1ST AFRICAN CONFERENCE ON RESEARCH IN CHEMISTRY EDUCATION [ACRICE-1]

MAIN THEME:

Chemical Education for Human Development in Africa

ORGANIZED BY:

FEDERATION OF AFRICAN SOCIETIES OF CHEMISTRY (FASC) AND

ADDIS ABABA UNIVERSITY, ETHIOPIA

Date: From 5 to 7 December 2013
Venue: Addis Ababa, Ethiopia

Papers will be presented under the following sub-themes (ST)

ST [A]: Best Practices in the teaching and learning chemistry
ST [B]: Chemistry education for sustainable development in Africa
ST [C]: ICT and Multimedia in teaching and learning chemistry
ST [D]: Nano-chemistry Education
ST [E]: New trends in student assessment
ST [F]: Micro-Scale chemistry teaching
ST [G]: Ethics in chemistry education
ST [H]: Multiple Uses of Chemicals
ST [I]: Lab safety and hazards
ST [J]: TQM, TQC in chemistry education

Call for Abstracts (Deadline 30 July 2013)

Conference President: Dr. Temechegn Engida, President of FASC and UNESCO-IICBA, Ethiopia
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CONTENTS

EDITORIAL

ACRICE-1 is coming soon
Temechegn Engida

LETTER TO THE EDITOR
Terry Renner

RESEARCH PAPERS
Relationship between self-efficacy, academic achievement and gender in analytical chemistry at Debre Markos College of Teacher Education
Yazachew Alemu Tenaw

Chemistry teachers and their senior secondary students’ answers to pictorial and verbal questions in evaporation
Macson J. Ahiakwo

A diagnostic assessment of eighth grade students’ and their teachers’ misconceptions about basic chemical concepts
Abayneh Lemma

[SATLC- Initiative] Uses of SATL & multiple intelligences [MI] for secondary and tertiary levels. Part-I: benzene structure activity
A.F.M.Fahmy and J.J.Lagowski

Systemic approaches to teaching and learning a module of Biochemistry [SATL-BC]
Suzana Golemi, Rajmonda Keçira, Neira Medja and Donalda Lacej

SATL model lesson in chemical kinetics
Misbah Nazir, Iftikhar Imam Naqvi and Rozina Khattak

SHORT COMMUNICATIONS
Science needs Africa as much as Africa needs science: A case in Tanzania
Wolfgang Czieslik and Hans-Dieter Barke

Successful practical work in challenging circumstances:
Lessons to be learned from Uganda
Robert Worley and Mary Owen, United Kingdom

GUIDELINES FOR AUTHORS
EDITORIAL

ACRICE-1 IS COMING SOON

Temechegn Engida
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Dear AJCE Communities,

I would like to inform you that FASC will hold the 1<sup>st</sup> African Conference on Research in Chemistry Education (ACRICE-1) with a theme of Chemical Education for Human Development in Africa 5-7 December 2013 in Addis Ababa. ACRICE conferences bring together chemistry educators, researchers and teachers from across African continent, and provide a unique pan-African forum for the sharing ideas and new findings to solve chemistry education problems in African countries. Participants will examine a wide range of pedagogical best practices that address local and global issues in educating African students for total quality in the global age. ACRICE conference is intended as a platform for understanding and enriching education for preparation of African citizens who are able to deal with local and global challenges. To that end, educators and researchers at all levels are invited to share vital knowledge and strategies for chemistry teaching and learning in culturally responsive ways.

As you may agree with me AJCE is progressing very well. In addition to its existence in the FASC website it is available at the AJOL website. Chemistry educators from Africa and the world at large have been contributing to the Journal. In this issue, you will find a Letter to the Editor sent by Dr. Terry Renner, the Executive Director of IUPAC. As usual this issue contains research papers and short communications in the area of Chemistry Education.

Enjoy reading!
Dear Dr. Engida,

It was with great interest that I read an article authored by Dr. Florence Ssereo that was published in the African Journal of Chemical Education (AJCE 2(3), July 2012). In it Dr. Ssereo describes her experiences as a young girl with her aunt who was applying indigenous knowledge to the production of alcohol from commonly available starting materials. At an early age she was exposed to several of the most fundamental principles of chemistry – fermentation, distillation, evaporation, condensation, heat transfer, and aspects of quality control. These experiences kindled a spark of curiosity to pursue a more formal path of learning in the chemical sciences. This brings me to my reason for writing.

During the International Year of Chemistry 2011, in my role as Executive Director of the International Union of Pure and Applied Chemistry (IUPAC), I had the opportunity to visit many countries in the world and to speak with many young people, most of whom were of high school and university age. My primary purpose was to encourage them to pursue careers in the sciences, but especially in chemistry. Many initially had a very negative view of chemistry and had no realization that their daily lives are so greatly immersed in and influenced by the marvels of our science. Usually, a few examples, much like the one above in Dr. Ssereo’s article, were sufficient to cause these young people to reflect on their previous attitudes, ask more questions, and often to become truly interested in the message that I was trying to deliver. These potential chemists of the future will be the enablers of sustainability for our way of life on earth.

It seems to me that one of the most difficult jobs that all of us face who are interested in Chemical Education is to create fundamental awareness among the general public, not just younger students. In order to achieve widespread success we must engage all segments of our societies and cultures to develop a basic appreciation of what chemistry means to everyone living on this planet. Once people learn not to fear chemistry but to embrace it as essential to all life, we will have made a large step in the right direction.

It is up to all of us chemists to plant the seeds of discovery in the minds of all with whom we come into contact. Sometimes even the simplest concept can render a huge impact when the person hearing it for the first time actually connects that concept to some essential aspect of his or her daily life. Those of us who already have careers in chemistry should take every opportunity to share our knowledge and experiences with whoever will take the time to listen. The potential rewards are enormous for all of us.

