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EDITORIAL

CHEMICAL CONCEPTS

Temechegn Engida
Email: temechegn@gmail.com

Dear AJCE Communities,

Although there seems to be no agreement about the nature of concepts, one can safely say that chemical concepts are ideas about matter. The major problem in teaching chemical concepts, however, is individuals (students) construct their own ideas about matter depending on their previous experiences in a way that in a given classroom there could be as many conceptions of the ideas as there are students.

In order to alleviate such difficulties many of the researchers in this issue of AJCE have been identifying the common difficulties held by learners and have been proposing a wide variety of strategies. This issue has also included topics related to practical works in Chemistry. The research works and features included in this issue were tackling chemistry teaching in 8 different contexts or countries in Africa.

I hope you will enjoy reading them all!

SJIF IMPACT FACTOR EVALUATION [SJIF 2012 = 3.963]
DEVELOPMENT OF A SIMPLE AMINO-MODIFIED SILICA-BASED COLORIMETRIC SENSOR FOR THE DETECTION OF COPPER (II) IONS IN AQUEOUS SAMPLES

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ABSTRACT
Research projects form an important part of learning and preparing students for graduate training. While most cutting edge research requires highly sophisticated instruments, there is no such luxury in the Least Developed Countries, least of all, being accessible to undergraduate students. Consequently, undergraduate research projects require some level of improvisation and innovation to use easily available materials to carry out research, without compromising the quality of science. This paper reports the development of a simple amino-modified colorimetric sensor using silica gel modified with (3-aminopropyl)-triethoxysilane (APS) for the qualitative detection of Cu2+ ions in aqueous solutions in an effort to demonstrate the concept of ligand field strength and imbue interest in research in the undergraduate students. The sensor was immobilized on a glass stirring rod for simulated field applications. It responded considerably well at concentrations above 200 parts per million and neutral pH (7-8) giving response under 60 minutes of exposure with the increase in detection times as the concentration of the ions decreased. Modification of the APS with different substrates reduced its efficiency, demonstrating the necessity for primary amines. The binding of the Cu2+ ions seemed considerably stable for the sensor to be applied as a passive sampling device. This experiment has demonstrated that indeed, science does not only depend on sophisticated instrumentation but also simple ideas can generate interest in students while also achieving credible research results. It further demonstrates the importance of encouraging independent thinking to arouse interest as a way of improving the learning process. [African Journal of Chemical Education—AJCE 6(2), July 2016]
INTRODUCTION

With the persistent neglect for funding of public higher education institutions in most African countries, the offering of science-based education remains a huge challenge owing to poor or complete lack of appropriate infrastructure [1]. This is argued to have been brought about by the shift in funding policy by World Bank and the International Monetary Fund to channel funding away from higher education towards basic (primary) education [2], and its ratification and implementation by African states thus putting immense pressure on the public universities to seek alternative funding [1]. In sciences, specifically, this has been exacerbated by generally poor appreciation of science by the general public including the political authorities who hold the key to the financial resources [3, 4] Despite all these, science educators still need to sufficiently expose the students to laboratory work in order to demonstrate certain concepts as well as generate interest in sciences in the students [5, 6].

Lesotho is not an exception to this; there has been a consistent decline in funding spanning over 10 years [7]. Poor infrastructure in Lesotho affects all levels of education, from the secondary schools to the tertiary level, since most secondary schools do not have laboratories. The few that have laboratories do not have adequate facilities and consumables [8]. The importance of experiments in explaining and understanding some difficult concepts in science cannot be emphasized enough. This is especially so in chemistry where most explanations require high intuition since most phenomena studied cannot be seen, nor be heard. With limited funding, chemistry remains the hardest hit since after every chemistry experiment, the chemicals used are discarded as opposed to disciplines like physics for example, where models could be constructed from almost anything and be stored for use over multiple times. The same is true for biology, where the students could observe themselves or use plants and insect for study models.
Different scenarios such as the use of virtual laboratories and digital audio-visual pictures have been proposed for use in teaching of chemistry at both school and undergraduate levels [9]. However, it is argued, these cannot replace the impact of a real physical experiment in the laboratory [8]. As such; simple experiments that do not require the use of sophisticated instrumentation and expensive chemicals are usually employed, as long as they do not compromise the quality of science being demonstrated. Relevance of examples and materials used in a study is also very critical as it is believed to influence the interest and understanding of certain subject by the students. As a result, common phenomena and materials that are experienced or used in everyday life could also generate interest in the students. One such is the environmental degradation and waste management. Therefore drawing examples from these areas in teaching usually arouses students’ interest.

Copper is one of the most abundant and widely used metals globally [10] with applications in electrical installations, construction, alloys, industrial machinery and agriculture [11]. Consequently, it often finds its way into the environment where it causes pollution. In recognition of this, the United States Environmental Protection Agency recommends the maximum acceptance level for Cu2+ ions at about 2×10⁻⁵ M in drinking water [12]. It is for this reason that it is necessary to search for efficient ways of not only removal, but also early detection of copper ions. There are a number of analytical methods used for quantitative determination of the Cu2+ ions. These include spectroscopy, namely, atomic absorption/emission spectrometry and atomic mass spectrometry [13], evanescent wave infrared absorption spectroscopy and voltammetry [14], as well as gravimetric and ion selective electrodes approaches [15].

Despite their efficiency, these techniques are relatively expensive and they commonly require highly trained personnel to operate the equipment. As such, they are rarely available in
economically challenged laboratories, especially for training of undergraduate students. This has thus sparked a considerable amount of research towards development of alternative and affordable sensors. Sensors are important for screening of suspected analytes before the somewhat expensive quantitative methods could be used even in the cases where such are not required. For example, in the cases where the suspected ions are not present or they are at very low levels that may not be detected.

This manuscript reports the preparation of a simple silica-based colorimetric sensor for copper ions in aqueous solutions. Cu$^{2+}$ ions turn blue in the presence of a ligand with sufficiently strong ligand field to narrow the gap between the eg and t2g orbital sets. As such, it is conceptually simple to develop a simple sensor that could detect copper ions in solution using a strong ligand such as nitrogen atom. To achieve this, silica gel was modified with (3-aminopropyl)-triethoxysilane to enable the introduction of the amine groups onto silica surface which characteristically affect the ligand field of the Cu$^{2+}$ ions leading the blue colour. Furthermore, the effect of addition of different nitrogen compounds onto the silica surface was studied in order to demonstrate the concept of ligand field strength, as well as studying the overall sensing dynamics. This is a simple experiment that was performed by two undergraduate students over a semester at National University of Lesotho, a resource-challenged university in Southern Africa. This project was undertaken as an independent study with minimal supervision by the students.

EXPERIMENTAL

Reagents and Apparatus

This experiment was performed using simple laboratory apparatus: weighing balances, stirring rods, beakers, test tubes, thermometer, hot plate, reflux apparatus.
Unless otherwise stated, general laboratory grade reagents were used as purchased. Silica gel, copper (II) nitrate, glycine, sodium chloride, sodium hydroxide, naphthalic anhydride, hexane and methanol were obtained from Associated Chemical Enterprise. Distilled water was prepared in-house using a simple water distiller. The (3-aminopropyl)-triethoxysilane was obtained from Sigma Aldrich.

**Procedures**

**Preparation of silica and the amino-modified silica adsorbents**

Preparation and modification of silica with the APS was carried out using 20 g of silica according to the procedure outlined in the PIERCE Application Note [16]. A blank treated silica gel was also prepared by treating pure silica the same way the APS modification was treated.

**Assembly of the probe and the sensing process**

The basic sensing process was achieved by applying a thin layer of vacuum grease uniformly on the tip of a glass stirring rod (about 1 cm) followed by rolling it over silica powder (blank or modified) to attach silica particles (see Figure 1). Once this was achieved, the probe was introduced into the solution containing Cu2+ ions at the specified concentration and time accordingly and the colour change was monitored. For the initial experiment, a solution of 500 ppm Cu2+ (which was almost colourless) was used with the equilibration of 30 minutes.

**Effect of varying concentration on APS modified probe**

A stock solution of 5000 ppm Cu2+ solution was prepared in 250 mL volumetric flask using appropriately weighed copper (II) nitrate. Different concentrations: 500 ppm, 200 ppm and
100 ppm were prepared by serial dilution of this stock solution. 2 mL aliquots of these solutions were poured into test-tubes and used for sensing as follows: the solid silica modified with APS was coated onto a glass rod that had been smeared uniformly with vacuum grease (silicon oil) covering about 1 cm from the tip. This probe was then introduced into the 2 mL aliquots of the testing solutions and the time for development of the expected blue color was recorded.

**Effect of addition of different groups on the APS modified silica**

Appropriate amounts of glycine (amino acid) and naphthalic anhydride were reacted with the modified silica employing the free amino group of the APS following the procedure outlined on the APS Pierce Application Note for APS silica modification [16]. The presumed “re-modified” silica was coated on the probe and tested appropriately using the 500 ppm copper solutions.

**The effect of pH on optimized amino-modified silica-based sensor**

Different pH conditions were created by adding different aliquots of either HCl or NaOH to different 10 mL copper solutions at 500 ppm to achieve certain pH levels at which the efficiency of the sensor was determined following the 30-minute equilibrations of each solution.

**RESULTS AND DISCUSSION**

**Assembly of the probe demonstration of the sensing mechanism**

The assembly of the sensing probe is shown in Figure 1. Silica powder was immobilized on the solid glass rod covering about 1 cm in length using vacuum grease.
Effect of APS silica on the probe

The APS-modified silica sensor was prepared from APS and washed silica. Figure 2 shows the schematic presentation of the reaction of APS with silica [17].

The schematic diagram in Figure 2 shows how APS modified silica is formed yielding a primary amine which complexes Cu2+ ions leading to a blue color as seen in Figure 3.
Blue color only developed on the APS silica and not on the blank silica probe used as a control. This was a positive sign that the silica gel was modified with the APS as anticipated. Thereafter, the concentration effect study was conducted to identify the lowest concentration that this probe could detect in a 30-minute period.

**Effect of varying Cu2+ ions concentrations on APS modified silica sensor**

The effect of varying concentration was studied based on the time it takes the probe to turn blue when immersed in Cu2+ solutions of different concentrations. When the sensor was suspended in 4000 ppm, 3000 ppm, 1000 ppm and 500 ppm Cu2+ solution, blue colour developed immediately upon contact with the Cu2+ solution. However, at 200 ppm it took four hours for blue color to develop while at 100 ppm it took four days for blue color to develop (see Figure 4).

Figure 3 A photograph of APS-modified silica sensor after 30-minute exposure to the 500 ppm Cu2+ solution
Figure 4 A plot of concentration against time taken for the probe to develop a blue color

From Figure 4, it seems that the rate of adsorption is first order in nature, where the rate depends on the concentration of Cu$^{2+}$ ions in water, thus the color appearance. At low Cu$^{2+}$ concentration, few nitrogen atoms interact with these ions forming few metal-ligand complexes whose colour is unobservable by the naked eye. Therefore, since at 200 ppm, there was little blue color on the surface of the silica sensor; furthermore this only developed after almost 4 hours. These results suggest that mass transfer is important in this experiment: at low concentration the probability of the ions reaching the probe is much less than at higher concentration.

**Effect of addition of different groups on the APS modified silica**

The significance of adding these groups was two-fold: 1) to increase the efficiency of the APS-modified silica sensor through provision of a multi-dentate chelation of the Cu$^{2+}$ ions; and 2) to study the effect of different groups on the sensing properties by varying the ligand field
strength. It was believed groups like amino-acids, such as glycine, would increase the binding strength of copper ions due to multiple binding sites, hence probably lead to increased colour intensity on the probe.

Figure 5 shows the picture of glycine modification and APS modified silica sensor in 500 ppm copper (II) solution.

![Figure 5 A photograph of glycine-modified APS-silica probe suspended in 500 ppm copper solution](image)

As can be seen, the probe did not turn blue as was expected instead the solution turned blue. The blue colour was seen to concentrate at the bottom of the test tube rather than dispersed evenly throughout the solution. This is possibly due to the aggregates of the Cu2+ – glycine complexes into possibly some nano/micro particles that settled down due to their resulting density. These aggregates compete with the probe hence reduce the activity of the probe as can be seen.

The behavior leads to a suspicion that perhaps glycine did not react with the APS-modified silica, but rather only adsorbed onto the surface, hence it peeled off when subjected to Cu2+ ions. The chelation of the ions by the freely suspended glycine reduces the interaction of the ions with
APS hence no detection or sensing on the probe. Suffice to say, the left APS-modified silica sensor did not turn blue because it might be all copper ions have already complexed with the suspected desorbed glycine.

To assess the interaction of different NH groups propylamine (primary amine) and acetamide (a secondary amine – amide), were deployed. When propylamine was added to a solution of 500 ppm Cu²⁺, tiny blue microdroplets were seen over time developing in the solution and slowly settling at the bottom of the test tube yielding a similar scenario to that depicted in Figure 5. In the case of acetamide, the blue color took a longer time (45 min – 1 hr) to appear. This confirms the idea that the primary amines are more sensitive than the secondary amines. It also points towards the possibility competition between glycine condensation and the reaction between glycine and the primary amines on the APS-modified silica. This would make sense since the APS is immobilized onto silica while the glycine molecules are freely suspended in solution, hence increasing their chances of collisions, leading to a higher reaction rate for this process.

The observation of the glycine modified probe, therefore, suggests that the glycine-modified APS-silica would not be suitable to be used as a field solid-based sensor but can be used as a “wet” laboratory sensor.

When the APS-modified silica was modified further with naphthalic anhydride generating an imide (a tertiary amine) instead of a primary amine, the sensor failed to yield any positive results towards the Cu²⁺ ions; thus confirming the success of the modification, while also confirming the importance of the free amines.
Effect of pH on optimized APS-modified silica

The pH of the aqueous medium is very important as it influences the uptake of the adsorbate due to the electronic distributions. The chemical characteristics of both the adsorbate and adsorbent vary with pH since pH of the solution affects the degree of ionization and speciation of various pollutants which subsequently leads to the change in the reaction kinetics and the overall dynamics of the adsorption process. The effect of pH is demonstrated in Figure 6 with the visual scores of the intensities of the colors since there were no instrumental techniques that could be used for this.

![Figure 6 The effect of pH of the test solution on the effectiveness of the sensor (score /10)](image)

As can be seen in Figure 6, efficiency peaked at pH 8 and dropped thereafter. This could be explained in terms of poorer electron density at the lower pH values and the possible formation of hydroxyl complexes at pH values higher than 8, affecting the affinity of the sensor. Most hydroxides of the heavy metals are insoluble. As such these would render the metal ions less available for sensing.
CONCLUSIONS

This study has demonstrated that simple handheld sensors can be prepared cheaply by employing simple chemistry. The type of interactions between the analyte and the sensor are key in deciding how the sensor should work. This work has further demonstrated in a practical way two issues: development of a simple screening sensor and the ligand field theory. It was intriguing that free amino acids such as glycine could not react with the APS modified silica. This places a limitation on the groups that can be added onto the surface while retaining the free amino group responsible for the sensing. The fact that the probe withstood exposure to water demonstrated the known chemistry that amines show higher ligand field and affinity towards Cu2+ ions than the water molecules, hence the sensor can be used easily for field operations as a potential passive sampler.

Besides the strength of the interactions, the other key to success of this sensor is the loading of the APS, as well as the strength of the silica coating onto the glass rod using the silicone oil. These are some of the limitations realized in this study which will be the focus of the follow-up study. To take this into post graduate research, issues such as the determination of amount of nitrogen in the APS-sensor, chemically immobilizing APS on the glass-rod, as well as quantitative determination of the amount of Cu2+ ions adsorbed by the sensor are some of the features to be considered further.

Overall, the main objective of demonstrating simple molecular interactions leading to detection of a certain analyte such as copper has been demonstrated. This in deed demonstrates that even simple approaches could still be used to perform basic research that could entice students into pursuing graduate studies. The students who participated in this have indicated the desire to pursue the same project in the graduate studies. This experiment has helped to improve the
students’ enthusiasm about the subject while strengthening the understanding of the ligand field theory.

REFERENCES
10. Y. Yang, F., Huo, C. Yin, Y. Chu,, J. Chao, Y. Zhang and D. Liu, Combined spectral experiment and theoretical calculation to study the chemosensors of copper and their applications in anion bioimaging. Sensors and Actuators B: Chemical, 2013, 177, 1189-1197.
16. Pierce Technical Note 8037, 3-Aminopropyltriethoxysilane, Illinois, USA.
COMMON DIFFICULTIES EXPERIENCED BY GRADE 12 STUDENTS IN LEARNING CHEMISTRY IN EBINAT PREPARATORY SCHOOL

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ABSTRACT
The objective of this study was to examine the nature and causes of common difficulties experienced by grade twelve students in learning chemistry in Ebinat preparatory school. A qualitative method was employed to investigate the questions, which used interviews and questionnaires with students and teachers. The key findings of the study indicated that students are being more challenged by topics like chemical bonding, thermodynamics, chemical equilibrium, kinetics, and colligative properties. The main factors that are contributed for the learning difficulties in chemistry faced by our students include: absence laboratory works, absence of teaching and learning resources, poor teaching and learning strategies, poor English and Mathematical skills and there is a need to improve these cause by using equip laboratory, improvement in assessment, use of proper English language by teachers etc. [African Journal of Chemical Education—AJCE 6(2), July 2016]
INTRODUCTION

Chemistry curricula commonly incorporate many abstract topics, which are central to further learning in both chemistry and other sciences [1]. The difficulties of chemistry topics are their abstract nature and words from everyday language with different meanings [2]. One of difficult topic student’s experiences in learning chemistry is chemical bonding because it involves variety of abstract natures [3]. Chemical equilibrium is one of the fundamental concepts in chemistry but it is difficult subject for students learning [4]. Thermodynamics is difficult topic at all level of learning and not popular subject among students [5]. Chemical equilibrium is affected by different factors such as concentration, temperature and pressure [6].

This difficulty could be influenced by experimental activities done in laboratories, availability of reference books, method of instruction, language of instruction, representation of materials in textbooks, or after-school support programs [7]. The effect of conducting experimental activities and teaching and learning methods used by teachers in developing positive attitude in learning chemistry is also confirmed [8]. Practical work needs essentially to be about thinking that is trying to understand the relation between evidence and theory to stimulate challenge students [9]. Low laboratory practices in secondary schools are the leading causes that bring negative impact on academic achievements in chemistry [10]. Students who learn by inquiry approaches are responsible for developing their own answers to questions rather than exclusively relying on the teacher and/or textbooks [11].

The preceding arguments suggest that a lesson presentation that is consistent with active learning is characterized by activities in which students fully engage their higher order thinking mental capacities like concepts, procedures, predicting and justifying with each other [12]. Teachers should cultivate work environments in which they are able to watch students at work and
listen to them explaining learning strategies that could be used in the presentation. Create opportunities to use problem solving, games, puzzles, and small group work [13].

Giving responsibility and leadership in scientific activities, keeping the students informed of their progress in chemistry, providing opportunity for students demonstration, arranging for students cooperative enterprise in science, organizing field trips, science clubs and science fairs, creating a sense of healthy competition among the students [14]. The learners should be actively involved in the learning experience. The teacher does not take center stage in the classroom but should be a facilitator and listener [15]. The teacher should design activities that focus on allowing students support, refine or refute their theories about a particular event [16]. Lack of competence in English language by both teachers and learners affect the teaching and learning chemistry and the immediate consequences of students’ performance in school subjects including chemistry. Students are unable to communicate fluently in English and find it difficult to take part in class discussions. Examinations remain a critical factor in influencing the learning of chemistry. Teachers tend to focus on those aspects which gain examination grades rather than on important outcomes such as practical skills and generally relevant attitudes and values [17].

As mentioned the above chemistry curriculum arranged for preparatory schools by the Federal Ministry of Education of Ethiopia (Grades 11 and 12) consists a wide spectrum of concepts related to organic, inorganic and physical chemistry that are to be learnt and mastered by the students in a 2-year period. The most common ones are chemical bonding, chemical kinetics, equilibrium, solutions, acid base equilibrium etc. In addition, high levels of skills and attitudes are expected to be acquired by learning preparatory school chemistry [18]. However, the document analysis in the past four years shown in Table 1 and 2 from the finding parts only 38.98 % and 35.48 % of the students in our school scored pass mark in chemistry in model examination prepared
at school level and university entrance examination administered at national level respectively. The result of the document analysis indicated us there is a huge gap between what is intended in the national curriculum in terms of students’ learning in chemistry, what actually happens in the classroom where students learning chemistry and shows students experience common difficulties in learning chemistry. The purpose of this study was therefore to investigate the nature and causes of learning difficulties students experience in chemistry in Preparatory School of Ebinat.

**Objectives of the Study**

1. To identify the nature of common difficulties experienced by grade twelve students in learning chemistry in Ebinat Preparatory School.

2. To determine the causes of these difficulties grade twelve students experience in learning chemistry in Ebinat Preparatory School.

3. To establish what can be done to minimize these difficulties in learning chemistry in Ebinat Preparatory School.

**Basic Questions**

1. What common difficulties do students experience in learning chemistry in Ebinat Preparatory School?

2. Why do students experience these difficulties in learning chemistry in Ebinat Preparatory School?

3. How can these difficulties be minimized in learning chemistry in Ebinat Preparatory School?
METHODOLOGY

Research Design, Samples and Research Instruments

A qualitative method was used for collecting data from chemistry teachers and grade twelve natural science students selected for the study. Data was collected through open ended questionnaire and semi structured interview from respondents.

The study population was 284 (144 males and 140 females) grade twelve natural science students and 4 (3 males and one female) chemistry teachers of Ebinat preparatory school of 2015 G.C. The researcher choose only grade twelve natural science students because they have covered most of the syllabus of chemistry in preparatory school and could be able to provide information about the common difficulties they experience during their stay in the school.

Study participants were selected using purposive sampling technique. This technique was used to select 30 (15 males and 15 females) of the students out of 284 grade twelve natural science students who took model examination of 2015 G.C. and four (three male and one female) chemistry teachers.

The research instruments used for data collection included interview and questionnaires. The interview and questionnaire were meant to collect data on common difficulties experienced by grade twelve students when learning chemistry, their causes and how they could be minimized.

The collected data were analyzed using the qualitative content analysis approach. This involved identifying, categorizing and listing responses according to themes. These responses were coded and grouped by establishing the emerging themes.
Grade 12th Students’ Results in the past four consecutive years are given the following table.

Table 1: Ebinat preparatory School Grade 12th Students Model Examination Results from 2012 to 2015.

<table>
<thead>
<tr>
<th>Year</th>
<th>Reg. candidates</th>
<th>Passed candidates in Exam.</th>
<th>Failed candidates in Exam.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>Tot</td>
</tr>
<tr>
<td>2012</td>
<td>69</td>
<td>67</td>
<td>136</td>
</tr>
<tr>
<td>2013</td>
<td>128</td>
<td>119</td>
<td>247</td>
</tr>
<tr>
<td>2014</td>
<td>135</td>
<td>131</td>
<td>266</td>
</tr>
<tr>
<td>2015</td>
<td>140</td>
<td>144</td>
<td>284</td>
</tr>
<tr>
<td>Total</td>
<td>472</td>
<td>461</td>
<td>933</td>
</tr>
</tbody>
</table>

Source: school record section

As can be seen from table one the pass percentage of students in the four years went 38.98%. It is clear from table one that a large percentage of candidates in the four years given just failed school model examinations. Again in 2012, 79 (58.10%) out of 136, in 2013, 155 (62.76%) out of 247, in 2014, 162(60.90%) out of 247 finally in 2015,177 (62.32%) out of 284 students are failed from total registered candidates respectively.

Table 2: Ebinat preparatory School Grade 12th Students university Entrance examination Results from 2012 to 2015.

<table>
<thead>
<tr>
<th>Year</th>
<th>Reg. candidates</th>
<th>Passed candidates in Exam.</th>
<th>Failed candidates in Exam.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
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<tr>
<td>2012</td>
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<td>2015</td>
<td>140</td>
<td>144</td>
<td>284</td>
</tr>
<tr>
<td>Total</td>
<td>472</td>
<td>461</td>
<td>933</td>
</tr>
</tbody>
</table>

Source: school record section

As can be seen from table two the pass percentage of students in the four years went 35.48%. It is clear from table two that a large percentage of candidates in the four years given just failed chemistry university entrance examinations. Again in 2012, 86 (63.24%), out of 136, in 2013, 174 (70.45%) out of 247, in 2014, 147 (61.28%) out of 266 finally in 2015, 195 (68.67%)
out of 284 students are failed from total registered candidates respectively. The result of the students was not considered the university enrolment of but who scored less than fifty percents. This document analysis is in line with the finding of the study which showed the teaching-learning process of science education in Ethiopian schools failed to meet the requirements of policy expectation. Generally, the results of students in the four years of school model and university entrance examinations are underachievement. These scores are less than the expected average score (50%) by the Education and Training Policy of Ethiopia [19]. They have significant different from this expected value and are decreasing too. Hence, it needs to assess the common difficulties experienced by students in learning chemistry.

