, attitudes, or behaviors?

**Implementation**

- What medications are indicated by pilot tests of activities and materials?
- Is scheduling, funding, and staffing adequate and efficient?

**Evaluation**

- How will you know if the strategy worked?
- What are the outputs and outcomes of the program?
- Have you assessed key indicators of success, such as changes in the environment or in audience knowledge levels, attitudes, or behaviors?

![Fig. Model of integration of peace values into school curriculum [3]](image)
One last but not least recommendation is in relation to who should be doing these. My suggestions are the following:

- Under the umbrella of NAs, National Chemical Societies need to take the lead as they will have easy access to the academia and relevant ministries in their respective countries.

- Regional federations of chemistry like FASC should play a catalytic role in terms liaising with African chemical societies, other chemical societies in the world and regional and international professional societies maybe through FASC’s Committee on Chemistry Education in Africa--CCEA. CCEA is entrusted in handling the African Conference on Research in Chemistry Education (ACRICE). ACRICE-1 was held in Addis Ababa/Ethiopia in December 2013, whereas ACRICE-2 is planned to take place in South Africa in November 2015.

- Development partners that promote science education for sustainable development agenda need to be convinced that, ultimately, it is the investment on the youths’ science education that determines the attainment of the sustainability agenda.

REFERENCES

ARGIC JOURNAL OF CHEMICAL EDUCATION

AJCE

GUIDELINES FOR AUTHORS

SJIF IMPACT FACTOR EVALUATION [SJIF 2012 = 3.963]

The African Journal of Chemical Education (AJCE) is a biannual online journal of the Federation of African Societies of Chemistry (FASC). The primary focus of the content of AJCE is chemistry education in Africa. It, however, addresses chemistry education issues from any part of the world that have relevance for Africa. The type of contents may include, but not limited to, the following:

RESEARCH PAPERS reporting the results of original research. It is a peer-reviewed submission that deals with chemistry education at any level (primary, secondary, undergraduate, and postgraduate) and can address a specific content area, describe a new pedagogy or teaching method, or provide results from an innovation or from a formal research project.

SHORT NOTES containing the results of a limited investigation or a shorter submission, generally containing updates or extensions of a topic that has already been published.

REVIEWS presenting a thorough documentation of subjects of current interest in chemical education.

LABORATORY EXPERIMENTS AND DEMONSTRATIONS describing a novel experiment/demonstration, including instructions for students and the instructor and information about safety and hazards.

SCIENTIFIC THEORIES describing the scientific, historical and philosophical foundations of theories and their implications to chemical education.

ACTIVITIES describing a hands-on activity that can be done in the classroom or laboratory and/or as a take home project.

INDIGENOUS KNOWLEDGE AND CHEMISTRY IN AFRICA as a special feature that addresses the relationship between indigenous knowledge and chemistry in Africa. It could be in the form of an article, a note, an activity, commentary, etc.

LETTER TO THE EDITOR: A reader response to an editorial, research report or article that had been published previously. The short piece should contribute to or elicit discussion on the subject without overstepping professional courtesy.

All manuscripts must be written in English and be preferably organized under the following headings: a) TITLE, Author(s), Address(es), and ABSTRACT in the first page, b) INTRODUCTION reviewing literature related to the theme of the manuscript, stating the problem and purpose of the study, c) METHODOLOGY/EXPERIMENTAL including the design and procedures of the study, instruments used and issues related to the reliability and/or validity of the instruments, when applicable, d) RESULTS AND DISCUSSION, e) REFERENCES in which reference numbers appear in the text sequentially in brackets, each reference be given a separate reference number, et al and other notations like Ibid are avoided, and finally f) ACKNOWLEDGEMENTS.

When submitting a manuscript, please indicate where your manuscript best fits from the above list of categories of content type. All enquiries and manuscripts should be addressed to the Editor-in-Chief: email eic@faschem.org, PO Box 2305, Addis Ababa, Ethiopia.