Dr. Terry Renner
Executive Director, IUPAC
ABSTRACT
The aim of this study was to investigate the level of students’ self-efficacy, gender difference in self-efficacy and achievement and also relationships between self-efficacy and achievement for second year students in the fall of 2012 in Analytical Chemistry I (ACI) at Debre Markos College of Teacher Education (DMCTE). The self-efficacy survey and the ACI achievement test were completed by 100 students. The self-efficacy survey data were gathered by Likert scale questionnaire. By using inferential statistics (t-test), difference of self-efficacy and achievement in gender is calculated and by using Pearson correlation, the relationships between self-efficacy and achievement were investigated. The analysis of the data indicated that students’ level of self-efficacy is medium (50.08), and there is no significant difference in their self-efficacy between sexes (t (98) = 0.161, p> 0.1), but there is a statistically significant difference in achievement between sexes (t (98) = 0.68, p< 0.1) and also a significant relationship exists between self-efficacy and achievement (r=0.385, at 0.01 level with 98 degree of freedom). Based on these results, recommendations which will improve the quality of our training specifically in the field of chemistry are forwarded. [AJCE, 3(1), January 2013]
INTRODUCTION

Gender bias in mathematics and science classrooms has been and still continues to be a problem (American Association of University Women) (1). Despite improvements in the past two decades, girls are still less likely than boys to take Chemistry and higher-level Mathematics and science courses in high school (1). As a consequence, fewer female students may study Mathematics and Science at the college level. The types of courses taken in high school and how students perform in these courses can affect acceptance into college, choice of college major, and subsequent career choice (1, 2).

Starting in seventh grade, girls tend to underestimate their abilities in Mathematics and Science despite the fact that their performance remains the same as boys (3). This trend continues on through high school. “A loss of self-confidence rather than any differences in abilities may be what produces the first leak in the female science pipeline” (4, p. 410). Confidence is strongly correlated to which students continue in Mathematics and Science courses and which do not (5). It is thought that self-efficacy may explain course selection patterns in schools that eventually lead to the under representation of women in science (6). Regardless of gender, more career options, including potentially higher career aspirations, are considered by those students who possess a high degree of self-efficacy (7, 8). In essence, “efficacy beliefs partly shape the courses that lives take” (9, p. 239). If a female believes she is unable to succeed in Mathematics or Science, this altered perception may then subsequently manifest itself in lower grades or in avoidance of Mathematics and Science courses altogether.

From my experience as a chemistry instructor for six years at Debre Markos College of Teacher Education (DMCTE), it was noticed that students had varying levels of confidence in their abilities for success in various Chemistry courses, such as General Chemistry I and II,
Organic Chemistry, Inorganic Chemistry and Analytical Chemistry. Female students seemed to express the highest doubts in their capabilities whereas male students frequently seemed overconfident. These variations in confidence will affect their learning of Science. Hence, self-efficacy in science affects science learning, choice of science, amount of effort exerted, and persistence in science (10).

The purpose of this study is to investigate the relationship between Analytical Chemistry I (ACI) course self-efficacy and academic achievement with gender of second year Chemistry and Biology students at DMCTE. ACI is a course that intensively studies the qualitative determination of cations and anions and also the quantitative determination of solubility, acid-base and oxidation-reduction equilibria of solutions and is typically taken by students of Chemistry major and Biology major students. The majority of students enrolled in this course are males completing grade ten and preparatory classes needed for enrollment in diploma teacher in primary schools. It was believed these students would have moderate to high levels of self-efficacy for chemistry; since students self-selected themselves into chemistry and biology. However, I expect that students with higher self-efficacy levels would earn higher grade in ACI than students with lower self-efficacy. Therefore, this expectation of mine needs to be confirmed.

Knowing the relationship between students’ self-efficacy and achievement with gender will help the college to select students who would be successful in science.

Many studies have been conducted on self-efficacy and academic achievement but adequate research has not yet established a firm connection between self-efficacy and college science performance. As far as my knowledge is concerned no research study was conducted which shows relationship between self-efficacy and academic achievement with gender in analytical chemistry at any level.
REVIEW OF RELATED LITERATURE

Definition and Description of Self-efficacy

Self-efficacy, also called perceived ability, refers to the confidence people have in their abilities for success in a given task (9). If they possess the ability to successfully perform, then that task will be attempted. The task will be avoided if it is perceived to be too difficult (7, 9). Although inefficacious individuals usually avoid challenging tasks, when they do attempt them they give up more easily than individuals with high efficacy. When inefficacious individuals fail, they attribute the unsuccessful result to a lack of ability and tend to lose faith in their capabilities. When they succeed, they are more likely to attribute their success to external factors (7, 9, 11). If students master a challenging task with limited assistance, their levels of self-efficacy rise (7).

Individuals who possess a high degree of self-efficacy are more likely to attempt challenging tasks, to persist longer at them, and to exert more effort in the process. If highly efficacious individuals fail, they attribute the outcome to a lack of effort or an adverse environment. When they succeed, they credit their achievement to their abilities. It is the perception that their abilities caused the achievement that affects the outcome rather than their actual abilities (7).

Four factors determine self-efficacy: enactive mastery experience, vicarious experience, verbal persuasion, and physiological and emotional states (7, 9). The most influential of these factors is enactive mastery experience, which refers to individuals’ experiences with success or failure in past situations. Information gathered from these experiences is then internalized. Past successes raise self-efficacy and repeated failures lower it, which indicates to individuals their levels of capability (7, 9). In a vicarious experience, individuals compare themselves to peers whom they perceive are similar in ability and intelligence to themselves. Watching peers succeed
raises observer’s self-efficacy and seeing them fail lowers it. Exposure to multiple successful role models helps increase self-efficacy in observers (7, 9). Verbal persuasion tries to convince individuals, who may doubt their capabilities, that they possess the skills needed for success at a given task. In education, verbal persuasion delivered by teachers often takes the form of verbal feedback, evaluation, and encouragement. Persuasion must be realistic, sincere, and from a credible source; otherwise it can negatively affect student self-efficacy beliefs (7). Emotional state can either positively or negatively affect interpretation of an event’s outcome (7, 9). In addition to the four factors that determine general self-efficacy, aptitude, attitudes, and attributions are found to predict science self-efficacy (12).

Efficacy beliefs vary between individuals and will actually fluctuate within an individual for different tasks (9). In many activities, self-efficacy contributes to self-esteem (7). Self-efficacy beliefs affect how people approach new challenges and will contribute to performance since these beliefs influence thought processes, motivation, and behavior (9). Self-efficacy is not static and can change over time resulting from periodic reassessments of how adequate one’s performance has been (7). For example, in a college population, Chemistry laboratory self-efficacy increased over the course of a school year whereas Biology self-efficacy decreased over the same duration (13).