**Interview questions and Questionnaires for Grade Twelve Students and chemistry teachers**

1. Which topics do you find more difficult to learn in grade 11 and 12 Chemistry texts? List them?
2. What difficulties do you experience when learning Chemistry?
3. What do you think causes of learning difficulties you have mentioned?
4. What measures do you think should be employed to minimize the learning difficulties which you experience chemistry?

These questions and their responses were discussed in the following cases.

1. **Question 1 and 2: Which topics do you find more difficult to learn in grade 11 and 12 Chemistry texts? List them? What difficulties do you experience when learning Chemistry?**

   Most of the student and teacher respondents who completed these questions the researcher prepared confirmed that they failed to understand the concepts of chemical equilibrium, chemical bonding, chemical kinetics, thermodynamics and colligative properties respectively.

**Chemical Equilibrium**

According to the finding most of respondents said that learning equilibrium is difficult and they cited that teaching student’s chemical bonding is difficult. On the researcher teacher’s respondent, most students assumed that learning about chemical equilibrium is difficult. Because they usually consider reaction quotient and equilibrium constant are the same. However, reaction
quotient can be gained at any point in the reaction but equilibrium constant can obtained at equilibrium point only where the rate of forward and backward reaction are balanced. Due to these misconceptions in equilibrium students failed not only calculate equilibrium constant but also memories the formula. One teacher said that about calculations, students are unable to calculate and understand them therefore they always do poorly when answering questions on reaction quotient ($Q_c$) and equilibrium constant ($K_c$). Hence they failed their examinations. One teacher also wrote that students have difficulties in identifying the forward and the backward reactions. They assume that at equilibrium the forward reaction is greater than the backward reaction.

**Chemical Bonding**

Most of the student respondents confirmed that most of the terms related to chemical bonding is abstract to understand. As nine of the respondent students confirmed they are unable to differentiate metallic, covalent and ionic bonding. They also failed to differentiate between intramolecular (metallic, covalent and ionic bonding) and intermolecular forces like hydrogen bond, dipole-dipole and dispersion forces. Three of the teacher’s respondent cited that students have poor knowledge in the concept of hybridization orbital like SP$^1$, Sp$^2$, and Sp$^3$ which are the bases of chemical bonding. They do not recognize the importance of sp1, Sp2 and Sp3 in determining single, double and triple bonds respectively. The other teacher confirmed that students failed to understand the concepts of chemical bonding because they do have poor knowledge in valence electrons and how atoms share electrons.

**Chemical Kinetics**

Ten of the interviewed students responded that they found learning chemical kinetics be the most difficult topic among chemistry lessons. According to these students response they develop no interest in learning these lesson because of the complex nature of calculating chemical kinetics. Both on researcher own personal experience and two of the respondent teachers, most of students assumed that learning about chemical kinetics is difficult. Because they usually consider rate constant is the same in all orders of reactions like zero, first, second, and third order of reactions. Due to these reasons students failed not only calculate rate constant but also rate of forward and backward reaction. As indicated by one teacher respondent reaction mechanisms are the most difficult topic for students because of the fact that they do not understand the nature of reaction factors such as concentrations, temperature and pressure.
Thermodynamics

When students are asked to state how they could understand the concepts of thermodynamics, eight of them responded that they failed to understand the concept of thermodynamics starting the definitions of terms like work, heat, specific heat, specific heat capacity, system, state and path function, surrounding etc. According to them these words are very difficult to differentiate them. One teacher observed that students had difficulty in understanding and differentiating chemistry terms such as heat with work, specific heat with heat capacity and on the system with by the system.

Colligative Properties

Most of respondents of students put the difficulties of calculation about colligative properties. They said that it is very difficult to remember and differentiate the formula of colligative properties with concentration parameters like mole fractions, molalities and molarities. On this topic one teacher said that students do not write the formula of vapor pressure lowering, boiling point elevation, freezing point depression and osmotic pressure during examination questions.

2. Question 3 what do you think causes of learning difficulties you have mentioned?

Most of respondent students and teachers are mentioned and expressed the following causes’ in learning chemistry.

Absences of Laboratory Work

All the students participated in the study were cited about the absence of laboratory when learning chemistry. They said that chemistry topics need experiments to understand them, when we are taught without experimenting or putting in practice. Most of students revealed that absence of experiment made some topics difficult to learn. This factor was also supported by three teachers who said that practical activities were not often conducted due to the absence of laboratory class, apparatus and chemicals in our school. They said that the major cause of common difficulties in learning chemistry among others are practical activities which are not conducted often due to the fact that absence of laboratory class, chemicals, apparatus and laboratory technician in the school.
Lack of Remedial Actions by teachers

Three respondent students said that we usually fail examinations due to inappropriate flow instructions. These gaps will continue without being corrected because the teachers did not take any remedial actions to fill the gaps of slow learner students. According them, most teachers are dominated by few fast learner students leaving the slow and middle learners aside. This idea is admitted by two of the respondent teachers. The other two teachers responded that we created a chance for students to help one another in their group.

Inadequate Explanations from the Teachers

Four students revealed that some teachers did not explain fully and they thought roughly difficult chemistry contents. Chemistry is a difficult subject which requires specific chemistry trained teachers. Because chemistry subject needs more explanations about concepts of facts, laws and rules. They usually spend most of their chemistry periods telling stories, giving guidelines to students instead of teaching these concepts.

Wide Chemistry Syllabus

All the respondent teachers admitted that they do not properly cover the intended syllabus since the period allotted for the course and the intended topics to be covered do not match.

Lack of Motivation and Language Skills

Most of students were reported to be lacking motivation to read on their own and described by two teachers as having language problems, and also they failed in examinations. One teacher said that the most serious thing is instruction of English, because most of students when we speak them don’t understand. Two teachers exposed that English language made them feel uncomfortable and that they failed to express themselves in language clearly and could not participate fully in a class. This factor was also supported by one teacher who stated that most students have poor English background.

Lack of Teaching and Learning Aids

Lack of textbooks and other materials was a common complain among the students who were interviewed. Two of students also complained that even one textbook is shared among five students due to inappropriate ratio of students and text books in the school. Five of the student’s interviewed also complained only few and outdated supportive books are available in the school. Unfortunately, the school was failing due to big student numbers. Three students wrote that common difficulties in learning chemistry were due to lack of proper learning materials in school.
Two students wrote that students had negative attitude towards chemistry. They failed to understand questions because they were not well prepared as a result students found them difficult to answer questions.

**Lack of Mathematical Skills**

Most of students expressed experiencing problems with calculations on colligative properties (vapor pressure lowering, boiling point elevation, freezing point depression and osmotic pressure) and rate law. They said that our teacher does not teach us how to calculate problems; as a result we failed calculation examinations.

**Heavy Teaching Loads**

Two teachers cited heavy teaching loads is a contributing factor of learning difficulties. They wrote that heavy teaching loads are tedious and prevents us from working harder like organizing special lessons for slow learners and offering individual help to those in need and in big and overcrowded classes, supervision during lessons and tests becomes very difficult.

3. **Question 4 what measures do you think should be employed to minimize learning difficulties which you experience chemistry?**

Participants cited a number of measures which they thought could help improve students’ learning in chemistry as follows.

**Teaching and Learning Aids**

Most of students indicated that books must be made available in school; they put it as we must be provided with adequate books because chemistry is a very wide subject that requires us to use our time studying something that we haven’t covered with our teachers. One cited that the government should to provide more learning materials and he put it as the school together with the government must provide more learning materials especially books. This suggestion was also provided by two teachers who said that in order to overcome common difficulties of learning chemistry, we must make sure that learners at any level are able to acquire good chemistry background by improving learning facilities and providing all the necessary learning materials and equipment to enhance learning.
Provision of Experimental Work

Three students observed that learning of chemistry could be improved by showing students how to carry out experiments because they usually appear during the final examination and teachers should find time to go through some chemistry terms and concepts. Students should emphasis to put on observation and conclusion, for example on conductivity and non-conductivity to be emphasized as well as their interpretations in respective practical work. Four students observed that students should also be serious and they should love the subject as well as the teachers and they should do experimental activities on their own. One teacher advised that chemicals should be made from locally available materials by teachers and students and should be bought in amounts that will be adequate in order to enable students carry out practical works.

Improvement in Assessment

Most of students advised that tests should be given at the end of each topic and those students should have read different books. The test should have practical activities at each end of the term tests, because we become ignore on answering practical activities during examination questions. Students should at least be told the topics that they are going to cover the coming term in order to prepare and research adequately on those topics. One teacher wanted students to be motivated when learning chemistry; he put it as students need to be encouraged and motivated when learning chemistry. In order to encourage learners to do their homework and assignments, teachers should mark the homework or the assignment regularly and talk to parents to encourage their children to do their work.

Teaching of Challenging Topic

Most of students wanted teachers to concentrate on teaching topics perceived to be difficult, they put it as advocate the teachers to teach on vital topics that are mainly brought in the examinations. We should be given a task at every chemistry period to make us revise. Teachers to give encouragement to the students concerning the subject and they advise students to study chemistry subject widely.

Use of Proper English Language by Teachers

Most of students wrote that teachers should use simple English when preparing questions so that students could understand clearly. They added that if possible they should be teaching us in our local languages. One teacher on the use of English language wrote that it is not only the obligation of the English language teachers to teach English to learners, the other teachers have
equally the same duties to explain the meaning of the wordings in their respective subjects as words could have different meaning in each subject.

**Avoid Hiding Information**

Seven students held the same view that teachers should avoid hiding information when teaching chemical bonding and chemical equilibrium that they must be teaching more materials from past examination papers. Three students suggested that teachers should be positive and encouraging when teaching chemistry. One teacher emphasized the need to consider fast and slow learners he put it as passing of lessons should take into account the different rates at which students learn, i.e. fast or slow. The teacher should also use appropriate teaching strategies matching with the outcome students intend to attain. The teacher should use teaching aids when dealing with abstract concepts. Two teachers admitted that more time should be allocated to topics perceived to be difficult.

**Provision of Qualified Teachers**

As ten students cited that, chemistry teachers in the school must be increased to provide for all the students in school and also improve the interaction between teachers and students. The number of periods allocated each week should be increased as it is very difficult to finish the syllabus at our school.

**DISCUSSIONS**

The study set out to investigate the nature and causes of common difficulties experienced by abstract nature of chemistry concepts. This is line with [19]. Some of chemistry concepts complained by both students and teachers were chemical bonding, chemical kinetics, chemical equilibrium, colligative properties and thermodynamics. The abstract nature of chemical bonding was also supported by previous studies [20]. However, both students and teachers confirmed that students in our school has problems in understanding the concept of valence electrons, atomic models, hybridization orbital’s which are the bases for understanding chemical bonding. It is confirmed that our students hate chemical equilibrium because they consider equilibrium constant and reaction quotient are similar. This is supported by [21]. Our students were unable to differentiate the basic terms of thermodynamics like heat, specific heat, specific heat capacity. The difficulty of thermodynamics due to the physical and mathematical nature instead of chemistry nature was complained by the students and teachers. This is linked with [22].
Based on participants (students and teachers) the common causes of learning difficulties in learning chemistry faced by our students include: absence of laboratory works that support the theoretical lesson, absence of teaching and learning resources, poor teaching and learning strategies, large class size, over loaded teachers, wide chemistry syllabus, poor English and Mathematical skills. Because most respondent teachers and students said that teachers’ capacity, ineffective teaching methods, scarcity of human and material resources are the causes of learning difficulties in chemistry lessons and achievement of students. This is similar with [23]. Similarly lack of experimental works, reference books, representation of materials in textbooks, are the other causes of learning chemistry.

In general, when we consider the teaching and learning process in chemistry in our school, is dominated by teachers. Teachers are considered as the only dispenser of knowledge which is in contrary to the education and training policy [24]. However, due to wide chemistry syllabus which cannot be covered on time, lack of text books, poor English and mathematical skills developed by our students most of the teaching and learning process in chemistry is largely dependent on the teachers. Though the instructional language of preparatory school chemistry is English, most teachers and students use Amharic but examinations are prepared in English. Poor mathematical skills to drive chemical formulas and absence of after-school support program slow learner students is also the other teaching learning process that bring difficulty in learning chemistry. Large class size and overloaded teachers were also complained to bring difficulty in learning chemistry in our school. This idea is supported with [25].

Lack of motivation by teachers and lack of willingness by students to be fully engaged in chemistry lessons are also reported to negatively affect teaching and learning in chemistry. This is in part due to large class size and student’s poor background in chemistry, most of our students and teachers perceived that common difficulties tend to exhibit a performance orientation to teaching and learning process, where by learners are viewed as need of motivation in order to learn and instead of viewing the teaching and learning process as a motivational strategy itself. In this area questions such as efficiency of administrative support, the type and influence of leadership, class size and the teacher student ratio and the administrative structure of the chemistry department needs to be considered. It is advisable that in order that different factors work in agreement to bring about maximum learning, there must be a good organization of staff, students, finances etc.
CONCLUSIONS AND RECOMMENDATIONS

Through the assessment of student’s responses on common difficulties they experience in learning chemistry and the views of chemistry teachers on these difficulties, the following were the major findings from the survey conducted.

- The study revealed that some chemistry concepts like chemical equilibrium, chemical bonding, chemical kinetics, thermodynamics and colligative properties are difficult.
- Most of chemistry teachers are unable to briefly explain the difficult concepts of chemistry because of inadequate knowledge of the subject matter and shortage of time to cover the syllabus.
- The main factors that are contributed for the learning difficulties in chemistry faced by our students include: absence of equipped laboratories and practical work that support the theoretical lesson, absence of teaching and learning resources, poor teaching and learning strategies etc.
- There is a need to equip the school laboratories with appropriate chemicals, equipment and there is a need to support the theoretical lessons with practical activities.

Based on the findings of the present study the following recommendations were made:

- Chemistry teachers should give more emphasis on difficult topics and assess whether students have understood laws, principles, and facts of chemistry lessons.
- They should use visual aids like models, locally available materials and power-point presentations.
- The school administrators should create a chance of experience sharing among teachers in the school for example chemistry teachers with mathematics and English teachers so that they could have better Mathematical and English skills which are tools for chemistry lessons.
- The department head of chemistry should develop a means of experience sharing among chemistry teachers so that they could have similar understanding of the difficult topics of chemistry indicated above and devise better common teaching and learning strategies for these lessons.
- The Education offices at the district level and other stakeholders should try their best laboratories with appropriate chemicals, apparatuses and human resources.
- There is also a need to capacitate chemistry teachers using additional on-job and long trainings.
REFERENCES

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APPENDIXES

A. Interview questions for Grade Twelve Students
1. Which topics do you find difficult to learn in grade 11 and 12 Chemistry texts? List them?
2. What difficulties do you experience when learning Chemistry?
3. What do you think causes of learning difficulties you have mentioned?
4. What measures do you think should be employed to minimize the learning difficulties which you experience chemistry?

B. Questionnaire for Grade Twelve Students
1. Which topics do you find difficult to learn in grade 11 and 12 Chemistry texts? List them?
2. What common difficulties do you experience when learning Chemistry?  
3. What do you think has caused these common difficulties in Chemistry?  
4. What do you think should be done to overcome these difficulties?

C. Interview questions for Chemistry Teachers
1. What do you think are the difficulties your students experience in learning Chemistry?
2. What common difficulties do you experience when teaching Chemistry?
3. What do you think causes learning difficulties which your students experience in Chemistry?
4. What do you think should be done to minimize the learning difficulties your students experience in chemistry?

D. Questionnaire for Chemistry Teachers
1. What do you consider to be your students learning difficulties in Chemistry?  
2. What do you think causes these learning difficulties?  
3. What do you think should be done to overcome these learning difficulties?
WHAT ARE THE MOLECULES DOING?

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ABSTRACT
Johnstone’s identification of teaching and learning difficulties derived from the three levels of description in chemistry is well-known and much debated, but effective responses are still needed. It is suggested that a macro-micro dictionary could help. The dictionary concept is exemplified and its potential value in dealing with the difficulties associated with two of the levels explained. [African Journal of Chemical Education—AJCE 6(2), July 2016]
INTRODUCTION

Over some 250 years, scientists in general, and chemists in particular, developed a descriptive language for all the phenomena they observed. Much of this language remains in use today, sometimes with amended meanings. Over this same period the atomic-molecular interpretation of phenomena grew rapidly in range and strength, so that by present times it is integral with almost every scientist’s work. A language has been developed to articulate atomic-molecular interpretations, some of this being new and some “appropriated” from the older language related to observed phenomena. Parallel streams of development, related to symbols used, can also be seen.

Johnstone [1] drew attention to the three different ways in which we communicate and understand science concepts: in essence these are macroscopic (phenomena), microscopic (or sub-microscopic) (atomic-molecular interpretation) and symbolic (relating to both the previous two). Importantly, he emphasized the difficulties for teaching and learning that can be traced to the co-existence of these three ways. These difficulties are aggravated by the failure of many teachers, lecturers, authors to distinguish whether they refer to phenomena or their atomic-molecular interpretation. The language of the description of phenomena (macroscopic) is mixed with the language of interpretation (microscopic) and symbols are used indiscriminately, thus ensuring an incomprehensible communication [2]. Dictionaries of chemistry are generally unhelpful in this regard. Even textbooks of chemistry that provide glossaries generally fail therein to provide definitions that cover the macro-, the micro- and the symbolic aspects of a concept.

It is generally accepted that the meaning of words changes over time and this can cause difficulties of understanding. However, here we are dealing with something different: two languages have grown up over the years and become intertwined in common usage. The result is
not just a quaint vocabulary reflecting the history of the discipline, but a commonly used language of teaching and learning that is misleading, confusing and at odds with the basic distinction between observation and interpretation (or the reality and the model). The problem of scientific language literacy identified by Woldeamanuel, Atagana and Engida [3], may be one expression of the consequences.

TOWARDS A MACRO-MICRO DICTIONARY

Although the above teaching and learning problems have been recognized for several years, and approaches to dealing with them advocated [4], [5], [6], [7], [8] there is not much sign that the problems are being taken seriously beyond the confines of research articles. In this paper we start the development of a “macro-micro dictionary” which aims to clarify and guide teachers and learners. The approach is to select a descriptive term for some observable phenomenon, give a brief statement about the phenomenon (the macro description), and then address the micro question – what are the molecules doing? The level of discussion is intended to be suited to those teaching chemistry at the secondary and tertiary levels and should be read with this purpose in mind. It is hoped that by studying the examples included in this paper, the potential of such a dictionary can be assessed.

As a preliminary we should make clear that all entities consisting of two or more atoms are called molecules in our usage [9]. Since free single atoms are comparatively rarely met with, the omission of atoms from the question seems appropriate.

**Gases**

One of the states of matter is the usually invisible gaseous state. When the gas is coloured we can see it is there, but otherwise we have to rely upon inference (eg trying to compress air in a
syringe). It is a state of matter where the substance fills all available space and has no shape or size of its own. It can expand and contract in response to temperature changes and we might say is the “softest” of all the states of matter. Nevertheless a gas exerts pressure and we can feel this when we try to compress air in a syringe.

*What are the molecules doing?*

Under the right conditions a collection of molecules may be a gas. The molecules are however not gases and they are not colored! The molecules are moving all the time and very fast, colliding with each other and with the walls of a container. Under typical conditions there is a lot of free space in a gas, and molecules actually occupy only a rather small fraction of the total volume of a gas held in a container. In a sample of gas, the molecules do not all travel at the same speed, and the speeds change as a result of collisions. However the total kinetic energy of a collection of molecules is constant as long as the temperature is constant. Increasing the temperature, increases the total kinetic energy of the collection of molecules; indeed the average kinetic energy is proportional to the temperature.

The pressure exerted by a gas results from the billions of collisions per second with the container walls.

Molecules in a gas are usually small, that is they usually have rather few atoms per molecule. Furthermore, the forces between the molecules (intermolecular forces) are comparatively weak. Hence when they collide they usually do not “stick” to one another.

*Liquids*

Liquids are another state of matter. They are visible and so we see their behavior directly. They flow and conform to the shape of a container, but they do not fill all available space. Although they do expand and contract in response to temperature increase and decrease, the volume change
is small. Similarly, although they do flow they are not as “soft” as gases: falling into a swimming pool full of water can be painful!

What are the molecules doing?

The molecules are not liquids, or even bits of liquids and we do not see them; under the right conditions a collection of molecules may be a liquid. The molecules are moving all the time, but there is very little free space. Any one molecule is in contact with several other molecules at all times. Nevertheless, the molecules move around, slipping into holes or gaps in the surrounding crowd of molecules. Although the movements are short it does not mean the molecules have little kinetic energy. As with gases, the average kinetic energy is proportional to the temperature.

Molecules in a liquid may (but do not have to) be much larger than one finds in a gas. There may be scores of atoms per molecule. The forces between the molecules may (but do not have to) be distinctly larger than is found between molecules of a gas. Collisions between molecules of a liquid are continuous and the molecules “stick” to one another. However the “stickiness” is not so strong that a molecule stays with the same neighbors all the time!

Solids

Solids are the most prevalent of all the states of matter. Like liquids they are visible and we can see their behaviour directly. They do not flow or change their shape to fit a container. (Note: A powder is a made of tiny bits of solid, and may flow and change its shape. In this case we are describing the behaviour of a sample containing very many tiny bits of solid. The tiny bits of solid do not flow or change shape.) Solids are generally the densest state of matter; furthermore, temperature changes cause only small changes to the volume of a solid. They are the “hardest” of the states of matter, but the range of hardness is large – that is, there are some solids which are soft (eg wax) and some that are very hard indeed (eg diamond).
A solid has a definite shape and sometimes this can be very regular. Usually these solids with regular shapes are called crystals. Solids which have no regularity about their shape (e.g., glass) are usually said to be amorphous solids.

What are the molecules doing?

The molecules are not solid! However, the molecules that constitute a solid may (but do not have to) be very large and have a very large number of atoms per molecule. Indeed, with a perfect crystal (e.g., a flawless diamond) one may say that we have a single molecule made of billions of atoms of carbon. Such a molecule may be termed a giant molecule and we can see it! In general, however, a solid is made of many molecules and these do not move from place to place. They are held quite tightly by neighboring molecules and the intermolecular forces are quite strong. The molecules may however be able to rotate on the spot if they are sufficiently ball-shaped. They can also vibrate back-and-forth within the very limited space that neighboring molecules allow. Here also the limits to the movement do not mean the kinetic energy is small; the average kinetic energy is determined by the temperature. A perfectly regular packing of molecules gives rise to a crystal.

Boiling

Boiling is the term we use to describe the change of a liquid to a gas when the vapor pressure of the liquid equals the ambient pressure. Evaporation also refers to the change of a liquid to a gas, but the vapor pressure of the liquid is less than the ambient pressure. The change of state is not due to the addition of some other substance; it happens to a substance when its temperature reaches a specific value (boiling point) at the ambient pressure.
What are the molecules doing?

They are not boiling! Molecules are leaving the liquid phase and entering the gas phase. They are escaping from the attractive forces that cause molecules to cling to each other, and they become free of such forces as they enter the gas phase. The same is true of evaporation.

**Melting**

Melting is the change of a solid substance to a liquid substance. This change is not due to the presence of another substance (as might happen in dissolving), but to the temperature. Melting takes place at the melting point of the pure substance, which is one of its characteristic properties. It is only slightly affected by the ambient pressure.

**What are the molecules doing?**

They are not melting! What they are doing depends on what kind of molecules constitute the solid. If the solid comprises relatively small molecules packed together in a regular fashion, then melting involves the molecules in loosening themselves from the constraints of neighbouring molecules, overcoming some of the intermolecular forces, and moving around – but still always in contact with several molecules. By contrast if the solid comprises an infinite network of atoms and bonds, that is a giant molecule, melting requires break up of the molecule. Bonds must be broken in order that smaller molecules form which are sufficiently mobile to constitute a liquid. Generally-speaking, melting due to this kind of molecular break up, requires much more energy than the simple freeing up of already-existing smaller molecules: this implies a high melting point (eg diamond melts above 3 500 C).

**Chemical Reaction**

Chemical reaction (or reaction) is the term used for the change in the composition of a substance brought about either by some other substance or by supplying energy (thermal,
What are the molecules doing?

Molecules are changing their structure and/or composition in a process that involves bond breaking and/or making. It is usually both. Often the overall change takes place by a set of steps, each one of which is very simple. Reaction only happens when molecules collide with other molecules or with other particles such as photons of radiation.

Are the molecules reacting? Perhaps! Bond changing might be a better term. Taber has suggested quantacting [10].

**Acid**

Acid is the term used for a class of substances that change the colour of indicators, have a sour taste, neutralize alkalis, cause formation of hydrogen from metals and carbon dioxide from carbonates. Acids may be strong or weak.

What are the molecules doing?

The molecules are not acids! The molecules have at least one H atom in their composition, and in aqueous solution the molecules (say HA) dissociate into a hydrogen ion, H+ (aq) and an anion, A- (aq). This is a chemical reaction since bond breaking is involved. This dissociation may be complete or partial; the former case arises with strong acids and the latter case with weak acids. Reactions of acids often involve the hydrogen ions formed by dissociation of the molecules, rather than the molecules themselves.
The term dissociation is a general term that is used to describe molecular break-up into smaller entities. It can be made more specific to acids perhaps by saying acid dissociation. Substances do not dissociate; molecules do.

**Acid-base indicator**

Acid-base indicators (often abbreviated to indicators) are substances that change colour when in solution with acids and/or bases. The colour change is reversible indefinitely. Different indicators show different colour changes and change their colours at different concentrations of acid or base.

*What are the molecules doing?*

The color of substances results from the absorption of selected components of white light by the collection of molecules constituting a visible sample of the substance. The molecules are however not coloured. Indicator molecules change their structure and composition when exposed to acids or bases, because they react with them. When they change their structure and composition they change their ability to absorb light. Thus a molecule that absorbs the red component of white light might change to absorbing blue light when reacting with an acid in solution. Adding some base to this solution reverses the changes to the molecular structure of the indicator and hence reverses the color change.

**Dissolving**

Dissolving (also dissolution) is the term used for a process in which two different substances form a homogeneous mixture (known as a solution). The term is also applied to cases where the formation of a solution is accompanied by formation of a gas that is not part of the solution (eg metals are often said to dissolve in acids, but this is accompanied by the formation of hydrogen).
What are the molecules doing?

The molecules are not dissolving! What they are doing depends on the kinds of substances involved. In some cases (e.g., sugar + water), the two types of molecules mix uniformly. They intermingle and do not change their composition. In other cases there is a chemical reaction (e.g., salt + water, or metal + acid) and the molecules change their composition.

Precipitation

Precipitation is a general term for formation of a heterogeneous mixture from a homogeneous one. This may arise from a temperature change or from a reaction.

What are the molecules doing?

The molecules are not precipitating! Usually precipitation due to temperature change takes place due to temperature decrease. This is what we see when clouds form in the sky or there is rain. Molecules of water in the air stick together on collision and when thousands of them do this we see a droplet of liquid water. There is no chemical reaction.

Chemical reaction may however be the cause of precipitation. Most commonly we see this when two aqueous solutions are mixed and a solid forms. This usually sinks to the bottom of the mixture because (as noted previously) solids are generally of greater density than liquids.

Exothermic Change

When substances change, energy also changes. This is true of boiling and also of reaction. If energy is transferred from the substance(s) to the surroundings we call it an exothermic change. (The opposite is an endothermic change.) Of all the myriad events happening within us and around us all the time, exothermic ones are the most common.
What are the molecules doing?

When molecules change their environment or change their composition, there are energy changes. Changing environment may refer to a change of state (e.g., as when clouds and rain form in the atmosphere). The sticking together of molecules through intermolecular forces, lowers the potential energy of the molecules and the energy released is transferred to the environment (initially via the kinetic energy of neighboring molecules). Changing the composition of molecules occurs when there is a chemical reaction. Bond-breaking and forming takes place, with stronger bonds on average being the result. This too implies the potential energy of the product molecules is lower than the potential energy of the reactant molecules and the energy released is transferred to the surroundings (again via the intermediacy of the kinetic energy of neighboring molecules).

In summary an exothermic change is one in which either the strength of the intermolecular forces increases or the strengths of bonds in the molecules increase. Both of these lower the potential energy of the molecules, the bond changes usually resulting in a quantitatively greater energy lowering.

Oxidation

Oxidation is one category of chemical reaction. Actually it is only half a reaction, because oxidation is always accompanied by reduction. One cannot occur without the other. Originally the term may have been applied only to reaction of a substance with oxygen. In such a case the substance was oxidized whilst the oxygen was reduced (often to water and/or carbon dioxide). The use of the term was then extended to analogous reactions involving chlorine (although an alternative term would then be chlorination) and to the loss of hydrogen (also called dehydrogenation). As a generalization it may be said that oxidation-reduction reactions involve
bigger energy changes than other types of reaction. Combustion of fuels would exemplify the large energy changes accompanying such reactions.

**What are the molecules doing?**

The molecules of the reactants are colliding and undergoing bond changes. This is characteristic of a chemical reaction. The particular features of an oxidation-reduction reaction are that as the bonds change the electron density around some atoms increases significantly whilst around other atoms it decreases significantly. In some cases this involves outright electron transfer whilst in others it is a partial electron transfer. Electrons tend to move towards the more electronegative atom – this sort of atom is found in the oxidant molecule. The concept of oxidation state is used in describing such changes. The reality of the electron shifts is evident in the electrochemical cell where the oxidant and reductant are physically separated from one another. Electron transfer takes place via an external circuit rather than in the direct collision of molecules.

**Elements (chemical elements)**

Elements (or elementary substances) were first clearly defined by Lavoisier (1789) who described them as the simplest of substances that cannot be broken down into any simpler substances. His definition is often said to be an operational definition – which means it implies a method for finding out whether a substance is an element or not. “Breaking down” meant using thermal, radiative or electrical methods (energy inputs!). The definition is maintained today although there are more sophisticated methods of identifying elements now. Despite the passage of time, there are still only slightly more than 100 elements known. Allotropes of some elements are known and they may have markedly different properties.
What are the molecules doing?

The molecules are not elements! Molecules of elements are the simplest of molecules, but only in the sense that they are made from just one type of atom. In other respects the molecules may not be so simple. Aside from the few cases (Noble Gases) where single atoms occur (e.g. Ar), the molecules may be simple and diatomic (e.g. O2) or polyatomic and complex (e.g. P4, S8, Cn, Fen). In addition the molecules of one element may be found in different shapes and sizes (e.g. O3 and O2, and C60 and Cn). Amongst the molecular formulae given as examples are ones with a subscript “n”. This implies that the number of atoms per molecule is not fixed: the molecules have an extensive network of atoms bonded together and the value of “n” may be extremely large (billions!).

Compounds

Compounds (or compound substances) are pure substances with a fixed composition that can be broken down into two or more elements. They are not the simplest of substances. However they are just as much pure substances as elements are. The reference to fixed composition needs some slight reservation because there are a few compounds where the composition is variable. Altogether there are more than 10 million compounds known, and several new ones are being made or discovered every day.

What are the molecules doing?

Molecules of compounds are made of more than one type of atom. However, as with elements, the molecules may (in a structural sense) be either simple or complex. The molecules may be as small as HCl or H2O or as complex as DNA or PVC. There is a virtually infinite range of molecular possibilities. Included in this range is the possibility of isomerism – molecules with the same atomic composition but different structures.
Decomposition

Compounds can be broken down into two or more elements. However they can also be broken down to simpler substances that are still compounds. Decomposition is the general term for the chemical reactions in both cases. Once again the description “simpler” refers to composition. Thus for example, heating, decomposes calcium carbonate, CaCO₃, leading to formation of calcium oxide, CaO, and carbon dioxide, CO₂: two substances are formed and the formulae of each is simpler (compounds of only 2 elements) than that of the original compound (compound of 3 elements).

*What are the molecules doing?*

When compounds are broken down, it is true to say their molecules are broken down. However it is important to add that two or more new types of molecules are formed: decomposition does not usually result in atoms, although this is achievable with more violent conditions (the special term atomization may then be used).

As noted the molecules formed in a decomposition may be simpler in terms of composition, but they may not be structurally simpler. For example, in the case of the decomposition of calcium carbonate, we begin with molecules that are extremely large (the formula of the molecules would be best represented as (CaCO₃)ₙ) and complex. However the same may be said of the calcium oxide (best represented as (CaO)ₙ) molecules; it is only the carbon dioxide molecules, CO₂, that are simpler in every respect.

**Activation Energy**

Chemical reactions may be exothermic or endothermic, but how fast the reaction occurs is a different question. The majority of reactions need some energy input (thermal, radiant, electrical) to get started. The required energy input is termed the activation energy. Substances with a low
activation energy for many of their reactions are “reactive”; substances with a high activation energy for many of their reactions are “unreactive” or inert. However it should be noted that one cannot assign an activation energy to a substance; it is reactions that have activation energies.

What are the molecules doing?

In chemical reactions molecules are breaking and forming bonds. Breaking bonds requires energy; forming bonds releases energy. It is common for one bond (at least) of a molecule to have to break before a new bond can be formed. Hence energy input runs ahead of energy output as far as the molecules are concerned. This fact of molecular life is a logical expectation: if one or more of the atoms in a molecule could form more bonds (without breaking any others) then it would have done so a long time ago! Atoms form bonds until their valency is satisfied. The energy required for bonding changes in the molecules is a potential energy; colliding molecules derive this from their collisional kinetic energy. The same figures do not apply to all collisions because the trajectories of the molecules affect the energy requirements.

Catalyst

Catalysts are substances the speed up chemical reactions between reactants. Catalysts are usually added to the reactant mixture in small quantities and can be recovered at the end of the process. They are not used up and they do not change the products of the reaction. They cause the speed increase by lowering the activation energy of the reaction. The phenomenon is termed catalysis. Catalysts do not slow reactions: substances that do that are termed inhibitors and they do get used up.

Catalysts may be quite specific for particular chemical reactions; one cannot just say “this substance is a catalyst” but rather “this substance is a catalyst for this reaction”. Enzymes are natural catalysts for biochemical reactions and often are very specific in the reactions they catalyse.
What are the molecules doing?

Molecules of a catalyst interact with reactant molecules to make them more reactive. The catalyst molecule reacts rapidly with one of the reactant molecules. It reacts rapidly because it has a low activation energy for the interaction. The molecule produced by the interaction has one or more weaker bonds than the original reactant molecule. Therefore it reacts with a lower activation energy. When the product molecule is formed, it is still bonded to the catalyst molecule, and the final step in the catalytic process is the breaking of this bond with the catalyst molecule. Overall there are more steps in the reaction, but each has a lower activation energy: this increases the overall speed.

Chemical equilibrium

Chemical reactions may or may not proceed to completion. Sometimes reaction stops even when some reactants remain. The reaction is then said to have reached equilibrium – or in full, chemical equilibrium. The equilibrium condition can only be observed in a closed system, that is a system in which no substances can enter or leave the reaction mixture. The proportions in which reactants and products co-exist at equilibrium can be expressed through an equilibrium constant, which has a specific value for a reaction at a given temperature.

What are the molecules doing?

The molecules are still changing, even though the reaction seems to have stopped! The equilibrium condition arises because product molecules are changing back to reactant molecules at the same rate at which the forward reaction is taking place. Thus there is both a forward and reverse reaction proceeding and no net change is observable when their rates are equal. It is a dynamic equilibrium. The forward and reverse reactions in general have different activation
energies, and so they are affected by temperature changes to a quantitatively different extent. This is why the overall equilibrium condition is dependent on the temperature.

**Electrical conduction**

One of the ways of classifying substances is in terms of their electrical conductivity (or its inverse, resistivity). There are conductors, semiconductors and insulators. Under normal circumstances gases are insulators, liquids may be conductors or insulators, and solids may be any of the three categories.

*What are the molecules doing?*

An electric current is a flow of charges. The charges may be negatively-charged electrons or ions – charged atoms or molecules – with either a positive charge or a negative charge. The two cases are referred to as electronic and ionic current, respectively. Substances within which these currents occur can then be called electronic or ionic conductors. Semiconductivity is always electronic.

Ionic conduction is most common in liquids because in this state movement of charged atoms and molecules can take place. Generally speaking such movement is not possible in solids. By contrast, electronic conduction is more common in solids (although it is found in liquid (molten) metals). Electronic conduction in solids is commonly found when the solid comprises giant molecules with an infinite network of atoms and bonds. In addition the atoms making up the molecule need to hold electrons weakly. Such atoms will usually be of metal elements. In these circumstances the electrons move throughout the network of atoms and bonds relatively freely. Where such a network exists but the atoms hold electrons more strongly, the solid may be a semiconductor. In electronic conductors it is the electrons that move through the molecule: the
atoms do not move, and the molecule does not change. This contrasts with ionic conduction where chemical changes occur at the electrodes.

**Electrolysis**

Electrolysis is the decomposition of a substance with electrical energy. It can take place with suitable aqueous solutions (must be conducting) and requires an external source of energy (cell or battery), connecting wires and two electrodes made of conducting material. Reactions are observed at both the electrode surfaces, but not in the body of the liquid.

*What are the molecules doing?*

At the electrode surface molecules either lose or gain electrons: at the anode (conventionally labeled +) they lose electrons, whilst at the cathode (conventionally labelled -) they gain electrons. Losing electrons is also called oxidation; gaining electrons is also called reduction. The molecules are forced to undergo these electron transfers as a result of the potential difference between the two electrodes. There can be a variety of consequences of these transfers:

1. positive hydrated ions are neutralized at the cathode and negative hydrated ions are neutralized at the anode. For example $2H^+ + 2e^- \rightarrow H_2$ and $2Cl^- - 2e^- \rightarrow Cl_2$.

2. neutral molecules become charged due to loss of electrons at the anode or gain of electrons at the cathode – as a result the charged molecules break-up to form a more stable ion and a neutral molecule. For example $2H_2O^+ \rightarrow 4H^+ + O_2$ and $2H_2O^- \rightarrow H_2 + 2OH^-$

There are always auxiliary events when these violent electron transfers take place at the electrode surfaces. These include movement of ions through the solution to balance charges created or destroyed in the regions around the electrodes: uniformity in the distribution of charges in the solution is essential for continuing electrolysis.
REFLECTIONS

In the above descriptions of the meaning of some common terms, we have only scratched the surface of a substantial task. The terms selected are all ones that originated in the description of phenomena during the development of chemistry, predominantly since the days of Lavoisier in the 18th century. Generally-speaking dictionaries, compendia and glossaries define and explain (to a limited extent) the terms, either adopting a macro-level description or a micro-level description, but not both. Furthermore there is usually no uniformity within one listing, the author(s) seemingly making different choices of level for different terms. The macro-micro dictionary approach exemplified above, juxtaposes the two levels of description. This emphatically draws attention to their co-existence and their relationship.

In the micro-level descriptions that were given in the previous section, no reference was made to details of chemical bonding or atomic structure. We may relate this to the logical structure of chemistry identified by Jensen [4], by stating that we have penetrated into his “molar” and “molecular” levels, but not the “electrical” level. This position reflects a belief that we are often over-eager in chemistry teaching to talk of the electronic configurations of atoms, ionic and covalent bonding, etc, that is to plunge into the electrical level of Jensen, without paying enough attention to relating the molar and molecular levels.

Reviewing the micro descriptions, we can discern a few simple things about molecules, namely that they may be diatomic or polyatomic (up to giant size) and that they may be homonuclear or heteronuclear. Whatever their classification they may:
1. move and have energy (both potential and kinetic) which may change;
2. change their molecular environment;
3. change their composition and structure (bond breaking and forming);
4. absorb and emit radiation;
5. gain and lose electrons.

Most chemical phenomena can be interpreted through this understanding of what molecules do. However, the vocabulary at our disposal to say what the molecules are doing is very weak. This often drives us to use words from the macro-level to talk about molecular events, thus confusing in the very act of clarifying. In the examples above, we have sometimes been guilty of this.

In conclusion, it was suggested previously [6] that the “chemist’s triangle”, relating the macroscopic, microscopic and symbolic descriptions, may be recognized as a closed-cluster concept map [11]. Perspective on chemistry as a whole, and on its many topics, can be aided by recognizing this. It therefore has potential as a basic organizing framework for teaching and learning. Realising that potential should be facilitated by developing a macro-micro dictionary of terms. This being said, the symbolic corner of the triangle, and its relation to the other two, also deserves attention, and this will be the subject of a further paper.

REFERENCES
THE SYMBOLIC LANGUAGE OF SUBSTANCES AND MOLECULES: NOISE OR HARMONY?

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ABSTRACT
Most substances are given names and formulae based upon knowledge of their molecules. However for substances most commonly met in elementary chemistry courses, especially inorganic substances, this is often not the case. The potential noise is amplified further when dealing with chemical reaction equations. It is argued that since the names and formulae given to substances and their molecules are often the same, we should give more attention to the use of state descriptors and symbols for substances and use the word molecules when we mean to refer to them. [African Journal of Chemical Education—AJCE 6(2), July 2016]
INTRODUCTION

In a previous paper [1] we have reviewed the language of teaching and learning in the context of the macroscopic and microscopic (or sub-microscopic) levels of concept descriptions. A case was made for developing a macro-micro dictionary that would juxtapose the two levels of description. These two levels also correspond closely to the molar and molecular levels identified by Jensen [2].

Johnstone [3] drew attention to three ways in which we communicate chemical concepts, two of which are the macroscopic and microscopic ways. The third way he called symbolic, and in this paper we examine how this relates to the other two. We address the question of the extent to which the relationships support the macroscopic-microscopic descriptions, developing ideas that were first presented in 2008 [4].

In so doing we shall particularly focus upon chemical formulae and names and chemical reaction equations. Do these harmonize with our descriptive language or do they add to the noise? The level of discussion is intended to be suited to those teaching chemistry at the secondary and tertiary levels and should be read with this purpose in mind.

NAMES AND FORMULAE OF SUBSTANCES AND MOLECULES

Before Lavoisier’s time, substances were given idiosyncratic names and hieroglyphic-like symbols [5]. All of this changed in the wake of Lavoisier’s definition of elements (1789). In an obvious development based upon identifying names of elements, he proposed that the names of compounds should reflect the names of the elements they comprised. Hence for example, copper oxide, sodium chloride, etc: the binary naming system, later extended to include common groups like sulfate and hence, copper sulfate etc. After some years the publication of Dalton’s atomic
theory and the determination of atomic weights by him and others and then the introduction of element symbols by Berzelius, led to the appearance of formulae, such as CuO and NaCl. Although the first of these could be called copper oxide, when another oxide was identified as Cu₂O, the need for a somewhat more sophisticated naming became apparent. The names cuprous oxide and cupric oxide were created for Cu₂O and CuO, respectively. A similar situation arose with the formulae CO and CO₂. In these two cases the names adopted were treated differently: carbon monoxide and carbon dioxide. The latter names are systematic in the sense that the names directly reflect the atomic composition. In the case of the copper oxides, this is not so; the terms cuprous and cupric require special interpretation. Another approach (using the concept of oxidation state) was also suggested: thus copper(I) oxide instead of cuprous oxide and copper(II) oxide instead of cupric oxide. All of this can be learned but it adds to the burden of new learners, who in the early stages of learning are rather unlikely to understand the oxidation state concept. Furthermore the temptation to misunderstand what the Roman numbers are saying is strong: the (II) does not imply two atoms of copper! The more systematic naming of the two oxides as dicopper oxide and copper oxide, has a more direct relationship with the atomic composition. Unfortunately these names are rarely used. We thus find today the persistence of names of many common substances that are essentially macroscopic in nature (belief in atoms not required!), whilst the formulae they have are microscopic in nature (reflecting atomic composition).

This short discussion draws attention to just a small part of the confusion that may be created with names and formulae. It is as if the older days of idiosyncratic naming retain their appeal, except for those who feel that oxidation states must be learned before we know what they are.
A similar problem arises when naming a series of compounds with the formulae NaCl, CaCl$_2$, AlCl$_3$, SiCl$_4$, etc. The commonly-used names of these compounds are sodium chloride, calcium chloride, aluminium chloride, silicon tetrachloride. Frustrating for the beginner is the failure to use names like calcium dichloride and aluminium trichloride, which reflect directly the chemical formula in each case. Experienced chemistry teachers may say that a name like calcium chloride is what everyone uses and there is no ambiguity because there is only one chloride: this of course is true, but again this usage adds to the burden of comprehension for beginners. There is much evidence of the reality of this burden: for example, Bradley and Steenberg found [6] that learners had greater difficulty in encoding from names to formulae, than the reverse decoding: learners resorted to creating their own chemical symbols and combining atoms and groups in 1:1 ratio by default.

Although Lavoisier started the systematic naming of substances and Berzelius developed systematic formulae thereafter [7], we seem to have failed to develop and use what they began in a completely logical way. In some cases (as exemplified above) we find that whereas the formula of a compound reflects its atomic composition (a microscopic description), the name essentially reflects elemental composition (a macroscopic description). Trying to bridge this gap by drawing upon other concepts like oxidation state seems perverse.

Another aspect of the problem is the common way in which the binary nomenclature is introduced in secondary schools. This is almost exclusively done by listing ions with their formulae and charges and then explaining the balancing or matching of charges in constructing the formula of a substance. Thus, even before the concept of ionic bonding, this naming approach leads learners to a conviction that ionic substances predominate and that entities (atoms and groups of atoms) like Cl, OH, SO$_4$, are always negatively charged. Hence alcohols are a source of hydroxide ions
and when a chlorine molecule dissociates it must yield chloride ions! In fact such entities have a valency, a concept which is not associated with any charge or model of bonding, and this would be a better characteristic to emphasize instead of charge [8].

All of the foregoing relates to the “classical” world of inorganic chemistry, which is a major part of secondary school chemistry curricula. The naming is described as binary nomenclature. Somewhat later in the development of chemistry, organic compounds became better understood and presented more serious challenges of communication. Although non-systematic names were used initially (and a few remain as “trivial” names), they were quickly and comprehensively overcome by the systematic naming developed and maintained by IUPAC. Predominantly a substitutional nomenclature was adopted and widely used at all levels. Although this does require the learning of a system, the system is logically related to the atomic composition of the compounds. Thus, for example, the name chloropropane directly informs that one chlorine atom has replaced one hydrogen atom in the propane molecule. Indeed it allows one to go even further in that it can give structural information about the molecules, by the use of locants together with a simple numbering scheme, eg 2-chloropropane. This caters for the prevalence of structural isomers in a natural way too, as in 1-chloropropane and 2-chloropropane.

Thus we can see that in organic chemistry both the name and the formula apply to the substance and the molecules of the substance. This is an admirably simple situation, although it makes it easier to confuse the macro and micro descriptions! The only salvation then is to add the word “molecule”, when the name or formula is used with reference to that entity rather than the substance.
EMPIRICAL AND MOLECULAR FORMULAE

Before the concept of molecules had been fully agreed upon, chemists were very happy to be able to determine the atomic proportions of a compound and to represent this information with a formula. This sort of formula is called an empirical formula. With the growing awareness of molecules, it became evident that whilst the atomic proportions must apply to the molecules as much as to the compound, the actual numbers of atoms per molecule was a different and very important matter. This too could be represented by a formula, called a molecular formula. Thus hydrogen peroxide (or more systematically, dihydrogen peroxide) has a molecular formula \( \text{H}_2\text{O}_2 \), indicating that the molecule comprises two hydrogen and two oxygen atoms. This is not revealed in the empirical formula of the compound, which is \( \text{HO} \). The molecular formula is far more informative than the empirical: however both formulae symbolically represent both substance and molecules.

Turning then to such familiar compounds as sodium chloride, \( \text{NaCl} \), here we find the formula is an empirical one, not a molecular one. Nevertheless the nature of the molecules of solid sodium chloride is known: they are formed of huge networks of atoms and bonds and have an indefinite size. Hence an appropriate molecular formula could be \( (\text{NaCl})_n \). Once again, the adoption of a molecular formula, is very informative. Furthermore, it makes sense of the fact that solid sodium chloride has a high melting point, unlike hydrogen chloride, \( \text{HCl} \), which is a gas! (It should be noted that nothing explicit need be said about the nature of the bonding or even the geometric arrangement of the atoms in the lattice.)