Numerous studies will show that females possess lower Math and Science self-efficacy than males and as a result, often earn lower grades in these academic subjects. Consequently, females may be less likely to pursue technical and scientific careers.
Self-efficacy and gender

Starting in grade seven, girls tend to underestimate their abilities in Math and Science (3). Several studies (14-17) have documented that female students have lower self-efficacy in Math and Science compared to male students. Girls’ capabilities are undermined by sex-role stereotypes in many cultures intimating that females are not as able as males, especially in such disciplines as math and science (7, 9). Another contributing factor could be the lower level of expectations that parents, teachers, and counselors often hold for girls, which can discourage further study in scientific and technical fields (1, 3, 9, 18). Although girls’ math and science enrollments increased during the nineties and even exceeded boys in Biology and Chemistry, boys are still enrolled more often in physics and higher-level science courses than girls (1). Confidence is strongly correlated to students continuing in math and science courses (5, 18). In addition, males display more positive attitudes towards careers in science than females (12).

Regardless of gender, more career options, including potentially higher career aspirations, are considered by those possessing a high degree of self-efficacy (7). Self-efficacy can even predict career choice (10). Because of this influence, “efficacy beliefs partly shape the courses that lives take” (9). If females perceive their abilities to be low in math and science, a whole technological sector of highly-esteemed, high-paying careers may become off-limits to them. In two separate studies of high school Math students, (19) found that females had lower perceived ability levels in math than males. Low mathematical self-efficacy and inadequate high school math preparation, both being observed give rise to more often in females than in males, lower female aspirations for future study in scientific and technical fields (20). Math self-efficacy is a “critical factor” in career choice (10). Students with higher levels of math confidence earn better grades in college and pursue science majors more often (18). However,
mathematics confidence often declines in college and more so for women than men; but for women who pursue math and science majors, mathematics confidence increases (18). In addition to the studies mentioned here, a significant amount of research has found low mathematical self-efficacy in females. A study conducted in the seventh-graders found higher science self-efficacy in boys and also they intended to take more elective science classes (15, 17).

In a college general chemistry class, a statistically significant finding was reported with males scoring higher than females in science self-efficacy for laboratory skills (13). The study also mentioned that females had lower self-efficacy scores than males for the sciences; however, this finding was not statistically significant. High school males were found to have higher self-efficacy in physics, chemistry and in the laboratory. The same study found females scored higher in self-efficacy than males for biology (12). One point to consider is that the researchers only collected information from gifted and talented students and therefore, not all student ability levels were represented.

Perceived ability was the greatest predictor of semester grades for females in high school biology (21). Also, females’ perceived ability was negatively related to stereotyped beliefs about science. Effort, persistence, and achievement appeared to have a stronger association with perceived ability for females than for males in this population (21). DeBacker and Nelson (21) also found that high school girls scored lower than boys on perceived ability in biology, accelerated chemistry, physics, and advanced placement physics. The researchers expressed concern because regardless of achievement level, girls scored lower.

Most of the research has focused on junior and high school students and has shown that females have lower levels of self-efficacy in math and science classes. Little is known about whether such differences exist in student self-efficacy levels based on gender in college science,
excluding the Smist (13) study where attrition was a problem. Lower self-efficacy in female students is a concern because low self-efficacy has been linked to lower academic performance.

**Self-Efficacy and Academic Achievement**

Self-efficacy predicts intellectual performance better than skills alone, and it directly influences academic performance through cognition. Self-efficacy also indirectly affects perseverance (9, 22). Although past achievement raises self-efficacy, it is student interpretation of past successes and failures that may be responsible for subsequent success. Perceived self-efficacy predicts future achievement better than past performance (7, 17, 19, 23, 24). Self-efficacy beliefs also contribute to performance since they influence thought processes, motivation, and behavior (9). Fluctuations in performance may be explained by fluctuations in self-efficacy. For example, varying beliefs in self-efficacy may alter task outcome, whether it involves two similarly-skilled individuals or the same person in two different situations (9).

Individuals high in self-efficacy attempt challenging tasks more often, persist longer at them, and exert more effort. If there are failures, highly efficacious individuals attribute it to a lack of effort or an adverse environment. When they succeed, they credit their achievement to their abilities. The perception that their abilities caused the achievement affects the outcome rather than their actual abilities (7). “Those who regard themselves as inefficacious shy away from difficult tasks, slacken their efforts and give up readily in the face of difficulties, dwell on their personal deficiencies, lower their aspirations, and suffer much anxiety and stress. Such self-misgivings undermine performance”(7, p.395). Conversely, individuals with high self-efficacy frequently persevere despite difficult tasks or challenging odds and often succeed because perseverance usually results in a successful outcome (7). Numerous studies (9, 15, 23-25) link
self-efficacy to academic achievement. For example, in seventh grade Science and English classes, self-efficacy was positively related to cognitive engagement and academic performance (17). Self-efficacy, self-regulated learning, and test anxiety also were found to be the best performance predictors (17).

In a meta-analysis of 39 studies from 1977 to 1988, positive and statistically significant relationships were found among self-efficacy, academic performance, and persistence for a number of disciplines (22). Out of the studies analyzed, 28.9% involved higher education. Four factors affected the link between self-efficacy and academic performance. One factor was the time period when the two were assessed. A stronger relationship resulted post-treatment meaning that experimental manipulations to change self-efficacy beliefs were successful not only in raising self-efficacy but in enhancing academic performance as well. Another factor involved a stronger link between self-efficacy beliefs and performance for low-achieving students. A study (26) found a positive correlation between perceived ability, learning goals, and meaningful cognitive engagement which then influenced academic achievement in college students enrolled in educational psychology. Additional analysis supported this causal model of perceived ability and learning goals leading to meaningful cognitive engagement which then led to academic achievement (19). They cautioned that the variables of rewards and penalties, strategies, and other self-regulatory activities, not specifically addressed by their study, could have influences on achievement (19). One criticism of their research is they measured achievement by only using one midterm exam score from the course. Also, they administered their instrument immediately before students took the midterm exam. Test anxiety may have affected the outcome.

In two studies conducted (19) perceived ability was the best predictor of achievement for high school math students. According to numerous studies, cognitive skills, modeling, feedback
and goal-setting together affected self-efficacy beliefs that, in turn, affected performance (27). Student-held beliefs affected the amount of effort and perseverance they engaged which subsequently influenced achievement (25).

Many studies support a link between self-efficacy and academic achievement, especially for junior and high school students. The connection is less clear in higher education with some studies supporting a connection and others not finding one.

**Self-Efficacy in Higher Education**

Few studies have investigated the relationship between self-efficacy and academic achievement in higher education. Of the college studies mentioned here, most (19, 22-24, 28) support a connection between self-efficacy and academic achievement. In general, students at the college level need to be self-directed and take greater responsibility for their learning. Students possessing a high degree of self-efficacy are more successful at accomplishing these tasks and as a result, perform better academically (5). Accordingly, self-efficacy beliefs are “crucial” when applied to the cognitive demands of higher education (9).

Stronger relationships were found between self-efficacy and performance for high school and college students when compared to younger students in a meta-analysis of 39 self-efficacy studies (22). Out of the studies included, 28.9 % involved higher education. However, from the list of studies analyzed, it was unclear how many, if any, involved science classes. The previously mentioned study (26) found a positive correlation between perceived ability, learning goals, and meaningful cognitive engagement which then influenced college achievement. Two different studies measured self-efficacy in two-year college students and reported conflicting results. In nontraditional associate degree nursing students, self-efficacy was not found to predict
academic achievement (29). Academic variables, such as study hours, study skills, and absenteeism, were the only statistically significant contributors to students’ achievement. Reliability for academic variable measurement in this study, however, was slightly below an acceptable limit (29). In contrast, another study (28) found self-efficacy positively related to achievement in social science classes for community college students.

A study of college students found academic self-efficacy to be significantly more predictive of career choice than academic achievement (30). The study also found semester academic performance was positively influenced by perceived goals and previous academic experience, instead of self-efficacy (30). The researcher stated her findings do not negate self-efficacy’s mediating influence on past achievement and thus, self-efficacy could contribute to academic achievement via this mediatory role. Other studies (17, 22, 26) support the mediating effects self-efficacy has on academic achievement.

STATEMENT OF THE PROBLEM

Analytical Chemistry I (ACI) is one of the main branches among chemistry courses. It is widely used to determine, separate and characterize both organic and inorganic molecules qualitatively as well as quantitatively. 85% of the contents of the course need numerical calculations of computing concentrations of acids, bases and salts. Thus, students are expected to have a skill of solving mathematical problems.

But through my teaching experience of this course at DMCTE, the interest of male and female students towards the course in the class decreased from time to time. Even if the participations of male students in the lecture class were not that much satisfactory, the problem is severe for female students. Actually, their poor participations in the course were similarly
reflected in their final exams. As a result, the number of students (more of females) retaking the course increased from time to time.

As a chemistry instructor, investigating the level of both male and female students’ self-efficacy in the course and also finding whether academic achievement is influential on self-efficacy is very important.

The main purpose of this study was therefore to identify DMCTE second year Chemistry and Biology students’ levels of self-efficacy during the fall 2011/12 first semester in ACI. This research also investigated whether there were differences in self-efficacy and academic achievement based on gender. To assist and develop the outlook of students in both sexes towards chemistry, identifying their level of self-efficacy is very important.

The outcome of this study is expected to:

- determine the self-efficacy level of students in ACI course
- find whether there is a relationship between academic achievement and self-efficacy based on gender in ACI

For the purpose of this research, the term “self-efficacy” is operationally defined as DMCTE Chemistry and Biology major students’ belief of achieving a good grade in ACI course. Likewise the term “academic achievement” is operationally defined as the letter grade that DMCTE Chemistry and Biology major students have obtained after taking the course ACI.

RESEARCH QUESTIONS

There were four research questions this study answered. They were:

i. What was the self-efficacy level of DMCTE students’ who registered for the course Analytical Chemistry I?
ii. Was there a difference in self-efficacy with gender?

iii. Was there a difference of academic achievement with gender?

iv. Was there a relationship between self-efficacy and academic achievement in ACI?

METHODOLOGY

Participants

The participants of this study were students of DMCTE who originally came from eleven administrative zones of the Amhara region. Students enrolled in the course ACI at DMCTE during the fall 2011/12 first semester were asked to voluntarily respond to the class survey in February 2012. 110 students (50%) out of 222 enrolled in ACI were chosen using systematic random sampling and asked to participate in this study. Out of 110 students, only 100 completed the survey, and took the Analytical Chemistry achievement test which gave a response rate of 90%. Of the students enrolled in ACI during the fall 2011/12 first semester, nearly half (49.6%) were Chemistry major students and the remaining students were Biology major. Subjects included 45 females (41%) and 55 males (50%). The remaining 9% did not complete the survey and hence did not take the Analytical Chemistry achievement test. Moreover, I took 30 (20 males, 66.67% and 10 females, 33.33%) available students for focus group discussion from the sample students in order to strengthen the values obtained from their self-efficacy surveys and final examination records.

Instruments for data collection

I adapted self-efficacy scale developed by Diane L. Witt-Rose (31) and I constructed the surveys by considering the three domains of educational objectives, namely the cognitive, affective and psychomotor. In addition, three psychology instructors critically assessed and
finally modified this instrument that ended up with a total of 15 self-efficacy test items. Student self-efficacy scale made up of five point Likert scale of strongly agree (SA), agree (A), neutral (N), disagree (DA) and strongly disagree (SD) corresponding to 5, 4, 3, 2, and 1 point respectively for positive statements and the reverse for negative statements was applied.

Students’ achievement test made up of 40 objective questions with true-false, multiple choice and short answer items was extracted from Analytical Chemistry I (Chem 122) course and given to them by that particular semester. To make the instrument valid, the achievement test was examined by four DMCTE chemistry instructors. I administered the questionnaire (pilot test) for 30 students that were not part of the study and calculated item total correlations, and finally some items were modified and some were rejected.

Students’ focus group discussion conducted based on four open ended questions which would help the researcher to investigate the main factors which brought a significant difference between male and female students’ self-efficacy and academic achievement in ACI.

Procedures

Before the study commenced, permission was sought and granted by all students to be surveyed, tested and to discuss in group. The survey and the achievement test were presented to students two weeks after they registered for the course and the day after completing their first semester final examination, respectively. These instruments administered to the volunteers and took about two hours to complete the test. To ensure confidentiality and reduce researcher bias, a separate list was created linking student survey numbers to either their names or student identification numbers on the test. This list was kept separate from the survey data. Finally I took 30 (20 male and 10 female available students) from the sample population and invited to reflect freely about their obstacles to develop low self-efficacy and academic achievement in ACI.
Statistical Analyses

After the data were in spreadsheet form, negatively-worded statements that were included to ensure reliability were recorded to positively-worded ones. Total self-efficacy scores were then calculated by summing the scores for all 15 Likert items. The data were then analyzed using appropriate descriptive and inferential statistics using SPSS. Descriptive statistics included computing means and standard deviations and reporting number and percent for each demographic choice. t-tests were run to determine statistical significance and difference. In the focus group discussion, the qualitative data was analyzed by percentage.