Somewhat similar issues are met with in respect of the formulae of elements. Thus single atoms are quite rare (Noble Gases) and we find molecules of elements from the simplest (eg \( \text{Cl}_2 \)) to the most complex (eg \( \text{C}_n \)). In common usage unfortunately, solid carbon is usually given an
empirical formula, that is C, whilst chlorine is always given a molecular formula. The lack of consistency again creates potential problems for learners; for example why is Cl\(_2\) a gas whilst C is a high melting solid? The macroscopic observable (mp in this case) bears no relationship to the commonly used formulae (microscopic), when one is empirical and the other molecular!

Jensen [9][10] has drawn attention to the lack of explanation by textbook authors for the formulae used in representing solid substances and to the inadequacy of the descriptors empirical and molecular (suggesting they be replaced by “relative” and “absolute”, respectively).

In conclusion, if we want to make meaning of the macro/micro/symbolic relationships as envisaged by Johnstone, amongst the things we need to undertake is a study of how our symbols and formulae work to make the relationship effective or otherwise [11]. Molecular formulae can serve the purpose much better than empirical formulae, and can help to make sense of the macro-micro relationship. However to achieve this we must be more consistent and logical in their use.

THE STATES OF SUBSTANCES AND MOLECULES

The states (or states of aggregation) of substances are often represented by symbols. The more familiar of these include (s) for solid, (l) for liquid, (g) for gas, and (aq) for aqueous solution. These symbols are appended to the formula of the substance, as for example, HCl(g), NaCl (s), C\(_6\)H\(_6\)(l) and CuSO\(_4\)(aq).

A molecule does not have a state. A set or collection of molecules (a chemical species [12]) does. Hence symbolically a molecule of hydrogen chloride, for example, is the same, regardless of its environment. This is not to ignore that in aqueous solution, molecules of hydrogen chloride are scarce because of their strong tendency to transfer a hydron to a water molecule. Thus when
symbolically representing a molecule of hydrogen chloride, the formula HCl is correct, regardless of its environment. Similar remarks would apply to benzene molecules, C₆H₆.

In the case of a solid substance like sodium chloride, a suitable molecular formula would be (NaCl)ₙ. In molten sodium chloride it is unclear what the nature of the microscopic entities is. In the gas state there are molecules of formula NaCl.

**CHANGES OF SUBSTANCES AND MOLECULES**

Equations are often used to represent changes of substances and molecules. Word equations use the names of substances and not formulae, and are often used when introducing the macroscopic features of chemical reactions. However, changes of substances and molecules are most frequently represented symbolically. When a single substance is involved the change may be a change of state:

\[ \text{HCl}(l) = \text{HCl}(g) \]

where the equal sign means there is a specific stoichiometric relationship between the initial state (represented on the left) and the final state (represented on the right). The symbolic representation of the sublimation of a substance like sodium chloride however needs careful thought: consistently one may use empirical formulae -

\[ \text{NaCl}(s) = \text{NaCl} (g) \]

or molecular formulae -

\[ (\text{NaCl})ₙ(s) = n\text{NaCl} (g) \]

Changes of this type are not limited to “salts”; for example, using molecular formulae to symbolically represent the sublimation of solid sulfur trioxide:
\[(\text{SO}_3)_3 \text{ (s)} = 3\text{SO}_3\text{(g)}\]

and similarly for the depolymerisation of many organic addition polymers.

These last two examples are chemical reactions because the molecules undergo bond changes. To refer to these as physical changes because they merely involve a change of state, would be misleading [13]. It is another instance of the persistence of macro-descriptions of changes when the micro-descriptions show them no longer to be suitable.

To represent symbolically the molecular changes requires that we use the molecular formulae without the state descriptors. In all other respects, the equations remain the same.

The same considerations apply to representing more conventional chemical reactions involving more than one reactant, such as:

\[\text{C(s)} + \text{O}_2\text{(g)} = \text{CO}_2\text{(g)}\]

This balanced chemical equation uses a mixture of empirical and molecular formulae. More consistent is the following use of molecular formulae:

\[\text{C}_n\text{(s)} + n\text{O}_2 \text{ (g)} = n\text{CO}_2\text{(g)}\]

More familiar differences in representation are found in reference to elements like sulfur where different texts use the empirical formula, S, or the molecular formula, S\(_8\).

The use of mixed equations, that is ones in which a mixture of empirical and molecular formulae is used, is surely adding to the confusion and should be avoided.

Chemical reactions in aqueous solution often present further challenges to helpful communication. At the macro-level it is surely simple as well as correct to write, for example:

\[\text{NaOH(aq)} + \text{HCl(aq)} = \text{NaCl(aq)} + \text{H}_2\text{O(l)}\]

This summarizes the important stoichiometric relationships upon which a variety of quantitative problems may be set, but its relationship with how we mostly think of the situation is
tenuous. The adoption of the symbolism NaOH(aq), etc, is convenient but may be said to mislead beginners. The same reaction is sometimes written for more advanced learners in ionic terms as:

\[ \text{Na}^+(aq) + \text{OH}^-(aq) + \text{H}^+(aq) + \text{Cl}^-(aq) = \text{Na}^+(aq) + \text{Cl}^-(aq) + \text{H}_2\text{O}(l) \]

Use of the state descriptor (aq) suited to macro-descriptions means this is a hybrid symbolism, which may be justified by our uncertainty regarding the molecular composition of the hydrated ions. A strict micro symbolism would surely require formulae of the type Na(H\textsubscript{2}O\textsubscript{x}\textsuperscript{+}), which shows the entity is a molecule with a charge (it is an ion that is a molecule) rather than showing the atomic ion apparently floating in a continuous “sea”. Although the value of “x” may be uncertain in the case of Na\textsuperscript{+} for many others it is established (eg for Cu\textsuperscript{2+} it is 4).

When the water is largely evaporated from such a reaction mixture, sodium chloride crystallizes. This is represented at the macro-level as:

\[ \text{NaCl}(aq) = \text{NaCl}(s) \]

or in hybrid form as:

\[ \text{Na}^+(aq) + \text{Cl}^-(aq) = \text{NaCl}(s) \]

At the micro-level this becomes more explicit as:

\[ n\text{Na(H}_2\text{O)}\text{x}^+ + n\text{Cl(H}_2\text{O)}\text{y}^- = (\text{NaCl})_n + (x+y)\text{H}_2\text{O} \]

Although we can claim to represent a reaction at the micro-level by using appropriate formulae, in general the complete representation of a chemical reaction at the micro-level would require knowledge of the reaction mechanism. When the mechanism is unknown or is not appropriate for the educational context, then it must be stressed that equations that show suitable molecular formulae are not necessarily full micro-representations, because they do not show the mechanism.
The conceptual havoc that may be created by ill-considered descriptions is well illustrated by the teaching and learning of the Brønsted theory of acid-base reactions. This theory involves the concept of proton transfer (better called hydron transfer) and results in such mind-blowing assertions as water is an acid or water is a base (when in fact water is neutral!), supported by symbolic equations. Or again that “acid + base = base + acid”, so what about neutralization and salt formation and all the traditional concepts that children learn from earlier grades? As Barke and Harsch have recently pointed out [14], the root of the conceptual upset lies in the switch from substance language and symbols to molecular language and symbols.

**STRUCTURAL FORMULAE OF MOLECULES**

Part of the symbolic language associated with molecules is their structural formulae. There is nothing equivalent in the language associated with substances. Structural formulae show explicitly the existence of chemical bonds between the atoms of a molecule. These formulae must be consistent with the molecular formulae but do not demand any electronic details. Apart from showing the connectivity between atoms they may also show 3-D spatial relationships. Understanding what structural formulae show (and do not show) is an important stepping stone towards discussion of chemical bonding, which opens up the electronic level as described by Jensen [2].

In organic chemistry the naming of molecules is directly based upon knowledge of their structure, so naming links with structural formula rather than molecular formula. Nevertheless, molecules and substances have the same name.

In inorganic chemistry structural formulae are less pervasive. Indeed it is normal for structural formulae to first make their appearance in a chemistry curriculum within the context of
theories of chemical bonding and the 3-D spatial geometry adopted by molecules (VSEPR theory). Consequently there is very little of a factual knowledge base to such teaching and learning in inorganic chemistry. Even a comparatively simple, yet familiar molecule such as H\textsubscript{2}SO\textsubscript{4} is a structural mystery to many teachers and learners. The bonding of the two hydrogen atoms to two of the oxygen atoms comes as a revelation!

Chemical bonds between atoms are shown in structural formulae usually by means of simple lines between the atomic symbols. In simple cases these lines may be equated with pairs of electrons between two atoms. However it is not necessary to accept this as a rigid requirement. Nor need there be concerns about the extent to which the bond is polar or approaches the ionic condition. As the IUPAC definition puts it [12]:

\textit{When forces acting between two atoms or groups of atoms lead to the formation of a stable independent molecular entity, a chemical bond is considered to exist between these atoms or groups.}

Thus less simple cases are amenable to the language of structural formulae, with for example, instances of delocalized bonds being represented with dotted lines. Care must be taken to avoid confusion with lines which aim to highlight geometrical relationships. This is a problem commonly encountered in textbooks that show the types of spatial arrangements associated with descriptors such as tetrahedral or octahedral. For example, the octahedral SF\textsubscript{6} molecule may be shown with bonds between the F atoms as well as between the F and S atoms! Clearly bond lines and geometry lines should not be in the same picture without very distinctive coding differences.

\textbf{NOISE OR HARMONY?}

The preceding sections have argued that, in the symbolic language of substances and molecules, we hear something like an orchestra practicing. There are times when harmony is
apparent and others when it is noise that we hear. As Johnstone has argued in another connection, noise is to be avoided if learning is to be facilitated [15]. We may also note that, although little explicit reference to misconceptions has been made above, it is implicit that symbolic language problems we have identified help to promote them.

To summarize we have found:

1. Substances have names and formulae and these may or may not be systematically related. In addition both empirical and molecular formulae are used for substances, and often without any indication as to which. Much of this noise originates from inorganic substances of the simpler and longest known type. The names of these “old” inorganic substances are often still rooted in the simple pre-Daltonian (macroscopic) language whereas the formulae are mostly post-Daltonian (microscopic). It is particularly unfortunate that the old names (e.g., calcium chloride) masquerade as systematic. These substances are the ones predominantly encountered by beginning learners of chemistry, thus adding to their difficulty in making sense of the subject.

2. Organic substances and “newer” inorganic substances generally have names that reflect not only the molecular formula, but the structural formula. Clearly the pressure to adopt a universal and systematic nomenclature was felt early in organic chemical history as the enormity and diversity of the organic chemistry “jungle” became evident. Use of structural formulae entails being explicit about the bonds in the molecules. This harmonious situation is in sharp contrast with the “old” inorganic chemistry where structural formulae are rather rarely encountered (except for the case of water!). In our experience teachers are often very surprised to see a structural formula for something as simple as sulfuric acid, and there is
much evidence that learners are uncertain which atoms are bonded together when presented with simple formulae, like H$_2$SO$_4$.

3. The fact that substances are mostly named in a manner determined by their molecular formulae, potentially constitutes a core conflict between describing a substance and describing the molecules of the substance. The simplest way to help distinguish the meaning is to use state symbols with substance formulae. This can be reinforced by appending the word molecule(s) when using formulae and names for these entities. Perhaps in this simple way noise may be transformed into harmony.

4. The potential confusion in understanding of substances and molecules due to the noise in some areas, extends into symbolic representations of physical and chemical change. We may even find equations in which a mix of empirical and molecular formulae is used without the distinction being noted. Of course it is often the case in an educational context, that methods for obtaining correct answers to stoichiometric calculations are the principal concern rather than comprehension of the chemical events [16].

Thus the relation of the symbolic corner of Johnstone’s triangle to the macroscopic and sub-microscopic corners is clear in principle, but not in practice. As Dori and Hamieri [17] argue, the symbols are the basic language that mediates the interrelationship of the other two, and without paying explicit attention to this, students are handicapped. Any macro-micro dictionary, as proposed previously [1], must therefore pay attention to the need for greater symbolic clarity.

REFERENCES
USES OF SYSTEMIC APPROACH AND CHEMIST'S TRIANGLE IN TEACHING AND LEARNING CHEMISTRY: SYSTEMIC CHEMISTRY TRIANGLE [SCT] AS A TEACHING & LEARNING STRATEGY

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ABSTRACT
This paper describes uses of the systemic chemistry triangle [SCT] in which we get the benefits of both systemic approach and chemist's triangle in teaching and learning chemistry. SCT creates active learning environment enable students to gain high mental and professional skills, correct cognition, positive attitudes towards chemistry, and environment, and finally systemic thinking. At the end of the learning process by SCT the student gain systemic learning outcomes of the concept in which the MAC- level interrelated to Symbolic-level and both are explained by MIC-level in a pattern of knowledge. [African Journal of Chemical Education—AJCE 6(2), July 2016]
INTRODUCTION

Systemic Approach to Teaching and Learning (SATL) is a teaching model that has been developed during the past decade by Fahmy & Lagowski [1-5]. They recognized that the basic goal of SATL is the achievement of meaningful understanding by students and suggest that this goal can be attained through the development of systemic thinking, in a context of constructivist and systemic oriented learning tasks (SATL techniques) [1-5]. Meaningful understanding of chemistry concepts includes the ability of student to link related chemical concepts resulting in making judgments, creating relationships, drawing conclusions, predicting what should happen, also includes the student abilities to draw chemical information from a chemical representation and to construct a chemical representation using chemical information [6]. SATL also used as a vehicle to engage the students in a deep learning that focuses on relating ideas and making connection between new and prior knowledge [3]. On the other hand learning chemistry requires modeling ability and representational competence enable to use multi-Model representational form that are explanatory tool. Gilbert [7] and Johnston [8] stated that the triangle has become the theoretical framework in understanding how chemistry concepts are presented. Commonly, students are exposed to all three learning levels of chemical representation of matter simultaneously. The model has also been found to be of great use to chemistry education researchers like Gilbert & Treagust [9]; and consists of three domains of knowledge as shown in Fig.1a. (i) Macroscopic, a tangible and visible level of thought and experiences comprising what students can experience or observe (ii) “Sub-microscopic” it refers to the molecular domain, and (iii) “Symbolic” which refers to “symbols, formulae, equations, and graphs”. The planar triangle of chemistry, Fig.1a, has proven to be of great benefits in designing of secondary and post-secondary school curriculum, including textbooks, lab manuals.
Mahafy [10-11] modified the chemist’s triangle to the tetrahedron by adding a fourth learning level (human contexts) for learning chemistry as in Fig.1b. However, Bradley [12] stated that some authors converted the chemist's triangle to a tetrahedron to take account of the interaction of chemistry with the environment. This seems to be a confusion rather than improvement. The environment is important, but they do not lie at the core of the discipline and would be better taken into account by a circle around the triangle. Bradley also stated that the triangle may be viewed as a core closed-cluster concept map of the type advocated in the systemic approach to teaching and learning of chemistry and used to get thoughts on any chemistry topic or theme. He postulated that chemist's triangle alone is an aide-memoire that can be understood after experiencing its use [12].

Johnstone and his group [13].have demonstrated the reducing effect of working memory overload on learning achievement. They note that novice learners have great difficulty in working at all three learning domains of chemistry at one and the same time because of information overload. Deliberate use of the chemist’s triangle has clear potential in this regard as do closed cluster concept maps in general. It can serve as an advance organizer and/or as a meaningful summarizing framework [13]. In the same time systemics were used as an advance organizer models for the successful teaching and learning chemistry [3, 6].

In continuation of our work on the uses of SATLC in different educational settings, herein we will combine both systemics and chemist’s triangle models to get benefits of both in teaching and learning chemistry. So, we make use of triangle as triangular systemic in which the three learning domains of concepts located at the corners. We name it as systemic chemistry triangle (SCT). If we imagine that the student stand at the center of the chemistry triangle, he/she will recognize the three corners of the triangle in a pattern of [Macroscopic-Microscopic-Symbolic]. If we start learning of any chemistry concept from MAC level (the student can describe physical and
chemical changes of matter), then he/she will write the balanced equation as part of symbolic level description of MAC level. Then the student comes to explanation of his/her observations on the atomic and molecular level- MIC. At the end of the learning process the student gain systemic learning outcomes of the concept in which the MAC- level interrelated to Symbolic-level and both are explained by MIC-level in a pattern of knowledge.

This systemic interaction between the three learning levels (domains) of SCT leads to meaningful understanding of chemistry concepts resulted from active learning environment represented by a circle around the triangle. The expected learning outcomes of SCT are correct cognition, positive attitudes towards chemistry and environment, high skills and systemic thinking [3], Fiq.1c. It could be presented by Quadrilateral around SCT. The growing ability of the systemic way of thinking of our students is one of the most important characteristics of Global Era [14]. The following diagram represents the evolution of chemistry triangle from planar triangle (Fig.1a) to tetrahedron (Fig.1b) then to our systemic triangle (Fig.1c).
Fig. 1a: Planar Chemistry Triangle

Fig. 1b: Tetrahedral Chemistry Triangle

Correct Systemic cognition

Active Learning

Systemic Thinking

MAC

MIC

Symb

Fig. 1c: Systemic Chemistry Triangle

Fig. 1a-c: Evolution of Chemistry Triangle Strategy
STC - strategy emphasizes that more than one teaching strategies are used under this umbrella (e.g. Systemic, problem solving, active learning, and cooperative learning. etc).

USES OF SCT IN TEACHING AND LEARNING GENERAL CHEMISTRY CONCEPTS

In the present work we make use of SATL & Chemists triangle as teaching and learning methodologies to introduce the systemic triangle [SCT] as an easy model for new teaching strategy of general chemistry concepts. As presented in [ST0;Fig.2] the three learning levels of the matter are systemically interacted and you can't teach one apart from the two others or even teach two apart from the third level otherwise we will go to surface & rote learning. ST0 represents the general strategy for teaching and learning chemistry concepts in a pattern of knowledge of the three learning levels (domains)

[MAC (Describe) –SYMB (Symbolic representation) - MIC (Interpretation) ]

For instance, if we teach chemistry concepts of matter at the [MAC-SYMB.] Levels and we ignored [MIC] level. This will lead to rote & surface learning due to the absence of any microscopic interpretation at [MIC-Level].

In the following part of this paper we will use systemic chemistry triangle SCT as a facile strategy for teaching and learning some general chemistry concepts listed in the following Table.1.
Table 1: Chemistry Concepts Learned by SCT Strategy

<table>
<thead>
<tr>
<th>No.</th>
<th>Concepts</th>
<th>Sub.Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Physical changes</td>
<td>Changes in color, Volume, Temperature-boling point-Melting Point-Dipole moment μ -PH,</td>
</tr>
<tr>
<td>2</td>
<td>Solubility</td>
<td>Exo-thermic, Endo-thermic</td>
</tr>
<tr>
<td>3</td>
<td>Acid</td>
<td>Aq. Solutions of acids, Hydration of H+ ions to H3O+</td>
</tr>
<tr>
<td>4</td>
<td>Base</td>
<td>Aq. Solutions of Bases</td>
</tr>
<tr>
<td>5</td>
<td>Acid –Base reactions</td>
<td>Neutralization reactions, End point, Indicators.</td>
</tr>
<tr>
<td>6</td>
<td>Redox Reactions</td>
<td>Oxidation - Reduction</td>
</tr>
<tr>
<td>7</td>
<td>Haber-Process</td>
<td>Reversible reaction, Effect of heat, Pressure on the reversible reaction.</td>
</tr>
<tr>
<td>8</td>
<td>Substitution reactions</td>
<td>Nucleophilic Substitution Reactions, SN2-Mechanism.</td>
</tr>
<tr>
<td>10</td>
<td>Addition Reactions</td>
<td>Electrophilic Addition of HBr to the π –bonds of Alkenes, E2-mechanism. Addition of hydrogen on the π –bond of C=O groups</td>
</tr>
</tbody>
</table>

Note: All figures are presented in a separate file at the end of the text.

I. Use of SCT in Teaching and Learning

Exothermic Solubility: eg. Solubility of NaOH in water (SCT1 –Fig.3).

Teachers follow up the following scenario for teaching solubility of NaOH in water [Fig. 3];

1. The scenario of teaching started by asking the students to carry out the following

Experiment:
- Add 10 ml of water to 0.5 gm of solid NaOH in a test tube and shake the tube.
- Then teacher asks students to describe the observed changes.
- **Observation [MAC-Level]**
  - **Physical changes.**
    - Sodium hydroxide (solid) dissolved in water to give homogeneous solution.
    - The solubility is accompanied by liberation of heat (exothermic).
    - Increase of the pH of water to a strong alkaline (alkaline effect on litmus paper).
2. Then teacher asked students to write the equation as Symbolic - Level description of the
   MAC-level.

3. Then teacher ask students to use MIC-Level to explain both MAC & Symb.

   Descriptions
   - Hydration of Na+ and -OH ions to give hydrated Na+ (aq.) and –OH (aq.) ions.
   - Solubility is Exothermic because hydration energy is greater than lattice energy.
   - So the student started learning by MAC-Level then use Symb to represent the changes of
     matter in MAC, then finally use MIC to explain both MAC & Symb descriptions.

II. Use of SCT in Teaching and Learning

Endothermic Solubility: eg. Solubility of NaCl in water (SCT2-Fig.4).

Teachers follow up the following scenario for teaching solubility of solid NaCl in water
[Fig.4]:

1. The scenario of teaching started by asking the students to carry out the following

   Experiment:
   - Add 10 ml of water to 0.5 gm of solid NaCl in a test tube, then shake the tube.
   - Then teacher asked students to describe the observed changes.
   - Observation: [MAC-Level]
     - Physical changes
       • Sodium chloride (solid) dissolved in water to give homogeneous solution.
       • The solubility is accompanied by absorption of heat (Endothermic).
       • The pH of the solution =7 (neutral effect on litmus paper).

2. Then teacher asks students write the symbolic equation as symbolic-Level description of
   MAC-level.

3. Finally teacher asks students to explain both MAC and Symb descriptions.

   - Hydration of Na+ and Cl- ions to give hydrated Na+ (aq.) and Cl- (aq.) ions.
   - Solubility is Endothermic because hydration energy is less than lattice energy.
   - So, the students started learning at MAC-Level to describe changes in matter then use
     Symb-Level to represent changes in a symbolic equation then finally use MIC-level to
     explain MAC & Symb descriptions.
III. Use of SCT in Teaching and Learning Solubility of HCl Gas in water [SCT3-Fig.5].

Teachers follow up the following scenario for teaching solubility of HCl (gas) in water [Fig.5]:

1. The scenario of teaching started by asking students to carry out the following experiment:

   - Hydrogen chloride HCl gas is prepared from the action of moderately conc. H2SO4 (aq.) on solid NaCl (s). Then the gas passed into water via inverted funnel.
   - Then teacher asked students to describe the observed changes.
   - **Observation: [MAC-Level]**
     - **Physical changes**
       - Hydrogen chloride (gas) dissolved in water to give homogenous solution.
       - The pH of the solution less than 7 (acidic effect on litmus paper).

2. Then teacher asked students to write the Symbolic Presentation [Fig.5] (symbolic equation) to represent changes described in the MAC-Level

3. Finally teacher asked students to explain both MAC& Symbolic descriptions by making use of MIC-Level [Fig. 5]

IV. Use of SCT in Teaching and Learning Dilution of Concentrated Sulphuric Acid in Water (SCT4-Fig.6)

Teachers follow up the following scenario for dilution of conc. sulphuric acid with water [Fig.6]:

1. The scenario of teaching started by asking students to carry out the following experiment:

   - Add 1 ml of conc. sulphuric acid (98%) to 5 ml. of water in a test tube.
   - Then teacher ask students to describe the observed changes.
   - **Observation: [MAC-Level, Fig.6].**
   - Exothermic solubility of the acid.
2. Then teacher asked students to write the Symbolic Presentation [Fig.6] (symbolic equation) to represent changes described in the MAC-Level.

3. Finally teacher asked students to explain both MAC & Symbolic descriptions by making use of MIC-Level [Fig.6]

V. Use of SCT in Teaching and Learning Oxidation of Fe\(^2+\) to Fe\(^3+\) by chlorine (SCT5-Fig.7)

Teachers follow up the following scenario for teaching and learning Oxidation of Fe\(^2+\) to Fe\(^3+\) by chlorine [Fig.7]:

1. Teacher started the scenario of teaching by opening discussion about the concepts of Oxidation, Reduction and Redox-reactions. Then asked students to describe the changes in the oxidation of Fe\(^2+\) to Fe\(^3+\) by chlorine. [MAC-Level; Fig.7].