RESULTS

Demographics

As stated earlier 110 students out of 222 enrolled in ACI were chosen using systematic random sampling and asked to participate in this study. Out of 110 students, only 100 students had completed the self-efficacy questionnaires and took the Analytical Chemistry Achievement test. This sample population includes 45 female (40.9 %) and 55 male students (50 %). Since only 100 students responded we will use this size as the sample size in the ensuing pages.

Demographic items include college status, number of completed college semesters, whether the students were retaking the course or not, major fields of study and gender. Roughly two third of the samples were regular students (86.2 %). Most students (99.8 %) had never taken ACI before. Students had nearly the same degrees of college experience, three completed college semesters (84.5 %), as indicated in Table 1 below.
Table 1. Description of the sample (N=100)

<table>
<thead>
<tr>
<th>Items</th>
<th>Frequency(N)</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>55</td>
<td>55%</td>
</tr>
<tr>
<td>Female</td>
<td>45</td>
<td>45%</td>
</tr>
<tr>
<td>Field of study</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemistry</td>
<td>60</td>
<td>54.5%</td>
</tr>
<tr>
<td>Biology</td>
<td>40</td>
<td>36.4%</td>
</tr>
<tr>
<td>Retaking the course</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>6</td>
<td>5%</td>
</tr>
<tr>
<td>No</td>
<td>94</td>
<td>95%</td>
</tr>
<tr>
<td>Number of completed college semester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>89</td>
<td>84.5%</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>16.3%</td>
</tr>
<tr>
<td>&gt;4</td>
<td>2</td>
<td>2.8%</td>
</tr>
</tbody>
</table>

Self-efficacy

Self-efficacy survey questions (Question 6 to 20) were Likert type items with 5-point scale (1 = strongly disagree to 5 = strongly agree). These items measured self-efficacy level and included statements such as: *I am confident I can do well in ACI* and *I don’t think I will get a good grade in ACI*. All statements were positively worded except for items 9, 12, 14, and 19, which were negatively worded to increase the instrument’s reliability. Likert items produced numerical data at the ordinal scale of measurement.

Students agreed most with items 6, 7, 17, and 18. These item statements included: *I am confident I have the ability to learn the material taught in ACI*; *I am confident I can do well in ACI*; *I am confident I can do well in the lab work for ACI*; and *I think I will receive a better grade in ACI*. Most students disagree with items 9 and 19 which stated: *I don’t think I will be successful in ACI* and *I don’t think I will get a good grade in ACI*. 
Was there a difference in self-efficacy & achievement of students based on gender?

Before determining the existence of difference in self-efficacy between male and female students it is essential to compute their level of self-efficacy of the total and the sexes separately. It is known that 5 point Likert scale scores for a 15 items questionnaire range from 15 to 75. According to Diane L. Witt-Rose (31) scores greater than or equal to 60 were classified as high self-efficacy, scores from 31 to 59 were classified as moderate self-efficacy, and scores less than or equal to 30 were classified as low self-efficacy. Total self-efficacy scores for each student in this study ranged from 31 to 61. The mean total self-efficacy score was 50.08 with standard deviations of 6.09 (Table 2). Therefore, 50.08 is a score just below a high level of self-efficacy.

Table 2. Means and Standard Deviations for Self-Efficacy Items

<table>
<thead>
<tr>
<th>Sex</th>
<th>Number</th>
<th>Mean Self Efficacy</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>45</td>
<td>49.13</td>
<td>5.52</td>
</tr>
<tr>
<td>Male</td>
<td>55</td>
<td>50.85</td>
<td>6.48</td>
</tr>
<tr>
<td>Total self-efficacy</td>
<td>100</td>
<td>50.08</td>
<td>6.09</td>
</tr>
</tbody>
</table>

Analytical Chemistry I achievement test measuring academic achievement produced numerical data at the interval scale of measurement. After the achievement test and self efficacy questionnaire were administered to the sample population (N=100), the data obtained were organized and means and standard deviations are computed. Mean of females’ self efficacy and achievement are 49.13 and 61.84 with standard deviations of 5.52 and 9.88, respectively. Mean of males’ self efficacy and achievement are 50.85 and 66.56 with standard deviations of 6.48 and 12.12, respectively. In addition, mean of total respondents’ self efficacy and achievement are 50.08 and 64.44 with standard deviations of 6.09 and 11.36, respectively (Table 3).
Table 3. Summary of Self Efficacy and Achievement by Gender

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Self Efficacy (Mean)</th>
<th>Std.Deviation</th>
<th>Achievement (Mean)</th>
<th>Std.Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>45</td>
<td>49.13</td>
<td>5.52</td>
<td>61.8444</td>
<td>9.88</td>
</tr>
<tr>
<td>Male</td>
<td>55</td>
<td>50.85</td>
<td>6.48</td>
<td>66.5636</td>
<td>12.12</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>50.08</td>
<td>6.09</td>
<td>64.204</td>
<td>11.36</td>
</tr>
</tbody>
</table>

A t-test was used to examine the difference in their total self-efficacy score that would exist between the sexes (gender). The mean self-efficacy score was 49.13 for females and 50.85 for males with standard deviations 5.52 and 6.48, respectively. Although the females’ collective self-efficacy score was slightly lower than the males’, this difference failed to reach significance as can be seen in Table 4.

Table 4. t-Test for Male and Female (Total Mean Efficacy)

<table>
<thead>
<tr>
<th></th>
<th>Sex</th>
<th>N</th>
<th>Mean</th>
<th>Std.deviation</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self- Efficacy</td>
<td>F</td>
<td>45</td>
<td>49.13</td>
<td>5.52</td>
<td>-1.412</td>
<td>98</td>
<td>0.161</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>55</td>
<td>50.85</td>
<td>6.48</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Equal variances assumed

A t-test was used to examine the difference in their ACI achievement test results that would exist between the sexes (gender). The mean achievement test result was 61.8444 for females and 66.5636 for males with standard deviations 9.88 and 12.12, respectively. Here, females’ mean achievement test result was lower than the males’ one. This is statistically significant at 0.1 levels with 95% confidence level between genders with their achievement.