2. Then teacher asked students to write the Symbolic Presentation [Fig.7] (symbolic equation) to represent changes of the MAC-Level.

3. Then student move to [MIC-Level; Fig.7] to explain both MAC & Symbolic descriptions.

VI. Use of SCT in Teaching and Learning Acid-Base Reaction of HCl with NaOH (SCT6-Fig.8)

Teachers follow up the following scenario for teaching Acid-Base reaction between HCl, and NaOH [Fig.8]:

1. Teacher asked students to carry out Titration of (0.1N) solution HCl with approximately (0.1N) NaOH solution using ph.ph as indicator to determine the end point.

2. Observation: (Students Describe changes) [MAC-Level; Fig.8]
- At the end point the solution becomes neutral PH =7 due to the transformation of NaOH to NaCl Salt.
2. Then teacher asked students to write the symbolic representation [Fig.8] the symbolic equation for neutralization reaction) to represent changes of MAC-Level.
3. Then teacher asked students to explain both MAC& Symb descriptions by making use of MIC-Level [Fig.8].

VII. Use of SCT in Teaching and Learning of Haber Process for Industrial Preparation of Ammonia (SCT7-Fig.9)

Teachers follow up the following scenario for teaching Haber process [Fig. 9]:
1. Teacher open discussions with students about use of Haber process in industrial preparation of ammonia, then asked them to describe the changes in the Process.[MAC-Level; Fig.8].
2. Then teacher asked students to write the symbolic equation of Haber Process Symbolic Presentation –Level [Fig.9] to represent the changes of MAC-Level.
3. Then teacher asked students to explain descriptions of both MAC& Symbolic by using MIC-Level [Fig.9].

VIII. Uses of SCT in Teaching and Learning Synthesis of Methanol from Methyl Chloride (SCT8-Fig.10)

Teachers follows up the following scenario for teaching synthesis of Methanol [Fig10]:
1. After discussions in the class room about the synthesis of methanol from methyl chloride by Bimolecular Nucleophilic substitution reaction. Teacher ask the students to describe the physical and chemical changes in this process [MAC-Level; Fig.10].
2. Then teacher asked students to write the Symbolic and Mechanistic equations of (SN2 mechanism) Symb-level Fig.10 to represent the changes of the MAC-Level.
3. Then student move to MIC-Level [Fig.10] to explain both MAC and Symbolic description levels.

IX. Use of SCT in Teaching and Learning Reaction of Sodium with Methanol (SCT9-Fig.11)

Teachers follows up the following scenario for teaching [Fig11]:

1. After discussions in the class room about the reaction of sodium metal with methanol. Teacher asked the students to describe physical and chemical changes in this reaction [MAC-Level; Fig11].

2. Then teacher asked the students to write the symbolic equation representation Level [Fig.11] of MAC-Level description.

3. Then teacher ask students to go to MIC- Level [Fig.12] for explanation of both MAC& Symbolic descriptions.

X. Use of SCT in Teaching and Learning of Photo-Chlorination of Methane to Methyl Chloride (SCT10-Fig.12)

The teachers follows up the following scenario for teaching [Fig.12]:

1. After discussions in the class room about photo-chlorination reactions. Teacher ask the students to describe the physical and chemical changes in this process [MAC-Level; Fig.12].

2. Then teacher asked the students to write the symbolic equation [representation-Level; Fig .12] of the MAC-Level description.

3. Then teacher ask students to go to MIC- Level [Fig.12] for explanation of both MIC& Symbolic descriptions.
XI. Use of SCT in Teaching and Learning Reaction of Ethylene with HBr (SCT11-Fig.13)

Teachers follow up the following scenario for teaching [Fig.13]:

1. Teacher open discussions about electrophilic addition reaction of HBr on the $\pi$ bond in ethylene molecule then teacher asked students to describe the changes in this process [MAC-Level; Fig.13].

2. Then teacher asked the students to go to [Symb-Level; Fig.13] to write the symbolic and mechanistic equations of MAC – Level description.

3. Then students go to [MIC-Level; Fig.13] for explanation of both MAC& Symbolic descriptions.

XII. Use of SCT in Teaching and Learning of Synthesis of Isopropanol from Acetone (ST12-Fig.14)

Teachers follow up the following scenario for teaching [Fig.14]:

1. After discussions in the class room about the addition of hydrogen on the carbonyl groups of aldehydes and ketones to give alcohols. Teacher asked students to describe the changes in this process [MAC-Level; Fig.14].

2. Then teacher asked students to move to [Symb.-Level; Fig.14] to write the symbolic presentation for MAC-Level description.

3. Then students move to [MIC-Level; Fig.14] to explain MAC& Symbolic descriptions.

CONCLOSUTIONS

At the end of teaching this unit by SCT, we expect from our students the following:

- Improving their ability to view chemistry from a more global perspective.
- Increases their ability to think systemically.
SCT helps them to develop their own mental framework at higher-level of processes such as application, analysis, and synthesis.

REFERENCES

The Systemic Chemistry Triangles Figures [SCT 0-12] Fig.2-13] are listed in the following pages as appendices.
Systemic Triangle to Teaching and Learning Physical and Chemical Processes (General Systemic Triangle) (ST0-Fig.2)

Using sense to describe materials and their changes
Describe Changes
- Physical changes.
- Color change.
- Temperature change.
- Dipole moment change.
- pH Change
- Chemical Changes

Systemic Explanation of Physical and Chemical Changes from [MAC – MIC – Symb.]

Investigating using models to 'explain''
- Ion formation
- Electron transfer
- New bond formation
- Bond cleavage
- Acid-base reaction.
- Combination reaction.
- Dissociation reaction.
- Attraction forces.

Investigation using Symbols “Representational”

MACROSCOPIC (MAC)

MICROSCOPIC (MIC)

Symbolic (Symb.)
Systemic Triangle of Solubility of NaOH in Water (ST1-Fig.3)

**CONCEPT: Solubility**

**MAC “Describe”**
- Physical changes.
- Exothermic solubility.
- Homogenous solution.
- Alkaline solution.

**MIC “Explain”**
- Hydration of Na\(^+\), OH\(^-\) ions to Na\(^+\)\(_{(aq)}\) & OH\(^-\)\(_{(aq)}\).
- Lattice energy < Hydration energy.
- Increases of PH of the solution over 7.

**Systemic Explanation of NaOH solubility in water from [MAC – MIC – Symb.]**

**Symb. “Representational”**

\[ \text{NaOH(s)} \longrightarrow \text{Na}^{+\ _{(aq)}} + \text{OH}^-\ _{(aq)} \]
Systemic Triangle of Solubility of NaCl Salt in Water (ST2-Fig.4)

**CONCEPT:** Solubility

- **MAC “Describe”**
  - Physical changes
  - Endothermic solubility.
  - Homogenous solution.
  - Neutral solution.

- **Symb. “Representational”**
  - NaCl(s) → Na⁺(aq) + Cl⁻(aq) + heat

- **MIC “Explain”**
  - Hydration of Na⁺ & Cl⁻ ions to Na⁺(aq) & Cl⁻(aq).
  - Endothermic solubility due to Lattice energy > Hydration energy

- **Systemic Explanation of Endothermic solubility of NaCl in water from [MAC – MIC – Symb.]**
  - Physical changes
  - Endothermic solubility.
  - Homogenous solution.
  - Neutral solution.
Systemic Triangle of Solubility of HCl Gas in Water (ST3-Fig.5)

**CONCEPT: Solubility**

HCl (g) + H₂O (liq) → H₃O⁺ (aq) + Cl⁻ (aq) + heat

**MAC**

**Describe Changes**
- Physical change
- Ionization reaction
- Exothermic
- Lowering in pH of water than (7) to the strong acid.

**MIC**

**Explain**
- Cleavage of H-Cl bond
- Formation of O-H bond
- Complete ionization of HCl by transformation of H⁺ from HCl to water to form H₃O⁺aq.
- Formation of hydrated (Cl⁻)aq.
- Electron pair transfer from oxygen to H⁺ proton to form H₃O⁺
Systemic Triangle of Dilution of Concentrated Sulphuric Acid with Water (ST4-Fig.6)

CONCEPTS: Solubility-Dilution

**MAC “Describe Changes”**
- Physical change
- Exothermic solubility
- Ionization reaction
  - pH change – lower than (7)

**MIC “Explain”**
- Cleavage of ionic bond in H$_2$SO$_4$
- Formation of σ bond between H$^+$ and H$_2$O.
- Formation of O-H bond.
- Proton transfer from H$_2$SO$_4$ acid to water (base) to form H$_3$O$^+$ ion.
- Electron pair transfer from oxygen to H$^+$ to form H$_3$O$^+$ ion.

**Symb. “Representational”**

H$_2$SO$_4$(aq) + H$_2$O(liq) $\rightarrow$ H$_3$O$^+(aq)$ + HSO$_4^-(aq)$
Systemic Triangle of Oxidation of Fe$^{2+}$ to Fe$^{3+}$ by Chlorine (ST5-Fig.7)

**CONCEPTS:** Oxidation/Reduction/Redox Reaction

**MAC “Describe Changes”**
- Physical Change.
- Color change from green to brown.
- Chemical change.
- Formation of ferric chloride salt.
- Redox reaction.

**MIC “Explain”**
- Electron transfer from Fe$^{2+}$ to Cl atom to form Cl$^{-}$ (ions).
- Bond cleavage [Cl-Cl] atoms.
- Oxidation of Fe$^{2+}$ to Fe$^{3+}$.
- Reduction of Cl (atoms) $\rightarrow$ Cl$^{-}$ (ions).
- Redox-reaction; Electron transfer from Iron II to Chlorine atom.

**Symb. “Representational”**
\[
\begin{align*}
\text{FeCl}_2(aq) + Cl_2(g) & \rightarrow 2\text{FeCl}_3(aq) \\
\text{Fe}^{2+}(aq) - 2e^- & \rightarrow \text{oxid} \rightarrow \text{2Fe}^{3+}(aq) \\
\text{Cl}_2(g) + 2e^- & \rightarrow \text{Red} \rightarrow 2\text{Cl}^-(aq)
\end{align*}
\]
Systemic Triangle for the Acid-Base Reaction of HCl with NaOH (ST6-Fig.8)

CONCEPTS: ACID/BASE/Neutralization Reaction

MAC
“Describe Changes”
- Physical changes:
- Exothermic.
- Color change with pH indicator.
- Chemical changes
- Formation of sodium chloride salt.
- Neutralization reaction.
- Acid base reaction.

MIC
“Explain”
- Bond cleavage (Na⁺-OH, ionic) and H-Cl (ionic).
- Proton transfer from HCl to NaOH (acid proton donor & base proton acceptor).
- Bond formation between Na⁺ and Cl⁻ to form NaCl.
- Bond formation between H⁺ and OH⁻ to form covalent bond in water molecule.
- Aq. NaCl solution is neutral.

Systemic Explanation of Neutralization reaction - from [MAC – MIC – Symb.]

Symb.
“Representational”
Na⁺OH(aq) + HCl(aq) → pH.pH →
Na⁺(aq)Cl⁻(aq) + H₂O(liq) + heat
Systemic Triangle for Industrial Preparation of NH₃ by “Haber Process” (ST7-Fig.9)

CONCEPTS: Haber Process/
Reversible Reactions/ Equilibrium

MIC “Explain”
- Bond cleavage: (N≡N), 2π, one σ bond and 3 H-H σ bonds.
- Bond formation: 3 N-H σ bonds.
- Nitrogen atom in ground state:
  \[
  \begin{array}{ccc}
  1s^2 & 2s^2 & 2p^2 \\
  \uparrow & \downarrow & \uparrow
  \end{array}
  \]
- Nitrogen atom in the sp³ state of hybridization gained (3) electron from chairing (3) hydrogen atoms
  \[
  \begin{array}{ccc}
  1s^2 & 2s^2 & sp^3 \\
  \uparrow & \downarrow & \uparrow \uparrow \uparrow
  \end{array}
  \]
- The reaction is accompanied by decreasing in volume, thus increases in pressure increases the probability of collision and tends to reduce volume and therefore tends to shift the equilibrium to the side of reducing volume (forward reaction).

MAC “Describe Changes”
- Physical changes
- Exothermic.
- Accompanied by change in volume & heat.
- Chemical change.
- Formation of Ammonia.
- Combination reaction.
- Reversible.

Systemic Explanation of “Haber Process from [MAC – MIC – Symb.]”

Symb. “Representational”
\[
\begin{array}{c}
N_2(g) + 3H_2(g) \xrightarrow{\text{Fe/P200-300}} 2NH_3(g) + \text{heat} \\
[500^\circ\text{C}] \\
\text{4 volume} \quad \text{2 volume}
\end{array}
\]
Systemic Triangle for the Synthesis of Methanol from Methyl Chloride (ST8-Fig.10)

CONCEPTS: Nucleophilic Substitution Reaction/ SN2-Mechanism

MAC “Describe Changes”
- Physical change:
- Change in dipole moment.
- Chemical change:
  - Transfer of Methanol to Methyl chloride
  - Nucleophilic displacement

MIC “Explain”
- Bond cleavage of σ C-Cl and ionic Na⁺ OH bond.
- Formation of σ C-OH and ionic Na⁺Cl⁻.
- Nucleophilic displacement of Cl⁻ with OH via TS.
- S₂ mechanism.

Systemic Explanation of formation of Methanol from Methyl chloride by Nucleophilic Substitution reaction [MAC – MIC – Symb.]

CH₃Cl + NaOH → CH₃OH + NaCl

Mechanism
Systemic Triangle for the Reaction of Sodium with Methanol

(ST9-Fig.10)

CONCEPTS: Displacement Reaction

MAC “Describe Changes”
- Physical change.
- Exothermic.
- Alkaline.
- Chemical change.
- Formation of methoxide.
- Displacement reaction.

MIC “Explain”
- Ion formation CH$_3$O$^-$, Na$^+$
- Bond cleavage of $\sigma$ (O-H) bond
- Ionic bond formation between CH$_3$O$^-$, Na$^+$
- Sodium Displaces hydrogen of methanol to give sodium methoxide.

Systemic Explanation of sodium methanol reaction. From [MAC – MIC – Symb.]

Symb. “Representational”
$$2\text{CH}_3\text{OH}_{(\text{liq})} + 2\text{Na}_{(s)} \rightarrow 2\text{CH}_3\text{O}^-\text{Na}^+_{(\text{liq})} + \text{H}_2(\text{g})\uparrow$$

MAC/MIC

MAC/Symb.
Systemic Triangle for Photo Chlorination of Methane to Methyl Chloride

**(ST10-Fig. 11)**

**CONCEPT:** Photo-Chlorination/Radical Chain Reaction

1. **MAC “Describe Changes”**
   - Physical Change.
   - Change in the dipole moment.
   - Chemical change
   - Displacement reaction
   - Photo reaction.
   - Radical reaction.

2. **MIC “Explain”**
   - σ-Bond cleavage (C-H, Cl-Cl).
   - σ-Bond formation (C-Cl, H-Cl).
   - Radical mechanism initiated by homolytic fission of Cl-Cl bond by light to give 2 Cl atoms.

3. **Symb. “Representational”**
   1. \( \text{Cl}_2 \rightarrow h\nu \rightarrow 2\text{Cl}’ \)
   2. \( \text{Cl}’ + \text{CH}_4 \rightarrow \text{CH}_3 + \text{HCl} \)
   3. \( \text{CH}_3 + \text{Cl-Cl} \rightarrow \text{CH}_3\text{Cl} + \text{Cl}’ \)
   4. \( \text{CH}_3 + \text{Cl}’ \rightarrow \text{CH}_3\text{Cl} \)

   (1) initiation step.
   (2,3) Propagation steps.
   (4) Termination step.
Systemic Triangle for the Reaction of Ethylene with HBr
(ST11-Fig.12)

CONCEPT: Electrophilic Addition Reaction

MAC
“Describe Changes”
- Physical changes.
- Gas into liquid.
  Increase in dipole moment
    ) (μ zero to 2.05).
Chemical Change.
Formation of ethyl chloride.
Addition reaction.

MIC
“Explain”
- Bond cleavage: C=C π bond, H-Br σ-Bond.
- Bond formation: σ C-H, σ C-Br.
- Electrophilic addition to C=C π bond.
- Rehybridization of C from sp² to sp³

Systemic Explanation of Addition of HBr on Ethylene,
From [MAC – MIC – Symb.]

Symb. “Representational”
H₂C=CH₂(g) + HBr(aq) → CH₃-CH₂Br(aq)

Mechanism: E₂-mechanism:
Systemic Triangle for the Synthesis of Isopropanol from Acetone
(ST12-Fig.13)

CONCEPT: Reduction of the ketones/Addition of H₂ to the Carbonyl group of Ketones

MAC
“Describe Changes”
- Physical change:
- Change in (b.p.)
- Change in dipole moment (μ)
- Chemical change
- Formation of isopropanol.
- Addition reaction

MIC
“Explain”
- Bond cleavage: (C=O π) bond and (σ H-H)-bond.
- Bond formation: (2 σ bonds formed (C-H, O-H).
- Functional groups:
  Transformation: (\(\text{C}=\text{O} \rightarrow \text{C}-\text{OH}\))
- Reduction reactions.
- Change in dipole/dipole attraction leading to change in B.P.

Symb. “Representational”

Systemic Explanation of Addition of Catalytic reduction of acetone. From [MAC – MIC – Symb.]
ENHANCING FIRST YEAR CHEMISTRY STUDENT'S PARTICIPATION IN PRACTICAL CHEMISTRY COURSE

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ABSTRACT
In this study, enhancing student’s participation in practical analytical chemistry course at Haramaya University with various reasons was conducted. The data were collected from I year chemistry undergraduate students of class size 56 of which 23 were females and 33 were males. The class was arranged in to two groups for laboratory class and the experiment was conducted once per week in analytical laboratory. The research used mainly three kinds of data collection techniques namely questionnaire and laboratory report and demonstration result to gather the required qualitative and quantitative data for improving the participation of first year chemistry students. From the result, it was found that students were interested towards the practical analytical courses on the basis of condition such as, necessity of the chemistry with life, their participation in the laboratory, getting experience from the laboratory and performing the experiment in group. The results of the study support the notion that, students were more interested to a group work rather than individual work since they share idea, read their manual before coming to laboratory which contributed to their own participation in learning practical chemistry courses. The research has also shown that student’s activity through experimental demonstration in group increases student’s participations in the laboratory effectively by achieving better results than using laboratory report writing methods. The findings also revealed that some of the causes of students’ negative attitudes towards learning practical Chemistry were mainly due to problems in preparing a flow chart for the experiments by themselves and lack of exposure to well-equipped laboratory for conducting demonstrations. In view of the findings and conclusions drawn in the study, Chemistry laboratories should be adequately equipped to ensure a smooth running of the practical classes and students should be encouraged to participate on practical chemistry courses and appropriate motivation should be given so that they will develop positive attitude towards the practical sessions. [African Journal of Chemical Education—AJCE 6(2), July 2016]
INTRODUCTION

One of the unique features of effective science teaching is laboratory work. It is a unique learning environment that is effective in helping students construct their knowledge, develop logical and inquiry type skills and develop psychomotor skills. Laboratory work also has great potential in promoting positive attitudes and providing students with opportunities to develop skills regarding cooperation and communication [1]. Part and parcel of learning chemistry is carrying out laboratory practical. From an educational point of view, chemistry without laboratory work was seen as a body of factual information and general laws which conveyed nothing of lasting power to the mind [2]. To this end, students are given ample opportunities to engage in scientific investigations through hands-on activities and experiments.

Several studies had shown that often the students and the teacher are preoccupied with technical and manipulative details that consume most of their time and energy. Such preoccupation seriously limits the time they can devote to meaningful, conceptually driven inquiry. In response, Woolnough [3] wrote that for these reasons, the potential contribution of laboratory experiences to assist students in constructing powerful concepts has generally been much more limited than it could have been. Such comments have been made often throughout the past 20 years.

Tobin [4] wrote that “Laboratory activities appeal as a way of allowing students to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science”. This important assertion may be valid, but current research also suggests that helping students achieve desired learning outcomes is a very complex process. The inquiry approach, incorporating thinking skills, thinking strategies and thoughtful learning, should be emphasized throughout the teaching-learning process.
The science laboratory has always been regarded as the place where students should learn the process of science. Ideally, each student should be wholly responsible for conducting the experiments from start to finish. However, research has shown that teachers favored conducting practical activities in groups [5]. They reported that of the teachers surveyed, 54 percent reported group sizes of 4 or 5 students per group.

Direct observation of classes noted range of 1 to 7 students per group. The large group size limited active participation to 2 to 3 students per group, leaving the others as passive onlookers. This resulted in low level acquisition of scientific skills and knowledge among the students. According to Gunstone [6], using the laboratory to have students restructure their knowledge may seem reasonable but this idea is also naive since developing scientific ideas from practical experiences is a very complex process.

Gunstone and Champagne [7] suggested that meaningful learning in the laboratory would occur if students were given sufficient time and opportunities for interaction and reflection. Gunstone [7] wrote that students generally did not have time or opportunity to interact and reflect on central ideas in the laboratory since they are usually involved in technical activities with few opportunities to express their interpretation and beliefs about the meaning of their inquiry. In other words; they normally have few opportunities for meta-cognitive activities.

Students require the hands-on practical and personal laboratory experiences to acquire the science process skills; other problems associated with practical work in schools include the lack of facilities. One case study revealed that in general, equipment was adequate for group work in all schools for group sizes of 4 to 5 students [5]. In addition, research has revealed that in some cases students exhibited different attitudes toward school, in particular, biology, chemistry, and physics [8, 9].
Cheung [10] conducted a thorough and comprehensive review of the literature and found that over the years; only nine studies examined secondary school students’ attitudes towards chemistry taught in secondary schools. He wrote that although these studies were informative, they produced mixed and inconsistent results. For example, Hofstein [11] conducted one of the studies among 11 and 12th grade students in Israel. Interestingly, they found that there was a significant decline in students’ attitudes towards learning chemistry when they progressed from grade 11 to grade 12. On the other hand, in the USA, Milton [12] found the opposite, namely, that 12th grade students exhibited a more positive attitude than 11th grade students. One should note, however, that Hofstein [11] and Milton [12] used different attitudinal measures.

Many scientists and science educators are convinced that practical work must play an important role in learning science, but the reasons for its prominence are less clear. This lack of clarity lies in the vagueness of the questions asked about the role of practical work. Asking about the effectiveness of practical work for learning is like asking whether children learn by reading. The answer lies in the nature and contents of the activities and the aims which they are trying to achieve [13].

In a recent survey, 99% of the sample of science teachers believed that enquiry learning had an (83\% ‘very’; 16\% - ‘a little’) impact on student performance and attainment [14]. However, views about the role of processes in science education have been contested: some science educators have argued that practical work might help students to understand how scientists work, while others (see above) have argued that a process-based approach (that is, an approach that focused on experimental skills) was likely to lead to better understanding of science concepts.

Simpson [15] found that in general, laboratory work enhanced students ‘attitudes towards learning chemistry. Ben-Zvi [16] reported on a chemistry study in which chemistry students wrote
that personal laboratory work (hands-on) was the most effective instructional method that they had experienced for promoting their interest in learning chemistry when contrasted with group discussion, teacher’s demonstrations, filmed experiments, and teacher’s whole-class frontal lectures.

This study was carried out by assessing the present practice for active teaching learning participation of students of first year chemistry in Haramaya University for the practical analytical chemistry session to contribute for the betterment on the teaching leaning process and achievement of the intended objective of the practical course curriculum.

MATERIALS AND METHOD

Research Design

In an effort to combat the problem in enhancing students participation in practical sessions we began to develop a laboratory format in which each student in a laboratory group is assigned to participate in each practical experiment. The classroom format was arranged to allow for increased participation of student within the bench. Each bench was divided into two sub-groups. The teacher begins the class by introducing the experiment and short time lecture about theoretical aspect of the experiment. During group learning, students worked in groups of four students per sub-group on laboratory experiments.

The formation of sub-groups was assigned by the teacher rather than allowing student to pick their own lab partners. This helps to minimize the collection of less capable students who will typically have more difficulty with the laboratory exercise to the same group, because if we left them to pick their own lab partners, the student will pick other good students for their groups.
Students were informed that this teaching strategy was designed to increase their overall participation and success in the analytical chemistry laboratory.