Table 5. t-test for ACI Achievement Test Results for Both Males and Females

<table>
<thead>
<tr>
<th>Achievement</th>
<th>Sex</th>
<th>N</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>df</th>
<th>t</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>45</td>
<td>61.8444</td>
<td>9.88</td>
<td>98</td>
<td>2.101</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>55</td>
<td>66.5636</td>
<td>12.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Equal variances assumed
Was there a relationship between self-efficacy and academic achievement in Analytical chemistry I (ACI)?

Relations between students’ total self-efficacy and their achievement in ACI were calculated using Pearson correlation coefficient (r). Therefore, correlation between achievement and self-efficacy for both sexes becomes $r=0.385$, which is statistically significant at 0.01 with 98 degree of freedom (2-tailed). Correlation between achievement and self-efficacy for females only becomes $r=0.377^*$, which is statistically significant at 0.05 with 45 degree of freedom (2-tailed). Correlation between achievement and self-efficacy for males only becomes $r=0.362$, which is statistically significant at 0.01 with 55 degree of freedom (2-tailed).

From qualitative data, the following results are also obtained. At focus group discussions, female students reflect as they are confident enough to solve problems equally with males. This idea of females is also acknowledged by their male peers. However, their achievement result is observed to be lower than that of males. They believe some of the reasons for this disparity are lack of information about the examinations, lower school background, excessive negative test anxieties and inabilities to manipulate calculators.

DISCUSSIONS

Was There a Difference in Self Efficacy & Achievement for Students Based on Gender?

From the analysis of the self-efficacy survey data, the following result is obtained. Students’ mean total self-efficacy score is 50.08 and their self efficacy scores are found to be in the range from 31 to 61. According to Diane L. Witt-Rose (31) scores greater than or equal to 60 were classified as high self-efficacy, scores from 31 to 59 were classified as moderate self-efficacy, and scores less than or equal to 30 were classified as low self-efficacy. In this
research, a score of 61 is the highest possible level investigated while a score of 31 is the lowest self-efficacy score. Therefore, most students in the sample are in moderate levels of self-efficacy in ACI.

According to Bandura (9) students possessing moderate or higher self-efficacy will be more successful in college, whereas those who lack the belief and abilities for success became inefficient and may avoid higher education altogether. Therefore, according to my analysis students who are enrolled in ACI at DMCTE to learn the subject with their choice have no serious problem in their self-efficacy at the beginning. However, self-efficacy can change over time (7). From the analysis of the self-efficacy survey data, there is no significant difference observed between female and male students. That is, females are confident in solving problems equally with males. However, from the focus group discussions it was clear that female students judging male students’ as more active participants in the class, they fear that their confidence will not persist with them. Knowing that letter grades in DMCTE is norm referenced, female students expect their result in ACI will be lower than males. Therefore, it is expected that the moderate level self efficacy investigated in this research may decline to lower level due to the effect of norm referenced assessment (when they compare themselves with their classmates in the college) and other possible reasons. This result highly supports the discussion made above. From the total discussion it seems that significant number of students from the sample population probably will develop negative self efficacy in ACI as summative assessments are approaching.

In relation to differences between male and female students in their self-efficacy and academic achievement, research studies conducted at the secondary school level indicate that there exists a gender difference in science self-efficacy (21). However, Smist (13) found opposite
result, in which there is no significant gender difference in their self-efficacy in college chemistry with exception of laboratory skills (males scored higher than females).

According to the analysis in this research, the females’ mean self-efficacy score (49.13) was slightly lower than males’ (50.85) even though this difference failed to reach significance (p=0.19). This research result replicates the results found by the above researcher (13). The slight difference observed between the sexes may be due to the inclusion of chemistry laboratory tasks in the self efficacy survey.

In the analysis, the mean of females’ achievement score is 61.84 with standard deviation 9.88, and the mean of males’ achievement score is 66.56 with standard deviation 12.12. Here, females’ mean achievement test result was lower than the males’. Above all, t-test indicates presence of a statistical difference in achievement between the sexes at 0.1 levels with 95% degree of confidence. The same result was previously found (8, 21).

Therefore, from the above discussions, we can conclude that males and females differ in their ACI despite their initially perceived similar abilities. This may be because of lack of basic study skills, inability to handle materials necessary in the examination which is raised in the focus group discussions.

**Was There a Relation Ship between Self-efficacy & Academic Achievement in Analytical Chemistry I (ACI)?**

Female and male students’ achievement and self-efficacy are positively correlated, (r=0.377 and r=0.362), which are statistically significant at 0.05 and 0.01 with 45 and 55 degree of freedom (2-tailed), respectively. In addition, total students’ achievement and self-efficacy are positively correlated (r=0.385), which is also statistically significant at 0.01 with 98 degree of
freedom (2-tailed). Some previous studies support this result; there exists positive link between self-efficacy and academic achievement (6, 9).

Therefore, according to the above discussion, students’ achievement is highly related to their inbuilt self efficacy. However, only few studies have been conducted investigating the relations between self-efficacy and academic achievement in college science in general and in chemistry in particular.

CONCLUSIONS

This study has investigated the level of students’ self-efficacy and their achievement in analytical chemistry I (ACI) and identified the difference in self efficacy and achievement between the males and females and determines relationships between the two variables. The total students’ mean self-efficacy level is found to be medium (50.08). The mean score of their achievement in ACI test is 61. Both males and females have no significant difference in self-efficacy. However, female students’ self efficacy is slightly lower than that of males. In addition, it was investigated that because of self evaluation in class participations and knowledge of the college’s norm referenced evaluation system, female students had developed a fear of not getting better results, which entirely would affect their achievement in analytical chemistry test.

In addition, their self-efficacy and achievement are positively and significantly related. Since student self-efficacy beliefs were found to be significantly and positively related to their achievement in analytical chemistry in this study, the importance of self-efficacy’s influence on academic performance in science fields cannot be underestimated. According to Bandura (9) efficacy beliefs partly shape the courses that lives take. Therefore as student self-efficacy and
academic achievement are highly connected, educators and counselors should identify students with low self-efficacy and then implement methods to raise the low student self-efficacy levels.