Every week students were asked to submit their laboratory report and show a mini demonstration on their previous practical experiment which gave them the opportunity to express their participation about the laboratory activity in terms of the teaching strategy and overall understanding of the experiment (for both sessions to write report in a group of 4 and 8 students). Student surveys were then used as a means to determine whether or not the modified teaching strategies and curriculum were helpful to students and what future changes could be made through observation and interview.

In addition to class format students were allowed to fill the questionnaires prepared by the researcher concerning their activity and interest towards the lab course and main class course. The questionnaires were filled by both groups. The distribution of questionnaires was at the final end of the course that enables students to identify the part in which they were more interested and participate actively.

**Population, Source of Data and Sampling**

The target population selected were all chemistry undergraduate first year student at the department of chemistry who had registered for the course practical analytical chemistry. Only primary data source was used for this study which includes questionnaire, observation, students’ laboratory report and demonstration result.

The data were collected from I year chemistry undergraduate students of class size 56. This research was done with one of our Chemistry 1st year classes at Haramaya University. In a class there were 56 students among them 23 were females and 33 were males. The class was arranged
in to two groups for laboratory class and the experiment was conducted once per week in analytical laboratory.

**Data Collection Procedures**

The research used mainly three kinds of data collection techniques namely questionnaire, laboratory report and demonstration result to gather the required qualitative and quantitative data for improving the participation of first year chemistry students.

A questionnaire was issued to students to get the interest of those students toward analytical chemistry laboratory and to assess on increasing their interest. The questionnaires were filled by students. To achieve this objective the researcher took all first year chemistry students with a total size of 56. The questionnaires consisted of 20 items and distributed to all 56 students, out of which 23 were females and 33 of them were males.

The laboratory report result is used to assess the performance of students and used to measure the change they record when they write lab report in a group of 4 students per sub-groups and after they write the lab report individually for section I and section II in order to assess the effect of group size on participation of students.

Laboratory demonstration results were taken to assess student’s performance after they had conducted a 30 minute demonstration in their practical experimental sessions. Students were arranged in a group of 4 to present a demonstration of an experiment from their selected practical work and were evaluated through a systematic series of oral questions.
RESULTS AND DISCUSSIONS

Table 1. Laboratory report results of the students after performing the experiment

<table>
<thead>
<tr>
<th>Lab. Report (section I)</th>
<th>Range of Marks 50%</th>
<th>Lab. Report (section II)</th>
<th>Ranges of Marks 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>In group of 4</td>
<td>33-38</td>
<td>In group of 4</td>
<td>33-38</td>
</tr>
<tr>
<td>In group of 8</td>
<td>42.5-43</td>
<td>In group of 8</td>
<td>41-44</td>
</tr>
</tbody>
</table>

Laboratory report results of the students after performing the experiment in a group of 4 and 8 students per each subgroup were recorded and the data obtained from their result is shown in Table 1. In contrast, students scored higher results (42-43 marks) while they were arranged in a group of 8 than they were arranged in a group of 4 students (33-38 marks) out of 50% of their total practical laboratory results which indicates students assigned in large group (a group of 8 students) showed better performance in their practical activities than in a small group of 4 students due to they shared more skills in interpretation, organization, deductions and recording of laboratory data easily. This implies that if they write report in a group, each individual need to observe and give attention to perform the experiment as much as possible in order to get good experimental data for the reports.

Table 2. Students’ response for close ended type of questionnaires at appendix I

<table>
<thead>
<tr>
<th>Q. No.</th>
<th>% A</th>
<th>% B</th>
<th>% C</th>
<th>% D</th>
<th>% E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.1</td>
<td>66.7</td>
<td>11.1</td>
<td>0</td>
<td>11.1</td>
</tr>
<tr>
<td>2</td>
<td>22.2</td>
<td>11.1</td>
<td>11.1</td>
<td>11.1</td>
<td>44</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>22.2</td>
<td>11.2</td>
<td>44</td>
<td>22.2</td>
</tr>
<tr>
<td>4</td>
<td>55.6</td>
<td>22.2</td>
<td>11.1</td>
<td>11.1</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>33.3</td>
<td>11.1</td>
<td>33.3</td>
<td>22.2</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>22.2</td>
<td>55.6</td>
<td>0</td>
<td>22.2</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>55.6</td>
<td>22.2</td>
<td>11.1</td>
<td>11.1</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>11.1</td>
<td>77.8</td>
<td>0</td>
<td>11.1</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>66.7</td>
<td>33.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>44.4</td>
<td>22.2</td>
<td>33.3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Data obtained from the students’ response for close ended type of questioners were shown in table 2 and 67% of students found that the learning environment in analytical chemistry laboratory were interesting. More than half of the students (56%) were interested to write a laboratory report in a group than individually. As can be shown from their responses (78%) of students have preference to perform experiments in laboratory class for each session in a small group rather than doing in large group which is contrary to their group organization at Laboratory report writing.

Generally, from the data response in Table 2 about student’s activities in their analytical chemistry laboratory were helpful for the learning environment they made in their laboratory experience to make more meaningful by relating to what they discuss in class. Students have responded that they are very interesting towards the theoretical session of the analytical chemistry course (67%) and have a good interest in the practical laboratory course since they share something with in experimental class with a group of students and the teacher.

As can be seen from their response, 57% of the students were generally willing to write up their laboratory report in groups. The research indicates that learning without laboratory experience is meaningless in case of only the theoretical part of the course sessions since it couldn’t be easily related to what they have discussed in class.
Table 3. The responses of students on the yes/no set of questions in appendix II

<table>
<thead>
<tr>
<th>Question No.</th>
<th>Yes(%)</th>
<th>No(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>66.7</td>
<td>33.3</td>
</tr>
<tr>
<td>12</td>
<td>22.2</td>
<td>78.8</td>
</tr>
<tr>
<td>13</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>22.2</td>
<td>78.8</td>
</tr>
<tr>
<td>15</td>
<td>88.9</td>
<td>11.1</td>
</tr>
<tr>
<td>16</td>
<td>77.8</td>
<td>22.2</td>
</tr>
<tr>
<td>17</td>
<td>44.4</td>
<td>55.6</td>
</tr>
<tr>
<td>18</td>
<td>55.6</td>
<td>44.4</td>
</tr>
<tr>
<td>19</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>20</td>
<td>80</td>
<td>20</td>
</tr>
</tbody>
</table>

Students response on the yes/no questions was recorded in Table 3, as can be seen from their response (100%), all students preferred to work on the practical sessions with partners or a friend by making an open discussion in a group time which is an indication of cooperative type of leaning is essential for the better performance of students in the practical analytical chemistry courses. Almost all students (80%) were interested to prepare a laboratory report in a standard format as stated in the laboratory manual after their laboratory session was going however 55.6% of the students were not interested to prepare flowchart before going to laboratory activities. The results of this study support the notion that, students were more interested to a group work rather than individual work.

Table 4. Laboratory demonstration result of students

<table>
<thead>
<tr>
<th>Section</th>
<th>Range of Marks 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (28 students)</td>
<td>17-18</td>
</tr>
<tr>
<td>II (28 students)</td>
<td>16-18</td>
</tr>
</tbody>
</table>

Students were arranged in a group of four to present demonstration of an experiment from their selected practical work and were evaluated through a systematic series of oral questions. This
aspect assessed students’ skills in problem identification, conducting of experiment, manipulation of equipment, hypothesizing, careful observation, interpretation of observation making of inference/deductions, organization and recording of data and effective communication. Laboratory demonstration results of students for experiment in a group of 4 students per each session were depicted in Table 4. As can be shown from the data all students have scored more than 80% of the mark when they perform experiment on demonstration schemes.

They scored better results if they work in group activities such as demonstration than individual experimental activities. This indicates that student’s activity through experimental demonstration in group increases student’s participations in the laboratory effectively by achieving better results than using laboratory report writing methods. This is because if they were evaluated through laboratory demonstrations each individual have an access to observe and give attention to perform the experiment as much as possible in order to get good experimental data. This implies that student’s skills in conducting experiments, manipulation of equipment, measurement of volumes, careful observation, and control of variables and recording of data through demonstration is an effective way to enhance the performance of students in a group interactive method of learning.

CONCLUSIONS

This paper has revealed the participation of students towards the practical analytical courses. Looking at the findings in general, it was found that student’s interest towards practical analytical courses was interesting on the basis of condition such as, necessity of the chemistry with life, their participation in the laboratory, getting experience from the laboratory, writing report in groups and performing the experiment in group. The results of the study support
the notion that, students were more interested to a group work rather than individual work since they share idea, read their manual before coming to laboratory that contributed to their own participation in learning practical chemistry courses.

The research also indicates that learning without laboratory experience is meaningless in case of only the theoretical part of the course sessions since it couldn’t be easily related to what they have discussed in class. The research has shown that student’s activity through experimental demonstration in group increases student’s participations in the laboratory effectively by achieving better results than using laboratory report writing methods. The findings also revealed that some of the causes of students’ negative attitudes towards learning practical Chemistry was mainly due preparing flow chart for the experiments by themselves and lack of exposure to well-equipped laboratory for conducting demonstrations.

**Competing interests:** Authors declares no competing interest among them and with any other third party

**Authors' contributions:** Second author edit all the manuscript work and the third author is participated in arranging the manuscript according the journal format.

**ACKNOWLEDGMENT**

The authors are very grateful for financial support to the Higher Diploma Program (HDP) at Haramaya University for this research work.

**REFERENCES**


APPENDIX I
Questionnaires to be filled by undergraduate Year I Chemistry Students

Instructions: Dear students, we kindly request you to fill up these questionnaires without stating your personal details thank you in advance!!!

1. How do you find the learning environment in your analytical lab?
   a) Conducive to learning
   b) Somewhat helpful for learning
   c) I don’t feel very comfortable
   d) Unfavorable atmosphere
   e) Doesn’t help me in learning chemistry

2. Choose the change most important to you personally to make this lab experience more meaningful?
   a) I wish we had a place to work and ask questions.
   b) Demonstration of experiments.
c) Lectures with more participation.
d) Showing more application of chemistry to life.
e) Labs that related more to what we discuss in class.

3. How have you prepared for the lab part of this course?
   a) I don't prepare before lab.
   c) Make quick scan of the lab manual and write a pre-lab
   b) I read the lab experiment.
   d) Read the lab experiment, writes the pre-lab and calculation sheet.
   e) Read the lab experiment and appropriate sections in the text, then prepare pre-lab and calculation sheet.

4. What was your practical analytical session’s experience?
   a) Very interesting   c) unclear   b) good d) poor e) totally irrelevant to my interests.

5. During and following lab. Sessions I write up discussions, interpretations and conclusions of
   the data from experiments.
   a) Always b) usually c) sometimes d) rarely e) never

6. What is your feeling about writing lab report?
   a) Better individually b) in a group c) while we are in lab class d) not necessary e) any other____________________

7. If report writing is in group what do you feel?
   a) Very interesting b) good c) poor d) not necessary e) any other____________________________________

8. What is your preference to perform experiments in laboratory class for each session?
   a) With large group b) with small group c) in pair d) individually

9. What is your feeling toward the theoretical part of this course?
   a) Very interesting b) satisfactory c) good d) poor e) not interesting at all

10. What is your feeling toward the lab session of this course?
    a) Very interesting b) satisfactory c) favorable d) poor e) not interesting at all

11. Did you share something with in experimental class? Yes/No

12. If yes, did you share with?
    a) students only;
    b) the teacher;
    c) a group of students; or
    d) a group of students and the teacher

APPENDIX II

Put tick mark on your choose

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>I like to do work with partners or a friend</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>I like to work individually</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>I like open discussion in a group time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>I like to participate actively in lab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>I like preparing flowchart before going to lab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>I like taking pre-lab quiz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>I like taking post lab quiz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>I like preparing lab report in a standard format stated in the lab manual after the lab is going</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NIGERIAN STUDENTS’ SELF-CONFIDENCE IN RESPONDING TO STATEMENTS OF CHEMICAL EQUILIBRIUM CONCEPTS AND PRINCIPLES

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Port Harcourt, Nigeria.
Email: mcsahia@yahoo.com

ABSTRACT
The goal of the study was to find out the self-confidence and confidence level of senior secondary schools in responding to statements associated with the concepts and principles of chemical equilibrium. Four hundred and fifty year 3 chemistry Senior Secondary Students indicated interest to participate in the study. The main data collecting instrument was the Chemical Equilibrium Test (CET). This test contained statements that required students to indicate how sure or not they were about the correctness of the statements. Overall results of the study revealed that except for students’ ability to determine reaction rate from equilibrium systems, about three students in every one hundred students (3:100) had self-confidence in responding to correct statements of the equilibrium system. Students’ level of confidence interval ranged from 0.26 to 0.30. This narrow gap translates to doubt that students have self-confidence in responding to statements of equilibrium system. [African Journal of Chemical Education—AJCE 6(2), July 2016]
INTRODUCTION

How sure are you that your answer is correct? This is one of the questions good teachers ask students when answers are given to tasks presented to them (students). All that the teacher wants to find out is the confidence and the level of confidence a student has in giving his/her nod to an answer to the problem. Specifically, chemistry teachers ask students this question when an answer is provided to a chemistry problem.

According to Oxford Advanced Learner’s dictionary (6th edition), confidence is the feeling that you can trust, believe in and be sure about the abilities or good qualities of somebody or something.

From Wikipedia’s free encyclopedia, confidence is generally described as a state of being certain either that a hypothesis or prediction is correct or that a chosen course of action is the best most effective. We are particularly interested in the individual’s confidence-having confidence in oneself. Self-confidence relates to self-assurance in one’s personal judgment, abilities and power. To be self-confident is to be secure in yourself and your abilities [1].

Student’s self–confidence in responding to educational tasks in a way affects the teacher’s lesson delivery in the classroom. In the cause of teaching, teachers ask students questions. As the students answer these questions correctly, teacher’s self-confidence is boosted. The implication is that the students are following the teacher and learning becomes meaningful to the students.

Having taught chemistry for over ten years at the secondary school level, I have noted difficulties students encounter in learning some topics and concepts. I also observed that some chemistry students lack confidence in responding to tasks arising from such topics and concepts. One of such topics and related concepts is chemical equilibrium.
The author is not alone. Researchers have indicated why chemical equilibrium poses some difficulty to the students. Glickstein [2] revealed that lack of a human touch is what often keeps high school students from connecting with scientific principles in the way they might connect with literary or historical works. For most teenagers, human relationships are intensely important so lack of this sort of connection in what they are studying can be a determining factor in whether they put their full effort into understanding a concept. Glickstein [2] observed further that standard chemistry textbooks can inadvertently place a barrier between students and the understanding of complex concepts. Chemistry, an inherently abstract discipline, often provides little tangible evidence from everyday experience from which a beginner can verify, by direct observation, the phenomena being witnessed. Equilibrium chemistry is one such concept that a teacher can hardly make a presentation that touches the students as a personal way.

Cheung [3] has observed that chemistry curriculum content and chemistry teacher education are two factors that need to be addressed. Secondary students find chemical equilibrium very difficult not only because the concept is abstract but also because there are problems in the selection of curriculum content. Misleading information presented by textbook writers can cause school teachers to hold misconceptions about chemical equilibrium. Teachers cannot help their students understand what they themselves do not understand.

For example, there is a misrepresentation of the equilibrium constants in general chemistry textbooks. Quilez-Diaz and Quilez-Pardo [4] reported that there is a terminology problem as many authors state that practical equilibrium constants, viz kp and kc are unitless quantities. In many chemistry textbooks kp plays the role of the thermodynamic equilibrium constant ko. The correct terminology should be presented to the students [4, 5]. In all, Ozmen [6], [7], [8], Voska and
Heikkinen [9], Quilez-Pardo Solaz-Portoter [10] while studying students from Turkey and other European countries noted that students generally have misconception about chemical equilibrium.

In Nigeria, Chief Examiners’ reports in chemistry have shown that students performed poorly in the concept of chemical equilibrium at Senior Secondary School Certificate Examination [11][12]. In spite of all these problems students have with learning the concept of chemical equilibrium, teachers are still teaching the concept and testing/examining the students. Some students succeed while some of them fail. Given the students that succeed do we teachers try to find out whether they (students) are sure that they have successfully learnt the topic as this problem is recurring at the higher level of learning [5]? The goal of this research was to investigate the self-confidence of chemistry students in responding to statements related to chemical equilibrium.

**METHODOLOGY**

A total of 2303 year three Senior Secondary chemistry students constituted the target population of the study. These students were from five randomly selected schools in Port Harcourt metropolis of Nigeria. These schools are relatively close to each other with a distance of approximately 200metres. These students were requested to indicate their interest to participate in a study involving their knowledge of chemical equilibrium. Four hundred and fifty students indicated their interest. This constituted the sample of study. Age range of the students was from 15 years with mean age of 16.3 years. The students also indicated that they were conversant with,

1. mathematical expressions for the determination of equilibrium constants, \( k \),
2. \( k \) is constant for a system at constant temperature,
3. the relationship between \( k_p \) and \( k_c \),
4. the calculation of \( k_p \) and \( k_c \) from given set of data, and
5. the difference between homogenous and heterogeneous equilibrium systems.
A Chemical Equilibrium Test (CET) constituted the main data collecting instrument.

Table 1: Specification table for chemical equilibrium test (CET)

<table>
<thead>
<tr>
<th>S/n</th>
<th>Content</th>
<th>Item numbers</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ability to recall definition of Equilibrium terms (concepts)</td>
<td>3, 5,9,12,23,25,26, 27,30,31,32,36,39</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>Ability to determine equilibrium constant from an equation of chemical reaction</td>
<td>7,8,11,13,19,20, 28, 29</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Ability to identify factors that affect equilibrium reactions</td>
<td>2,6,14,15,16,17,18,21, 33,34,35,37,38,40.</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>Ability to determine reaction rate from equilibrium systems</td>
<td>1,4,10,22,24</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

A specification table showed the content and the distribution of the items (Table 1). Altogether the test is made up of 40 items covering students’ ability to recall definition of chemical equilibrium terms (concepts), ability to determine equilibrium constant from an equation of chemical reaction, ability to identify factors that affect equilibrium reactions and ability to determine reaction rate from equilibrium systems.

CET contained chemical equilibrium concepts and principles that may be adjudged to be correct or incorrect. There was also an opportunity for the students to remain neutral or undecided if they were not sure of the correctness or incorrectness of the statements. A copy of CET was given to each of three chemistry teachers who had been teaching chemistry for the past ten years at the senior secondary school level. The teachers agreed on the clarity and correctness of 35 items (87.5% of the time). With the suggestions given by the teachers, the remaining items of disagreement were reconsidered and changes effected.
Reliability co-efficient of 0.89 for correctness 0.59 for undecided 0.41 for incorrectness were achieved by comparing two sets of scores of the CET of 25 students from a school not used for the study, after administering the test on two different occasions spanned by two weeks.

CET was administered to the subjects (students) in their various schools. Permission was sought from the schools’ authorities and provision was made for the administration of the instrument. The investigator with assistance from the subject’s teachers in the schools administered the instrument. Copies of CET were numbered 001 to 450 for the purpose of identification. It took five days to administer the instrument in the chosen five schools. The students were simply requested to tick (√) against each statement, the correctness (sure the answer is correct); If they were not sure, they should indicate “undecided” or ‘‘incorrect’’ if they felt that such statement was not correct. The students were allowed 50 minutes to provide their responses to the statements.

ANALYSES OF DATA AND RESULTS

Students’ responses to correctness of statements, incorrectness and not being sure (undecided) were converted to percentages. The range of percentages for correctness of statements spanned from 12.1% to 48.6% with mean of 34.4% (see Table 2). The range was taken as the confidence interval within which student have confidence in their choice of the correctness of the statements in chemical equilibrium.

Confidence level of each item response to the correctness of the equilibrium statements was estimated by dividing frequency of response by the total sample used for the study namely, (f/N). The confidence level range from 0.08 to 0.42 with mean of 0.28. The overall confidence level of the students in responding to the correctness of concepts and principles in equilibrium systems was taken as 0.28.
Table 2: Item analyses of students’ response to the statements of equilibrium systems

<table>
<thead>
<tr>
<th>S/n</th>
<th>Statement</th>
<th>Correct</th>
<th>Undecided</th>
<th>Incorrect</th>
<th>Confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>When the rate of backward reaction equals the rate of forward reaction, the system is said to be in a state of dynamic equilibrium</td>
<td>39.8</td>
<td>28.2</td>
<td>32.0</td>
<td>0.40</td>
</tr>
<tr>
<td>2</td>
<td>The concentration of A in aA + bB $\leftrightarrow$ zZ + yZ is doubled, it is expected that the number of collisions between A and B will increase.</td>
<td>43.9</td>
<td>30.0</td>
<td>26.1</td>
<td>0.42</td>
</tr>
<tr>
<td>3</td>
<td>The equilibrium constant which expressed the chemical reaction $\text{CH}_3\text{COOH} \leftrightarrow \text{CH}_3\text{COO}^- + \text{H}^+$ can be written as $K_a = [\text{CH}_3\text{COOH}] \text{[H}^+\text{]}$.</td>
<td>40.0</td>
<td>37.3</td>
<td>22.7</td>
<td>0.33</td>
</tr>
<tr>
<td>4</td>
<td>The rate of the reaction A + B $\leftrightarrow$ C + D can be expressed as rate = $k [A] [B]$.</td>
<td>35.1</td>
<td>32.1</td>
<td>32.8</td>
<td>0.28</td>
</tr>
<tr>
<td>5</td>
<td>If a system contains SO$_2$, O$_2$ and SO$_3$ gases at equilibrium, this will lead to a reaction in which more SO$_3$ is formed.</td>
<td>48.6</td>
<td>35.7</td>
<td>15.7</td>
<td>0.38</td>
</tr>
<tr>
<td>6</td>
<td>In the reaction $\text{CH}_3\text{COOH} \leftrightarrow \text{CH}_3\text{COO}^- + \text{H}^+$ the introduction of a catalyst will favour the forward reaction.</td>
<td>28.2</td>
<td>40.6</td>
<td>31.2</td>
<td>0.28</td>
</tr>
<tr>
<td>7</td>
<td>The expression for equilibrium constant $k_c$ always shows all gaseous species.</td>
<td>42.6</td>
<td>43.7</td>
<td>13.7</td>
<td>0.33</td>
</tr>
<tr>
<td>8</td>
<td>The expression for $k_c$ for the equilibrium C(s) + CO$_2$ (g) $\leftrightarrow$ CO (g) is CO$_2$.</td>
<td>39.4</td>
<td>35.8</td>
<td>24.8</td>
<td>0.33</td>
</tr>
<tr>
<td>9</td>
<td>In a system of one mole of H$_2$ and two roles of NH$_3$ at 500°C at equilibrium, the ratio of the component will be 1:3:2.</td>
<td>43.1</td>
<td>32.9</td>
<td>24.0</td>
<td>0.37</td>
</tr>
<tr>
<td>10</td>
<td>In the equation $\text{N}_2\text{O}_3$ (g) $\leftrightarrow$ 2NH$_3$ (g) the rate of forward reaction can be expressed as Rate (f) = $k_f [A]^a [B]^b$.</td>
<td>40.0</td>
<td>29.7</td>
<td>30.3</td>
<td>0.26</td>
</tr>
<tr>
<td>11</td>
<td>The expression for $k_c$ for the equation $\text{N}_2$(g) + 2O$_2$(g) $\leftrightarrow$ 2 NO$_2$(g) is $2[\text{NO}_2] [\text{N}_2] [\text{O}_2]^2$.</td>
<td>41.8</td>
<td>34.8</td>
<td>23.4</td>
<td>0.33</td>
</tr>
<tr>
<td>12</td>
<td>The position of equilibrium would not be appreciably affected by change in container volume for $\text{N}_2$(g) + O$_2$(g) $\leftrightarrow$ 2NO (g).</td>
<td>19.2</td>
<td>36.6</td>
<td>44.2</td>
<td>0.31</td>
</tr>
<tr>
<td>13</td>
<td>The expression for $k_c$ for the equilibrium $\text{N}_2$(g) + 3H$_2$(g) $\leftrightarrow$ 2NH$_3$(g) is $[\text{NH}_3] [\text{N}_2][\text{H}_2]^3$.</td>
<td>28.1</td>
<td>32.1</td>
<td>39.8</td>
<td>0.30</td>
</tr>
<tr>
<td>14</td>
<td>Increasing original reaction concentration will invariably increase the yield of products at equilibrium</td>
<td>19.5</td>
<td>44.5</td>
<td>36.0</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Rate</td>
<td>Enthalpy</td>
<td>Exothermic</td>
<td>Endothermic</td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------</td>
<td>----------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>15</td>
<td>Addition of more $\text{H}_2$ to the system $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ will favour forward reaction.</td>
<td>38.5</td>
<td>25.4</td>
<td>35.7</td>
<td>0.31</td>
</tr>
<tr>
<td>16</td>
<td>Addition of more $\text{H}_2$ to the system $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ will favour production of Hydrogen only.</td>
<td>40.0</td>
<td>45.0</td>
<td>15.0</td>
<td>0.26</td>
</tr>
<tr>
<td>17</td>
<td>Increasing the total pressure for $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ will lower the reaction rate.</td>
<td>37.8</td>
<td>32.7</td>
<td>29.5</td>
<td>0.31</td>
</tr>
<tr>
<td>18</td>
<td>Increasing the temperature for $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ will reverse the reaction.</td>
<td>29.5</td>
<td>38.5</td>
<td>32.0</td>
<td>0.25</td>
</tr>
<tr>
<td>19</td>
<td>The expression of $k_c$ for $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ is $[\text{SO}_3]^2 [\text{SO}_2]^2 [\text{O}_2]$.</td>
<td>28.6</td>
<td>49.7</td>
<td>21.7</td>
<td>0.23</td>
</tr>
<tr>
<td>20</td>
<td>The value of equilibrium constant $k_c$ for a given reaction depends only on the temperature.</td>
<td>33.4</td>
<td>27.3</td>
<td>39.3</td>
<td>0.27</td>
</tr>
<tr>
<td>21</td>
<td>In the equation $\text{PCl}_5 + \text{heat} \rightleftharpoons \text{PCl}_3 + \text{Cl}_2(\text{g})$, higher temperature will favour the production of more products in the system.</td>
<td>38.5</td>
<td>30.5</td>
<td>31.0</td>
<td>0.33</td>
</tr>
<tr>
<td>22</td>
<td>The rate of the reaction $A + B \rightarrow C + D$ may be expressed as Rate = $k[A][B]$.</td>
<td>13.9</td>
<td>44.6</td>
<td>41.5</td>
<td>0.08</td>
</tr>
<tr>
<td>23</td>
<td>Considering the reaction $\text{C}_3\text{O}_4 + \text{CO}_2(\text{g}) \rightarrow 2\text{CO}(\text{g})$ the amount of gaseous reaction is one mole.</td>
<td>29.8</td>
<td>31.6</td>
<td>38.6</td>
<td>0.26</td>
</tr>
<tr>
<td>24</td>
<td>The rate of the forward reaction for $Aa + Bb \rightleftharpoons Cc + Dd$ can be expressed as rate $f = k_f [A]^a$</td>
<td>33.9</td>
<td>40.7</td>
<td>25.4</td>
<td>0.28</td>
</tr>
<tr>
<td>25</td>
<td>Consider $\text{C}_3\text{O}_4 + \text{CO}(\text{g}) \rightarrow 2\text{CO}(\text{g})$, if one mole of carbon reacts with one mole of carbon dioxide to produce two moles of carbon monoxide, the ratio of carbon (c) to carbon-dioxide is 1.1 .</td>
<td>37.0</td>
<td>42.7</td>
<td>20.3</td>
<td>0.24</td>
</tr>
<tr>
<td>26</td>
<td>Dynamic equilibrium involving chemical change is Chemical equilibrium.</td>
<td>45.5</td>
<td>28.3</td>
<td>26.2</td>
<td>0.25</td>
</tr>
<tr>
<td>27</td>
<td>Reactions that can proceed in either direction under suitable conditions are reversible reactions.</td>
<td>24.1</td>
<td>27.3</td>
<td>48.6</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>For a given reversible reaction a high value of ( k ) will lead to greater yield of product.</td>
<td>33.4</td>
<td>27.3</td>
<td>39.3</td>
<td>0.26</td>
</tr>
<tr>
<td>29</td>
<td>In the expression ( mA + nB \leftrightarrow pC + qD ) given by ( k = \frac{[C]^p[D]^q}{[A]^m[A]^n[B]^n} ), ( A, B, C, D ) present the concentration of ( A, B, C ) and ( D ).</td>
<td>36.1</td>
<td>35.8</td>
<td>28.1</td>
<td>0.28</td>
</tr>
<tr>
<td>30</td>
<td>In ( k = \frac{[C]^p[D]^q[A]^m[B]^n} ), ( k ) means equilibrium constant.</td>
<td>34.8</td>
<td>38.4</td>
<td>26.8</td>
<td>0.26</td>
</tr>
<tr>
<td>31</td>
<td>In ( K = \frac{[C]^p[D]^q[A]^m[B]^n} ), ( p ) and ( q ) represent the amount in moles of the products.</td>
<td>34.1</td>
<td>39.7</td>
<td>26.2</td>
<td>0.24</td>
</tr>
<tr>
<td>32</td>
<td>The reaction, ( N_2 O_4(g) \leftrightarrow 2NO_2(g) ) is reversible.</td>
<td>32.2</td>
<td>32.7</td>
<td>35.1</td>
<td>0.27</td>
</tr>
<tr>
<td>33</td>
<td>In ( X_2(g) + Y_2(g) \leftrightarrow 3Z_2(l) ) ( \triangle H ) is negative. A decrease in pressure and an increase in temperature will shift the equilibrium position to the right.</td>
<td>36.2</td>
<td>33.4</td>
<td>30.4</td>
<td>0.26</td>
</tr>
<tr>
<td>34</td>
<td>In a closed vessel of ( A(g) + B(g) \rightarrow C(g) + D(g) ) ( \triangle H ) is negative will increase the yield of ( C ) by removing some ( D ).</td>
<td>36.2</td>
<td>33.4</td>
<td>30.4</td>
<td>0.28</td>
</tr>
<tr>
<td>35</td>
<td>In ( A(g) + B(g) \leftrightarrow C(g) + D(g) ) increase in pressure will shift the equilibrium position.</td>
<td>34.7</td>
<td>32.8</td>
<td>32.5</td>
<td>0.28</td>
</tr>
<tr>
<td>36</td>
<td>In ( A(g) + B(g) \leftrightarrow C(g) + D(g) ), the amount gaseous reactants is 3 moles.</td>
<td>46.4</td>
<td>14.4</td>
<td>39.2</td>
<td>0.40</td>
</tr>
<tr>
<td>37</td>
<td>In ( C(g) + CO_2(g) \leftrightarrow 2CO(g) ), if some of the carbon did not change, the equilibrium will shift to right.</td>
<td>29.5</td>
<td>45.5</td>
<td>25.0</td>
<td>0.26</td>
</tr>
<tr>
<td>38</td>
<td>Considering ( Ca CO_3(s) \rightarrow CaO(s) + CO_2(g) ), addition of more ( CaCO_3(s) ) will shift the equilibrium to the right.</td>
<td>12.1</td>
<td>41.9</td>
<td>46.0</td>
<td>0.40</td>
</tr>
<tr>
<td>39</td>
<td>Dynamic equilibrium involving a physical change is known as physical equilibrium.</td>
<td>39.3</td>
<td>22.3</td>
<td>38.2</td>
<td>0.18</td>
</tr>
<tr>
<td>40</td>
<td>Introduction of a catalyst in a system will enable equilibrium to be reached in a shorter time</td>
<td>43.6</td>
<td>26.3</td>
<td>30.1</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Table 3: Overall means of self-confidence levels of the students’ responses to chemical equilibrium statements

<table>
<thead>
<tr>
<th>S/N</th>
<th>Ability to mean (μ) self-confidence levels of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>recall definition of chemical equilibrium terms (concepts)</td>
</tr>
<tr>
<td>2</td>
<td>determine equilibrium constant from an equation of chemical reaction</td>
</tr>
<tr>
<td>3</td>
<td>Identify factors that affect equilibrium reactions</td>
</tr>
<tr>
<td>4</td>
<td>determine reaction rate from equilibrium systems</td>
</tr>
<tr>
<td></td>
<td>overall</td>
</tr>
</tbody>
</table>

It was observed in table 3 that except for students’ ability to determine reaction rate from equilibrium systems (S/No.4), about three students in every one hundred students (3:100) had self confidence in responding to correct statements of the equilibrium system. Table 3 also provides a range of values or interval within which to assess further the confidence of the students. Therefore the interval 0.26 to 0.30 consists of the probability of accepting the self-confidence of the students in correctly responding to the statements of the equilibrium system.

DISCUSSION OF FINDINGS

Teachers use objective and essay tests or both in evaluating what the students have learnt. It is also necessary to find out whether the students are sure of what they have learnt. This is possible by presenting the students with the fact and making them to assert their confidence on the correctness of the facts. This study has shown that the students are confused when they are presented with the facts which they would have learnt. The student used for the study indicated
that they were conversant with chemical equilibrium concepts and principles. The study showed over 14% of the students were undecided about the equilibrium statements. And about 13% indicated incorrectness of the chemical equilibrium statements. This was quite surprising because the students that participated in the study had earlier indicated that they were familiar with the concepts and principles of chemical equilibrium.

The equilibrium systems include amongst others those of homeostatic balance as in biology, equilibrium of forces as found in mechanics of physics and chemical equilibrium. When chemical equilibrium is mentioned these equilibrium systems come to memory of the learner. The implication of this is that something is common with the systems which is the concept of balance. A student learning chemical equilibrium is likely to use the knowledge gained with respect to balance to understand equilibrium in biology and physics. There are static and dynamic equilibrium. These are generally applied in the understanding of the equilibrium systems. It becomes necessary for students to understand in totality the concept of equilibrium when learning chemical equilibrium. A measure of the students’ confidence in responding to chemical equilibrium reveals their level of seriousness in learning the concepts which is of concern to a chemistry teacher and chemical educator.

RECOMMENDATIONS

The study has shown that secondary students do not have confidence in responding to concepts and principles related to chemical equilibrium system. The narrow gap between the confidence interval of 0.26 and 0.30 reveals, this. This result may be due to some variables identified by some earlier researchers. These include the students’ attitude towards learning, teachers’ conception and misconception in chemical equilibrium, presentation of information
related to statements in chemical equilibrium as revealed in some chemistry textbooks and the
curriculum content of chemical equilibrium [4,7] to mention a few.

On this note, it becomes necessary to re-examine the curriculum content of chemical
equilibrium with respect to validity, reliability, significance and relevance. Chemical equilibrium
systems in the chemistry books commonly used by the secondary students should be reassessed
for the right conceptions and misconceptions corrected. It appears that the students are not sure of
what they are learning.

Studies [3] have shown that chemistry teachers and chemical educators are part of the
misunderstanding the students have in learning chemical equilibrium. Teachers do not seem to
have a grasp of the knowledge contents of chemical equilibrium. Teachers cannot teach what they
(teachers) do not know. Maybe the government should ensure regular in-service training for the
chemistry teachers.

It is also necessary to consider the memory capacity of the students in terms of concretizing
related concepts and principles in chemical equilibrium.

REFERENCE
   (3), 391-392.
3. Cheung, D.(2009) The adverse effects, of lechatelier’s principle on teacher understanding of
   chemical equilibrium Journal of chemical education 86 (4), 514-518.
   equilibrium; A review of research and the case of Turkey. Chemical Education Researches Pract 9, 225-233.
FACTORS AFFECTING IMPLEMENTATION OF PRACTICAL ACTIVITIES IN SCIENCE EDUCATION IN SOME SELECTED SECONDARY AND PREPARATORY SCHOOLS OF AFAR REGION

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ABSTRACT
The study aimed at assessing factors affecting implementation of practical activities in science education in some selected secondary and preparatory schools of Afar Region. Practical activity is at the heart of mastery of science discipline and it is believed that if there is no practice either individually or in a group, all what have been learnt become inert knowledge. The implementation process of practices in science education is limited in Ethiopian schools and students in Ethiopia generally perform poorly in science subjects at secondary schools. Academically less prepared students of secondary schools prefer humanities and social sciences than science and technology in higher education. The majority of students in schools of the study area join social science. Therefore assessing factors affecting implementation of practical activities in science education in study area is important to identify root cause and forward the way for the improvement. Of the total 404 respondents from all schools, 68.81% responded as teachers do not use practical activities in teaching science and (78.71%) of them respond as they do less than 5% of the practical activities on their text books. Absence of separate and well equipped laboratory for each science, absence of efforts made by science teacher to use local material for practice of basic activities and less attention of local government and school administrative to existing problem results in less student motivation to practical activity which have influence on student’s preference to science education in the study area. Therefore attention should be given by all concerned bodies and stakeholders to solve the problem and encourage students to science practical activities to join science classes of future science and technology graduate. [African Journal of Chemical Education—AJCE 6(2), July 2016]
INTRODUCTION

Science education is the developing of technologically literate citizens who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday activities [1]. Study of science is important because it has the potential for improving the quality of life and making the world safer, empowers people, giving them greater control over their lives by providing pathways for finding answers to questions [2].

The quality, relevance, methods of teaching, human resource, scientific literacy, science process skills, higher order thinking, science-technology-society, teachers quality, textbooks of science education directly impacts on the extent of growth and development of science and technology [3]. The development of a modern civilization has a lot to do with advancement of science and technology. Focusing on the Science and Technology Education is becoming a common goal for nations to increase their developmental level [4] since advancement in science and technology help as a tool for boasting countries economic, social and political development.

It is believed that practice is at the heart of mastery of science discipline. If there is no practice either individually or in a group all what have been learnt become inert knowledge [5]. Mostly science practice takes place in science laboratory. Science laboratory is a very important resource input for teaching science and is an important predictor of academic achievement [6]. Science laboratories made this world very advanced and scientific in its purposes.

Many researchers suggested that learning science is enhanced and the understanding level is improved when students are engaged in science laboratory for practical experiments [7-9]. The laboratory has been given a central and distinctive role in science education, and science educators have suggested that rich benefits in learning science come as result of using laboratory activities
However, the facilities for teaching science are not up to the mark at secondary and higher secondary stages [6].

Secondary school is the base in preparing students for science education. It is at this level they were exposed to laboratory equipment, activities and precaution or safety rules. A high school laboratory should have the equipment necessary to conduct meaningful demonstrations and experiments. Teachers must understand that students with limited strength or mobility can have a full laboratory experience with appropriate accommodation, such as a lab assistant [11].

Hunde and Tegegne [12] reported that, despite the fact that laboratories have multiple benefits ranging from making learning concrete to lying basis for science education; students were deprived of such opportunities. Many countries have given attention to the effective implementation and practice of science education at their secondary schools [1]. Malaysian Government had announced a new education policy to strengthen the education standards in science and technology to compete with advanced countries and vowed to stand in the list of developed countries in 2020 [13].

The Commission for Africa report recommends that African countries have to take specific action that strengthen science, engineering and technology capacity since such knowledge and skills help countries to find their own solution to their own problem [14]. Similarly, currently the Ethiopian government determined and introduced what is now known as a “70:30 professional mix which 70% will be Science and technology streams while 30% will be Social Sciences and Humanities streams at higher education. This demonstrated that the government has given due consideration to science education [3].
However, production of quality professionals in science and technology is influenced by entrants who in turn influenced by the extent to which secondary education laid foundation in Mathematics and Natural Sciences as stated by Swail et al. (2003) cited in Hunde and Tegegne [12]. The implementation process of science education is limited in Ethiopian schools and students in Ethiopia generally perform poorly in science subjects [15].

Academically less prepared students of secondary schools prefer humanities and social sciences than science and technology. This not different in Afar region where majority of preparatory complete students join social science and humanities for their higher education study. The current study is aimed to assess factors that hinder the implementation of science education in secondary and preparatory schools found in Afar Region.

**Basic Questions of the Study**

Based on the stated problem, the study attempt to provide answers to the following questions.

1. Do teachers use practical activities in teaching science education?
2. How frequent do teachers use practical activities in teaching science education?
3. From the total practical activities in your science text books how money of them you did averagely?
4. What is the attitude of teachers in implementing practical activities in science education?
5. What is the interest of students toward practical activities in science education?
6. How do students involved in practicing science education?
7. Do each science subject in your school have their own laboratory?
8. Is the available laboratory well equipped?
9. Is Professional laboratory technician available for each course of each subject?
Scope and Significance of the Study

The study was delimited to five school of Afar Region, in North East Ethiopia, in which both secondary and preparatory students are available for the fact that the problem of this study is serious issue in the region. The study focused on grade 9 and 11 students. This is because grade 9 is the stage at which the students join their secondary school and have decision to focus on the area of their study while grade 11 is the stage at which students implement their decision of areas of the study.

The study may be significant in the following regards:

- This study would help Ministry of Education/ Afar Region Education Office to identify ways to attract students of the region to science education.
- It gives direction for Ministry of Education/ Afar Region Education Office to allocate resource to construct laboratory rooms and improve the existing laboratory facility.
- It helps the science teachers to hence love for practical activities and attract their students to science.
- It enables school principals to motivate teachers and laboratory technicians to use local materials to teach practical activity and make students use it.
- It helps local government of the region and other concerned stakeholders to be involved very much in improving the implementation of practical activities in science education so as to make students to join sciences to contribute to the 70:30 higher education intake ratio of the country in the region.
METHODOLOGY

Description of study area

Geographically, Afar Regional State is located in the northeastern part of Ethiopia. The total geographical area of the region is about 270,000 km2 (16). It is geographically located between 39°34’ and 42°28’ East Longitude and 8°49’ and 14°30’ North Latitude. The region shares common international boundaries with the State of Eritrea in the north-east and Djibouti in the east, as well as regional boundaries with the Regional States of Tigray in the north-west, Amhara in the south-west, Oromia in the south and Somali in the south-east. Administratively, Afar National Regional State consists of 5 administrative zones (sub-regions), 32 weredas (administrative districts), 28 towns, and 401 rural and urban Kebeles [16].

Study Design, Methods of Data Collection and Sampling

Descriptive survey study was used to assess factors affecting implementation of practical activities in science education in some selected Preparatory Schools of Afar Region from February 2013 to December 2014.

The data was obtained from primary sources through self-administrated questionnaire. A sample from population was selected to generalize the whole students and science teacher’s idea in order to make the overall conclusions.

Stratified random sampling technique was used in order to get more precise estimators which represent the whole population. Five secondary and preparatory schools were randomly selected from the region and each school is taken as different groups. The target population was students of grade nine and eleven and science teachers. Of the total 2254 grade nine and eleven students, 404 students and of the total 46 science teachers 17 of them were randomly selected for the study. The gathered data were reviewed, and then analyzed to form some sort of finding or
conclusion. Both descriptive statistics such as frequency distribution, pie chart, and bar chart and inferential statistics were used to analyze the data.

Figure 1. Map of the study area

Ethical Consideration

Consent Letter was written from Samara University to Afar region education bureau and from the bureau to the concerned secondary and preparatory schools. Before disseminating questionnaires’ to students and teachers, formal permission was taken from the informants.

RESULTS AND DISCUSSIONS

Table 1 below show total students participated in current study by school and sex. Of the total participated in the study 263 (67.96%) of them were male while 124 (32.04%) were female.
The table also indicates, of the total students, 83 (21.45%), 65 (16.80%), 114 (29.46%), 22 (5.68%) and 103 (26.61%) were participated in the study from Aba’ala, Asayita, Awash, Berhale and Dupti secondary and preparatory schools respectively. Of the total students, the highest 114 (29.46%) respondents were participated from Awash Secondary and Preparatory school.

The table indicate of the total female (124) participated in the study, the highest 40 (32.26%) female were participated in the study from Awash Secondary and preparatory school.

The data also indicate the participation female student in all school is far less than male which is the indication female participation in natural science is low compared to males in the study area.

Table 1. Student Respondents by Sex and Grade Level

<table>
<thead>
<tr>
<th>Schools</th>
<th>Student Respondents by Grade Level</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Aba’ala</td>
<td>30 (71.43%)</td>
<td>12 (28.57%)</td>
</tr>
<tr>
<td>Asayita</td>
<td>23 (48.94%)</td>
<td>24 (51.06%)</td>
</tr>
<tr>
<td>Awash</td>
<td>37 (57.81%)</td>
<td>27 (42.19%)</td>
</tr>
<tr>
<td>Berhale</td>
<td>17 (77.27%)</td>
<td>5 (22.73%)</td>
</tr>
<tr>
<td>Dupti</td>
<td>25 (56.82%)</td>
<td>19 (43.18%)</td>
</tr>
<tr>
<td>Total</td>
<td>132 (60.27%)</td>
<td>87 (39.73%)</td>
</tr>
</tbody>
</table>

| Total Male | 263 (67.96%) | Total Female | 124 (32.04%) |

Of the total grade nine students 219 (100%) participated in the study 132 (60.27%) are males while 87 (39.73%) of them are females. The highest number 64 (29.22%) of the students
are from Awash secondary and preparatory school and lowest number 22 (10.05%) of grade nine students are participated in the study from Berhale secondary and Preparatory school.

Of the total grade eleven students 168 (100%) participated in the study 131 (77.98%) are males while 37 (22.02%) of them are females. The highest number 59 (35.12%) of the students are from Dupti secondary and preparatory school and lowest 18 (10.71%) of grade eleven students are participated in the study from Asayita secondary and preparatory school.

Table 2 below show teacher respondents of all schools participated in the study. Of all teacher 17 (100%) respondents participated in the study, only 1 (5.88%) are females from Berhale Secondary and Preparatory school while the rest are male teachers.

Table 2. Teacher Respondents by Sex

<table>
<thead>
<tr>
<th>Schools</th>
<th>Teacher Respondents by Sex</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Aba’ala</td>
<td>3 (100%)</td>
<td>0</td>
</tr>
<tr>
<td>Asayita</td>
<td>4 (100%)</td>
<td>0</td>
</tr>
<tr>
<td>Awash</td>
<td>4 (100%)</td>
<td>0</td>
</tr>
<tr>
<td>Berhale</td>
<td>1 (50%)</td>
<td>1(50%)</td>
</tr>
<tr>
<td>Dupti</td>
<td>4 (100%)</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>16 (94.12%)</td>
<td>1 (5.88%)</td>
</tr>
</tbody>
</table>

Table 3 below show student’s response to teacher’s use of practical activity in teaching science education. Of the total students participated in the study, 271 (70.03%) of them respond as their teacher do not use of practical activity in teaching science teaching while 116 (29.97%) respond as their teacher use practical activity in teaching science teaching. Of the five schools studied, highest number 50 (60.24%) of students responded from Aba’ala Secondary and Preparatory school as their teacher use practical activity in teaching science while lowest number
of the students responded from Asayita 63 (96.92%) and Berhale 19 (86.36%) Secondary and Preparatory school as their teacher do not use practical activity in teaching science.

Table 3. Students Response to teacher’s use of practical activity in teaching science Education

<table>
<thead>
<tr>
<th>Schools</th>
<th>Students Response to teachers use of practical activity in teaching science</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Aba’ala</td>
<td>50 (60.24%)</td>
<td>33 (39.76%)</td>
</tr>
<tr>
<td>Asayita</td>
<td>2 (3.07%)</td>
<td>63 (96.92%)</td>
</tr>
<tr>
<td>Awash</td>
<td>40 (35.09%)</td>
<td>74 (64.91%)</td>
</tr>
<tr>
<td>Berhale</td>
<td>3 (13.64%)</td>
<td>19 (86.36%)</td>
</tr>
<tr>
<td>Dupti</td>
<td>21 (20.39%)</td>
<td>82 (79.61%)</td>
</tr>
<tr>
<td>Total</td>
<td>116 (29.97%)</td>
<td>271 (70.03%)</td>
</tr>
</tbody>
</table>

Figure 2 below show percentage teacher’s use of practical activities in teaching science.

Of the total 404 respondents from all schools, 68.81% responded as teachers do not use practical activities in teaching science while 31.19% of them indicated as teachers use it.

![Figure 2 Percentage teachers use of practical activities in teaching sciences](image-url)
Figure 3 below show percentage frequency of science teachers using practical activities in science. Of the total students participated in the study majority of them (53.96%) reported as their teacher do not use practical activity in teaching science while 21.04% of them indicated as their science teacher use it.