RECOMMENDATIONS

Because of the significant link between self-efficacy and achievement in ACI, it is highly recommended that educators and counselors assess the existing levels of self-efficacy in students at classroom level. If lower levels of self-efficacy are identified, then appropriate measures should be taken to help raise student self-efficacy levels. The primary factors that determine self-efficacy such as enactive mastery experience, vicarious experience, verbal persuasion, and physiological and emotional states (7, 9) are prime targets on which educators and counselors should focus their efforts. Additional areas that can be addressed to help increase student self-efficacy would be goal-setting, rewards and active learning. Finally, the following recommendations are forwarded:

- Teachers should be responsible to their students to enhance students self-efficacy.
- Additional tuition should be provided for female students to increase their achievement.
- Counselors and educators should give continuous advice and develop techniques that help lower anxiety and reduce stress, to increase students self-efficacy

For further research, it is necessary to consider the following issues:

- Control of extraneous variables is advised. For example, factors which may influence academic achievement such as educational background, aptitude, attitude, motivation, and past academic achievement were not controlled in this study.
• Measuring different science disciplines and comparing science and non-science majors are also recommended. A comparison of science self-efficacy between second-year and third-year students may also reveal interesting information.

• Even if there is no significant difference between males and females in self-efficacy in this research, there is significant difference in academic achievement so, further researchers need to focus on identifying those factors that brought this difference.

REFERENCES


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ABSTRACT

The purpose of the study was to compare chemistry teachers’ answers in a question related to evaporation with that of their senior secondary students. Two hundred and seventy six senior secondary students and their seven teachers participated in the study. The main data collecting instrument was the pictorial and verbal tests in evaporation. According to some teachers (57.14%) when water in a closed container evaporates, no particles would be noticed while about 42.86% of the teachers believe that evaporated water will contain more of water molecules and less than is found in the liquid water. Students’ choice of answers to the evaporation question cut across all the options ranging from molecules of oxygen and molecules of hydrogen to water molecules present in evaporated water but less than is found in the liquid water. These and other observations were discussed in the study. Implications for chemical education were considered. [AJCE, 3(1), January 2013]
INTRODUCTION

One major objective of teaching Chemistry is to ensure that students learn chemical concepts meaningfully. Teachers find out what students have learnt in chemistry through evaluation. One form of such evaluation is testing. Testing exposes students’ learning difficulties in subject matter and indeed in chemistry. Two issues need to be considered in students’ achievement in chemistry. Firstly, what students learn and how they view science and indeed chemistry are greatly influenced by how they are taught. Secondly, teachers tend to teach using the same methods and in the same ways they are taught. Although these observations are made for general science teaching, they have implications for chemistry teaching. Following the observations, chemistry students may perform as they are taught.

Educational reform initiatives have identified the need for giving increased attention to teachers’ knowledge base and ability in educational testing and assessment. Researchers in chemical education have since changed focus along this direction. For instance, in one research work (1) teachers’ estimations of students’ performance and actual students’ achievement were studied. The study revealed that chemistry teachers tend to overestimate their students’ level of achievement on the conceptual understanding test in chemistry. Teachers feel that most of their students have appropriate or partial understanding of chemical concepts and principles. Chemistry teachers’ overestimation of their students’ performance could also reveal that teachers lack adequate understanding about their students’ difficulties in learning chemistry.

Another research (2) has also pointed out that every mistake made by students is quickly judged as a misconception, without further reflection on the actual source of the problem or any analysis of the underlying patterns in the students’ reasoning that might in fact be used as a source to promote understanding.
For years, practitioners and researchers have explored how to better assist students in developing a robust conceptual understanding of chemistry. Three levels of chemical representations include macroscopic (observable properties and processes), microscopic (arrangement and motions of particles), and symbolic (chemical and mathematical notations and equations) (3). Many fundamental concepts in chemistry involve microscopic and symbolic representations, which are especially difficult for students to learn. Students’ understandings rely primarily on sensory experiences that provide information about tangible, macroscopic phenomena rather than particulate-level explanations.

To support students’ understandings, teachers’ structured and deep conceptual knowledge base must include the ability to translate among the macroscopic, microscopic, and symbolic representations of chemistry, and specifically, in making meaningful connections between observations of macroscopic phenomena and explanations at the particulate level (4).

In a study (5) designed to compare chemistry teachers’ conception with that of the college students, teachers performed better than the students on the Chemistry Concept Inventory. One finding in that study is relevant in the present study. This has to do with the teachers’ conception of evaporation. The study noted that 30% of the teachers did not understand the concentration behavior of the saturated solution, stating that as water evaporates, the concentration of salt in solution goes up. Obviously, these teachers give this information to their students. Teachers have often not been exposed to situations that challenge the validity of their constructed idea, and thus they may be unaware of their own misconceptions, much less see a need to provide such meaningful situations to their students.

This study is therefore designed to assess the performance of chemistry students and that of their teachers with the view of finding out what misconceptions teachers held in the concept of
evaporations that would have been held by their students. Specifically, the researcher attempted to provide answers to the following research questions:

(i) What are the teachers’ answers to the questions on evaporation?
(ii) What are the students’ answers to the questions on evaporation?
(iii) How do the teachers’ answers compare with the answers of the students in questions on evaporation?

METHODOLOGY

Sample

Two hundred and seventy six [276] senior secondary students from a university demonstration school and their seven teachers participated in the study. The students were made up of eighty nine [89] year 1 (SS1), ninety [90] year 2 (SS2), and ninety seven [97] year 3 (SS3) senior secondary students. These students were all offering chemistry as one of the subjects to be taken in Senior Secondary Certificate Examination. The students indicated interest to participate in the study after they were informed about the nature and the purpose of the study. Seven [7] chemistry teachers that taught the students participated in the study. These teachers have been teaching chemistry for the past ten years.

Instrument

Evaporation Test was the main data collecting instrument of the study. This test is made up of two components—the pictorial form and the verbal form. The pictorial form consists of two containers, one containing some liquid water and the other empty showing evaporated water. Students were presented with a magnified view of a very small portion of the liquid water in a closed container without air. Students were required to find out what the magnified view would
show after the liquid water had evaporated. This is similar with the test used in another study (6). Verbal form of the test was a Multiple Choice Objective Test item that required the students to find out the nature of evaporated water in a closed container (see fig. 1 for the evaporation test).

**Pictorial Form**

The magnified view of a very small portion of liquid water in a closed container without any air would show us the molecules of water. What would the magnified view show after the water evaporated?