Figure 3 Percentage Frequency of Science Teachers Using Practical Work in Class teaching

Of the total 387 students participated in the study 202 (52.20%) of them replied as their science teacher don not use of which the highest respondents 60 (58.25%) were from Dupti Secondary school while 85 (21.96%) of them replied as their science teacher sometimes use practical activities in teaching science in the class. None of the respondents replied as their teacher very often use practical activities in teaching science. Of all schools under study, highest respondents 49 (42.98%) from Awash Secondary School respond as their teacher Sometimes use practical activities in teaching science while 39 (34.21%) from the same school respond as their teacher rarely use it.
Table 4 below show that, of all science teacher respondents none of them responds as they very often use practical activities in teaching while majority 12 (70.59%) of them do not use it. The other 3 (17.65%) of them replied that they sometimes use practical activities. Of all schools, Awash secondary school is the only school in which teacher Sometimes 3 (75%) and rarely 1 (25%) use practical activity in teaching science.

Table 4. Students’ response to frequency of using practical activity in teaching science education

<table>
<thead>
<tr>
<th>Schools</th>
<th>Students Response to Frequency of using practical Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very Often</td>
</tr>
<tr>
<td>Aba’ala</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>Asayita</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>Awash</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>Berhale</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>Dupti</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>Total</td>
<td>85 (21.96%)</td>
</tr>
</tbody>
</table>

Figure 4 Percentage Practical Activities Done in the school
The above figure 4 show that of all respondents participated in the study, majority (78.71%) of them respond as they do less than 5% of the activities on their text books while small respondents (4.70%) indicate as they do 50.74% of activities on their text book. This indicates that majority of students in each school do less than 5% of the activities on their text books.

![Figure 5 Teachers Attitude towards Applying Practical Activities in teaching science](image)

Figure 5 Teachers Attitude towards Applying Practical Activities in teaching science

The above figure 5 shows that majority (57.92%) of the teacher have positive attitude toward applying practical activities in teaching science while others (42.08%) of them have negative attitude toward applying practical activities. The science teacher in the each study school reported that even though they have positive attitude to practical activities, absence laboratory facility, less motivation of school principals to fulfill laboratory facility and environmental condition makes them not implement practical activities in science teaching.
Figure 6 shows student’s interest towards practical activities. Of the total respondents 84.65% respond as they have interest of learning practical activity while 15.36% of them have no interest to it. But the reason behind is less practical activity.

General secondary school is the base in preparing students for science and technology education and it is at this level where they were exposed to laboratories equipment, activities and precaution or safety rules. If there is no practice either individually or in a group all what have been learnt become inert knowledge [5]. In the current study, for each science subjects, almost all secondary and preparatory schools have common laboratory. Each schools laboratory is not equipped and chemicals which are even important to small extent are missing. In all schools there is no facility except Awash and Aba’ala secondary schools in which there are some facilities but laboratories are not functional and equipments and chemicals are simply stored in non-ventilated store due to absence of skilled laboratory technicians and cooling system.
Similarly [12] reported that Jimma university community school and Yebu School have laboratory which is not functional while Bilida School has no laboratory set up at all. Except Awash and Dupti which have plasma television instruction, others have no any plasma television distribution due to electric power supply problem and other factors and there is no continuous distribution even in those schools which have plasma television.

Therefore students in these schools are at a disadvantage compared to students who are receiving televised instruction who have at least exposure to laboratory equipment, demonstration of experiments. Similarly Jimma University community school, Yebu School and Bilida School in Jimma face the same problem due to absence of televised instruction which is useful for conceptual understanding of the practice [12].

The study revealed that students have interest to learn practical activities. This is indifferent from the study conducted by Negassa [18] in which the students were not interested to conduct practical activities. But the less admission and participation of students to science education result from assumption that less or absence of any practical activity in science subjects due to laboratory facilities have influence on their score in science and their future study.

The other factors is that, the room of available common laboratories are too small to hold all students and not suitable to work in, due to lack of ventilation as far as the temperature of the environment is very hot. In some schools even the rooms are not built for laboratory purpose, doors, windows, roofs are broken. Totally the laboratory rooms and laboratory environments are dirty and not suitable to work in.

This shared truth with the report of Tesfamariam et al. [19] which most laboratory rooms available in secondary schools of Mekele town were not built for laboratory purpose and lacked even the most basic facilities like running water, source of electricity; working tables, sinks, hoods,
the rooms windows, roofs and doors are broken. These forces all under study school teachers to use only theories to teach their students. This is similar with idea that “most high schools in Ethiopia used to teach practical subjects theoretically without adequate support with experiments due to high scarcity of laboratory equipment and chemicals” [20].

Students’ interest and their academic achievement in science education have direct relation and as the same time affective practices of students in classroom are strongly related to their academic achievement [21]. Students are effectively successful through practicing the subject matters. Farounbi [22] argued that students tend to understand and recall what they see more than what they hear as a result of using laboratories in the teaching and learning of science students so as to get better achievement. Laboratories have multiple benefits ranging from making learning concrete to lying basis for science education in the subsequent levels [12]. Students in current study schools were deprived of such opportunities because of the following hindering factors, which makes negative impact on students’ preference to science education:

- The absence of separate well-equipped laboratory in each school under study.
- The absence of laboratory technician for each science (Biology, Chemistry and Physics) in the school, who can carefully facilitate and lead the laboratory procedure.
- Absence of well-prepared laboratory manuals.
- Chemicals, apparatus and laboratory room give less function for the fact that the chemicals on the laboratory are highly expired and outdated, and dangerous for the students.
- The laboratory room does not match with the number of students.
- Some schools do not have totally laboratory rooms and even those which are available not suitable for work.
• Very hot environmental condition and absence of cooling system in areas where the schools available is another factor.

• Less attention is given from administrative government of the region and school administrators to sciences education

• Less motivation of science teachers to use local materials to at least conduct basic activities on student’s text.

• Absence of televised instruction which at least exposes students to practical materials, procedures and diagrams in most schools in the study area and non-continuous functionality of the television even the school it available.

CONCLUSIONS AND RECOMMENDATIONS

It has been found that teaching science without practical activities have effect on student’s interest towards science disciplines which result in less student enrolments in science class. The hindering factors identified in the current study make students do not get satisfactory laboratory practices. As a result of these students at secondary and preparatory schools of Afar region lack interest to join science class.

In each school under study, female student enrollment to general secondary school is less which is far less in preparatory schools compared male indicating less preference to science education. As the same time students enrollment to science class is different in each school.

From the study, it is possible to conclude that even though there is no separate laboratory for each science and even the existing laboratory is not well equipped which is not suitable for conducting activities, there is no efforts made by science teacher to use local material even to show demonstration to science students. This results in less student motivation to practical activity which has influence on student’s preference to science education.
In general, less local government education office, school administrators and community attention to fulfill laboratory facility, less commitment of science teachers to fully use the effort to encourage their students to practices and less motivation of students, implementation of practical activities in secondary and preparatory school of the study area is by far less and result in less preference and admission of students in science classes.

Therefore, Ministry of Education, Afar region education bureau should launch science education project in the study area which focuses on school laboratory establishment and facility fulfilling as well as enhancing knowledge and skills of science teachers. A great awareness on the importance of science education has to be given to students by role model professionals, educational structural organizations and science teachers.

Science teachers and other concerned bodies should be committed to build students’ confidence in their ability to do well and better. They should check the practice of students’ science education for students in general to female students in particular so as to enhance the low performance of students in the science subjects. On the other hand students should take an active role by taking responsibility for their own learning, ask their teachers and school principals for the fulfillment of their laboratory and ask their teachers to encourage and assist them to use local material for practice.

The nearby Samara University and Mekele University in collaboration with other institution should work on the schools science teacher capacity building, make the available laboratory functional by giving training, by making arrangements of the laboratory through their community service project.

Ministry of Education and Afar Education Bureau should construct standard laboratory classes separately to each science subjects; fulfill well-trained laboratory technicians, chemicals,
apparatuses, well-designed laboratory manuals and fix cooling system to chemical store and the laboratory at whole. Parents should get effective awareness on the importance and benefit of science education by school principal and other concerned bodies so that they can support their children’s effectively and send them to admit science class. Local or international NGOs should focus in improving science education in general secondary schools.

In generally, since, Ethiopia’s higher institution training focuses on science and technology through 70:30 policy to transform agricultural led industry to industry led agriculture, the country needs well trained man power in the fields of science and the central missions of all schools are to produce good citizens, academically talented and future scientists. Therefore, in order to have students with high science achievement, schools should give special attention to the implementation of effective practical and laboratory activities in science teaching and attract students to science classes in secondary schools.

ACKNOWLEDGMENTS

We are grateful for Research and Publication Office Samara University for funding the study. We acknowledge also all of our respondents for their willingness to take part in the study. The heart full thanks also go to Mr. Olana Angessa of statistics department of Bule Hora University for his support in statistical analysis part of the study.

The authors declare no conflict of interest.

REFERENCES

TEACHING ‘NATURAL PRODUCT CHEMISTRY’ IN TANZANIA

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ABSTRACT

Natural products ‘historically’ and ‘today’ have vast importance. This article describes the course ‘Natural Product Chemistry’, a new course in the 2011/2012 academic year in the Faculty of Natural and Applied Sciences at St. John’s University of Tanzania. It reveals how the course has been applied to the African and Tanzanian context and expresses the importance of a ‘Natural Product Chemistry’ course within chemical education. This paper also serves as a resource to help other scientists develop a similar course within their context. [African Journal of Chemical Education—AJCE 6(2), July 2016]
INTRODUCTION

A simple definition for a ‘Natural Product’ is a chemical compound or substance produced by a living organism [1] [2]. The term includes complex extracts, and individual compounds and minerals isolated from these extracts. Many of today’s pharmaceutical drugs are natural products or based on natural products, for example: (a) Crestor® is the natural product mevastatin, a statin drug, used for lowering cholesterol (b) Finibax® is an antibiotic drug derived from the natural product thienamycin (c) YondelisTM is the marine natural product trabectedin, a cancer drug [3]. Natural Product Chemistry educational initiatives are not absent from educational institutions around the world. It has been said that in China natural product chemistry is one of the most developed scientific fields and almost every Chinese university has a research or teaching unit for natural product chemistry or chemistry of natural medicines [4]. There is even an educational survey of chocolate: a marvellous natural product of chemistry [5] and more recently academics in Indonesia have developed a mini laboratory project to make a natural product chemistry course meaningful [6].

The cultural context is not often thought about in chemical education. The significance of cultural differences to chemistry learning was highlighted in a Chemistry Education Research and Practice editorial in 2012 ‘The International Dimension of Chemistry Education Research and Practice’ [7]. Furthermore, a recent article ‘Chemistry Education Research Trends: 2004–2013’ in the same journal stressed the need for more chemistry education research in areas which include culture and philosophy [8]. In a 1999 article titled ‘Transcending Cultural Borders: Implications for Science Teaching’, Jegede and Aikenhead provided the valuable deduction ‘When science culture is in harmony with a learner’s life-world knowledge, learning science concepts reinforces the pupils’ worldview suppositions’ [9].
To bring African culture into education requires originality which includes the realities and needs of living in a world which is closely connected. This paper describes insights from practice. As well as providing an outline for a natural product chemistry course some areas where cultural knowledge has been blended into the course are discussed. The paper therefore has the following three components: (a) Details of the course ‘Natural Product Chemistry’ (b) Discussing cultural inclusions (c) Reflections from the course instructor.

**COURSE DETAILS: NATURAL PRODUCT CHEMISTRY**

**General Information**

The course is an optional course (not core) open to 3rd year (final year) students in the Faculty of Natural and Applied Sciences at St. John’s University of Tanzania (SJUT), a private Christian university in Dodoma, Tanzania. This faculty runs a three year B.Sc. (Education) program, primarily training students to be secondary school teachers in Tanzania.

**Course Description**

By natural products, we mean the molecules of nature produced by living organisms (plants, microorganisms, fungi, insects, animals etc.). This course focuses on the secondary metabolites which give particular species their characteristic features. The study of these natural products has played a major part in the development of organic and medicinal chemistry and we are now starting to understand the important ecological role that these compounds have.

After an introduction the course focuses on the different classes of natural product and this is followed by learning secondary metabolite biosynthesis. Isolation and structure elucidation techniques are then studied. Finally, the application of natural product chemistry to drug discovery is studied.
General Course Objectives

Upon completion of this course students should be able to:

• Know the biosynthetic building blocks to the different classes of secondary metabolites and be familiar with their biosynthetic pathways

• Assign a natural product to a general class of secondary metabolite (and if appropriate to a more specific part of the general class)

• Understand how to isolate a natural product and know some of the techniques used

• Explain the stages of structure elucidation and know some of the techniques used

• Understand the significance of natural products within drug discovery and the valuable knowledge gained from traditional medicine

Lecture Outline

Introduction to Natural Product Chemistry

• What are natural products?

• The history of natural products

• Traditional medicine

The Classes of Secondary Metabolites

• Introduction

• Polyketides and fatty acids

• Terpenoids and steroids

• Phenylpropanoids

• Alkaloids (and specialized secondary metabolites)
The Biosynthesis of Secondary Metabolites

- Introduction
- Polyketides and fatty acids
- Terpenoids and steroids
- Phenylpropanoids
- Alkaloids (and specialized secondary metabolites)

The Isolation of a Natural Product

- Introduction
- Extraction
- Separation and Chromatography

Structure Elucidation of Natural Products

- The stages of structure elucidation
- Stage 1: Preliminary characterization
- Stage 2: Determine the carbon skeleton
- Stage 3: Determine the relative stereochemistry
- Stage 4: Establish the absolute stereochemistry

Application of Natural Product Chemistry

- Drug discovery

There was a wide diversity of resources used in preparing the lectures and here are some of the main ones [3, 10-18].
Seminar Outline

There were six seminars/problem session periods which vary from 1 – 3 hours in length. Each of these seminars require students to have done some prior study in the form of attempting problems or background reading and answering questions. The seminars were as follows:

Seminar 1 – Classes of Secondary Metabolites – Problem solving: the focus was on identifying the different classes of secondary metabolite, the building blocks and the number of units of building blocks; students were given some problems to attempt before the seminar.

Seminar 2 – Biosynthesis of Secondary Metabolites – Problem solving: the focus was on becoming familiar with secondary metabolite biosynthetic pathways and isotopic labelling; students were given some problems to attempt before the seminar.

Seminar 3 – Isolation of Natural Products – Discussion: the focus was on becoming familiar with isolation procedures; students were given a natural product scientific paper to read and asked to come prepared to discuss the isolation of the natural products.

Seminar 4 – Structure Elucidation – Problem solving: the focus was on practicing determining structures of natural products; students were given some problems to attempt before the seminar.

Seminar 5 – Chiroptical Methods in Determining Absolute Stereochemistry – Discussion: the focus is on learning some different chiroptical techniques; students were given material to read with two questions, and asked to come prepared for a discussion.

Seminar 6 – Drugs, Religion and Chemistry in Tanzania – Discussion: the focus was on students learning the connections between different knowledge areas in a culturally relevant natural product drug discovery seminar; students were given a quiz, have prior reading to do, participate in a hands-on-activity with molecular models, and take part in a discussion. This seminar has previously been reported fully in [19].
Students were directed to the following e-journals for supplementary reading [20-21].

Assessment

- End-of-Semester Examination (50% of the overall assessment).
- Coursework (50% of the overall assessment). This consisted of three components:

1) A traditional medicine focused assignment (20%): In academic year 2014-2015 the title was ‘Traditional Medicine in Tanzania: How do Spiritual Beliefs Influence Traditional African Medicine?’ Students were asked to discuss with individuals, read literature and use personal knowledge to write-up a report (1,200 words) responding to the question posed.

2) Class test (20%).

3) A structure elucidation problem (10%).

DISCUSSING THE CULTURAL INCLUSIONS

Religion

Africans including Tanzanians are very religious people [22, 23]. In this course during the ‘Introduction to Natural Product Chemistry’ one major component was ‘The history of natural products’. Throughout history, human beings have relied on nature to provide for their basic needs. This provides a great opportunity to connect Tanzanians to their religious identity by informing students that there are many natural products within the Bible, the sacred book of Christianity, a collection of ancient writings including the books of both the Old Testament and the New Testament. The two examples used in this course were frankincense and olive oil. These were discussed as follows:

- **Frankincense (olibanum), is an aromatic resin obtained from trees of the genus Boswellia and it is used in incense and perfumes. It is obtained from the tree by slashing the bark and allowing the discharged resins to bleed out and harden. The resin has a large acid content including the pentacyclic triterpene boswellic acids. The essential oil of frankincense is**
produced by steam distillation of the tree resin and contains a large percentage (ca. 75%) of monoterpenes and sesquiterpenes. It has medicinal properties and is used in the perfume industry. Frankincense has significance in the Bible. It was an ingredient in the holy incense used in the tabernacle in the wilderness (Exodus 30:34), and was also offered as a gift to the newborn Jesus (Matthew 2:11) [24].

- Olive oil is obtained from the olive tree (Olea europaea), a traditional tree crop of the Mediterranean Basin. Olive oil is produced by grinding olives and extracting the oil. The oil is composed mainly of the mixed triglyceride esters of oleic acid and palmitic acid and of other fatty acids, along with traces of squalene (up to 0.7%) and sterols (about 0.2% phytosterol and tocosterols). The composition varies by cultivar, region, altitude, time of harvest, and extraction process. In the Bible olive oil has been referred to many times for use in offerings (Leviticus 7:12), fuel (Exodus 39:37), anointing (1 Samuel 10:1) and medicinal (Isaiah 1:6) purposes [24].

There are several other natural products mentioned in the Bible, including myrrh, cinnamon, aloes, cassia, cumin, garlic, hyssop, and more.

**Traditional Medicine**

Traditional medicine, including its practice, remains a very strong part of Tanzanian culture [25]. Again during the ‘Introduction to Natural Product Chemistry’ in this course there was a strong emphasis on ‘Traditional Medicine’. The following are some of the features studied:

- Various terminology around traditional medicine was defined, for example, herbalism, ethnopharmacology, traditional medical practitioner, and so on. The following definition was given for Traditional African Medicine (TAM): “Traditional African medicine is a holistic discipline involving extensive use of indigenous herbalism with aspects of African spirituality” [26].

- The philosophy of African medical practice being rooted in the African worldview was entered into and the ideas of diagnosis and treatment within African Traditional Religions (ATR) discussed. In ATR the concept of treatment is comprehensive and holistic as the body, mind and soul are treated [12]. There is not one standard way of practicing TAM and there is great variety between countries and tribal groups within countries. Discussions in

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class and course assignments revealed that TAM is still very much respected in Tanzania, but at the same time there is an element of suspicion by many. The ‘medical safety of traditional medicine’ and ‘the dabbling with evil forces in traditional medicine’ are both questioned.

- The advances in TAM today were delivered.

- Out of the multitude of medicinal plants in Africa one of the examples used was Prunus africana. Traditionally parts are used for a variety of conditions, but more recently the extract pygeum prepared from the bark is used worldwide as an alternative medicine for benign prostatic hyperplasia [27]. Students were informed about the need for conservation in respect to medicinal plants as indiscriminate harvesting endangers plant populations.

- In 2002 The Tanzanian Parliament passed The Traditional and Alternative Medicine Act [28], which became operational in 2005 with the aims of integrating traditional medicine in primary health care and encouraging cooperation between traditional medicine practitioners and western trained doctors [13]. The traditional healers are known to be the source of knowledge on medicinal plants. It is recognized that respect for the knowledge of traditional healers and operational regulations for benefit sharing is something to aspire to and regarded as an essential basis for fruitful cooperation across sectors. This is within the mission of the Convention on Biological Diversity [29].

- The Institute of Traditional Medicine (ITM) at Muhimbili University of Health and Allied Sciences in Dar es Salaam is charged with ‘the responsibility to research into traditional healing systems, in Tanzania, to identify useful practices which can be adopted and also to identify useful materia medica which can be modernized and developed into drugs for use to improve human health’ [14]. The ITM website informs us that Tanzania is estimated to have over 80,000 traditional
healers with varying specialities. Most healers are herbalists using mainly plants and a few animal and mineral products in their practices. The estimated traditional healer:population ratio is 1:400 compared to 1:30,000 doctor to population ratio. It is specified that from the over 12,000 higher plant species growing in Tanzania, at least a quarter of them have medicinal value. Some of the promising medicinal plants for drug production are Cinchona ledgeriana, Artemisia afra, Rauvolfia caffra, Rauvolfia serpetina, Atropa belladonna, Catharanthus rosea, Pischiera fuchsiaefolia, Moringa oleifera, Vuacanga africana, Prunus Africana, Aloe vera, Hibiscus sabdariffa, and Waltheria indica.

The Association for African Medicinal Plants Standards (AAMPS) is a non-profit company registered in Mauritius dedicated to the development of quality control and quality assurance standards for African medicinal plants and herbal products [27]. In 2010, AAMPS published the African Herbal Pharmacopoeia, which provides comprehensive, up to date botanical, commercial and phytochemical information on over fifty of the most important African medicinal plants.

This section on traditional medicine was completed by a statement appreciated by the instructor (M.S.B.) from Richard Onwuanibe [15]:

*The strongest argument for traditional medical practice, from the philosophical point of view, is that it is holistic; it incorporates the personal, social, physical, and spiritual aspects of man. This holistic approach to medical practice is what traditional African medical practice can offer to departmentalized and technologically oriented modern practice. While rejecting the superstitious elements of traditional practice, the modern African medical doctor has a gold mine of traditional sources to integrate into his practice.*

**A Continuous Order of Understanding**

As has been revealed in the course details a culturally relevant interactive seminar was delivered ‘Drugs, Religion and Chemistry in Tanzania’ [19]. This seminar appeals to traditional African thought ‘different knowledge areas forming one continuous order of understanding’ [30].
During the natural product drug discovery seminar Tanzanian students were able to appreciate how Tanzanian culture (traditional medicine and religion) is connected with the fundamentals of the chemical sciences (molecular interactions) and relevant application of the chemical sciences (in this case natural product drug discovery to combat diseases prevalent in Tanzania). As stated earlier the seminar has been explained in detail elsewhere [19], however, the sequential connections were explained as follows:

- Tanzania has a rich traditional medicine knowledge that can be used to find new medicines;
- There are life threatening diseases in Tanzania which can potentially be combated by natural compounds from endemic medicinal plants;
- Molecular interactions are fundamental to drug action in biological systems;
- Molecular interactions are subject to the ‘laws of nature’ for example electromagnetic force;
- The ‘laws of nature’ are governed by constants (such as Planck’s constant, charge and masses of electrons, protons etc.);
- The actual values of these constants are unexplained by science, but must have precise values for the universe to work;
- The laws of nature provide a universe which is ordered, consistent and so knowable;
- The religious African sees God (or spirits) as the ultimate cause behind the laws of nature.

**REFLECTIONS FROM THE COURSE INSTRUCTOR**

In general students appreciated and benefited from the introduction of this optional (elective) course to the curriculum. A number of students in the course evaluation suggested it should be a core course. By including Natural Product Chemistry, breadth was added to students’
knowledge, in an area which is ‘currently relevant’, ‘historically relevant’ and ‘culturally relevant’. Until now the course has been essentially theoretical and could have improved by including a practical component. Student comments in the course evaluation supported this fact. Having said this, despite the limited laboratory resources (i.e. only flasks, beakers, separating funnels, measuring cylinders, weighing balances, water baths, routine chemicals and solvents, and so on, with no sophisticated items of equipment), in preceding semesters in organic chemistry practicals, students conducted the experiments ‘Extraction of Caffeine from Tea Leaves’ and ‘Isolation of Aliphatic Hydrocarbons from Tomato Paste’. A commonality in course evaluations and class discussions was students’ appreciation for gaining knowledge about medicinal plants, their value, and the secondary metabolites which can be isolated and developed into pharmaceutical drugs. Several students expressed the desire to pursue postgraduate studies in the area. At present a curriculum review of the B.Sc. (Education) program is in progress and the plan is for the new course ‘Natural Product and Medicinal Chemistry’ to be offered to chemistry major students including relevant practical activities. This will replace the current separate courses ‘Natural Product Chemistry’ and ‘Medicinal Chemistry’ and will be taught in a way that shows the interrelationship these disciplines possess.

CONCLUSIONS

Natural products remains a strategic field of study, not least in its relation to pharmaceutical research. Herein is an example of a ‘Natural Product Chemistry’ course. In order for chemical education to be more relevant and interesting, within the world students live, cultural inclusions should be encouraged to enrich the whole learning experience. This will reduce cognitive conflict, harmonizing the science learning with the students own worldview and indigenous knowledge.
The ‘Natural Product Chemistry’ course presented here was an attempt to do so and included the aspects of ‘religion’, ‘traditional medicine’, and ‘a continuous order of understanding’.

REFERENCES


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