? =

\[\begin{array}{c}
A \\
B \\
C \\
D \\
E 
\end{array}\]

**Verbal Form**

Which of these would illustrate the nature of evaporated water in a closed container?
A  Molecules of oxygen and molecules of hydrogen
B  Some water molecules, atoms of oxygen, and atoms of hydrogen
C  Nothing, no particles would be noticed
D  Atoms of oxygen and atoms of hydrogen
E  Water molecules, but less than in liquid water

*Fig 1: Evaporation Test: Pictorial and Verbal Forms*
Opinions of these forms of test were sought from four practicing chemistry teachers who had taught chemistry for over ten years at the secondary school level. These teachers were not part of those used for the main study. These teachers were to ascertain the suitability of the test for the purpose of the study as regard students’ and teachers’ choices of answers related to evaporation questions. Notably this test item has been used before in studies (6-8).

Each correct answer for both the pictorial and verbal forms was scored one point respectively. Incorrect answer was scored zero. Option E in both the pictorial and verbal forms of the test item represented the answers.

**Administration of the Test**

The researcher sought permission from the authority of school and explained to her the nature and the purpose of the study. Teachers, other than those used for the study in the school were called in to assist in the administration of the test. The researcher also explained to the students the nature and the purpose of the study. Students who were interested participated in the study. Students who were not interested were allowed to leave the examination hall. Pictorial form of the test was administered first which took five minutes followed by the verbal form which took another five minutes to complete. Answer scripts of the students were withdrawn after each administration. The researcher personally administered the test to the teachers following the order it was administered on the students. Administration of the test to the students and the teachers took such a short time that the participants were excited that they participated in such a study.
RESULTS AND DISCUSSIONS

Some major findings are revealed in table 1 regarding the answers picked by the chemistry teachers.

Table 1: Teachers’ and Students’ Answers (%) to Pictorial and Verbal Test Items

<table>
<thead>
<tr>
<th>Academic Level</th>
<th>Pictorial Test Item (PTI)</th>
<th>Verbal Test Item (VTI)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Answer options</td>
<td>Answer options</td>
<td>X²</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>SS1 (n=89)</td>
<td>11.23</td>
<td>15.73</td>
<td>35.95</td>
</tr>
<tr>
<td>SS2 (n =90)</td>
<td>16.67</td>
<td>15.55</td>
<td>28.89</td>
</tr>
<tr>
<td>SS3 (n=97)</td>
<td>25.77</td>
<td>15.46</td>
<td>23.71</td>
</tr>
<tr>
<td>Overall (n = 276)</td>
<td>17.89</td>
<td>15.58</td>
<td>29.52</td>
</tr>
<tr>
<td>Teachers (n =7)</td>
<td>-</td>
<td>-</td>
<td>57.14</td>
</tr>
</tbody>
</table>

*Significant at P<.05, df = 4

These findings are centered on answer options C and E for the Pictorial Test Item (PTI) and the Verbal Test Item (VTI). These options show the thinking of the teachers that evaporated water consists of (i) an empty space as indicated by more than half of the teachers and (ii) few molecules of water as indicated by less than half of the teachers. This is for the PTI. This is further corroborated by answers given by the teachers in the VTI, thus option C shows “nothing, no particle would be noticed” and option E “Water molecules, but less than in liquid water”.

Students’ answers gave a wide range of what they think about evaporated water, namely:

(i) Over 17% of the total number of students indicated that it consists of hydrogen and oxygen molecules. SS1 had the least number of students who thought this way;

(ii) About 15% of the total number of students thought that evaporated water consists of molecules of water, few hydrogen and oxygen atoms;

(iii) Over 29% of the total number of students reasoned that evaporated water consists of “nothing”. The trend here is that more SS1 than SS2 and SS3 had this conception;
Evaporated water is made up of mainly hydrogen and oxygen atoms. Over 20% of the students chose this answer;

About 15% of the total number of students got the correct answer that evaporated water is made up of few molecules of water (option, E);

Comparing teachers’ answers with that of the students’ show that while students answers were on the five options, teachers’ answers were only on two (C and E);

Except for the teachers and SS2, there were significant differences in the frequencies of students’ responses to the answer options of the pictorial and the verbal test items.

A recent study (9) found that students’ performance on Multiple Choice exam questions depend strongly on the placement of questions and answers, with the answer order probably being the more important factor. One is not sure whether public examination bodies in Nigeria such as West African Examination Council (WAEC) and National Examination Council (NECO) consider this idea in preparing Multiple Choice examinations of various subjects they examine. The concern of the present study was not to probe what the examination bodies do. Before the students proceed to the level of writing these examinations, they have had formal instructions in the classrooms. The students, no doubt, are also familiar with multiple choice examinations. In this case teacher-made tests are placed in the picture.

In this context, it is the teacher-made test in chemistry, and specifically, a topic concerning evaporation. Students are always being assessed by their teachers. Teachers do a lot with students’ assessment. For example, such assessments are used for promotion from one lower level to a higher level, classification, for scholarship award and for feedback. Students’ poor performance on SSCE chemistry in June 2008 raised a lot of questions concerning how
teachers carried out their duties. Do the chemistry teachers possess the required content knowledge to teach Senior Secondary Students?

Although the present study is more or less a pilot study, it exposed teacher-learner link in chemistry. In the test given to the students in which their teachers were requested to respond to, variations of teacher-teacher answers, teacher-student answers and student-student answers were observed. What quickly draws one’s attention is the responses of the teacher and that of the students to the test item. While students’ responses cut across the five options given for both the pictorial and verbal test items, teachers’ responses were restricted to only two. This seems to suggest, in a way, that teachers show particular interest in teaching some chemistry topics at the expense of others. Possibly students are left on their own to study such topics that are not taught by the teachers. Teachers should try as much as possible to cover all the topics in chemistry syllabus knowing full well that the examination body can pick question from any part of the syllabus. In this light, science educators and indeed chemical educators have advocated team teaching in order to help students fully grapple with all aspects of the chemistry content.

Regarding the test on evaporation, students and teachers showed indications of misconception. It is probable that students’ misconception arose from their teachers’ misconception. Students responded to the test items according to how they were taught. Further research need to confirm these assertions.

REFERENCES


A DIAGNOSTIC ASSESSMENT OF EIGHTH GRADE STUDENTS’ AND THEIR TEACHERS’ MISCONCEPTIONS ABOUT BASIC CHEMICAL CONCEPTS

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ABSTRACT

Even though many students at all levels struggle to learn chemistry and feel its exact essence, they are often unsuccessful. In this regard, most studies identified that the key cause of such failure to succeed especially in post primary and college education is formations of misconceptions towards basic chemistry/science concepts from the very beginning in primary education. However, what these studies couldn’t exactly figure out is all about the possible source and cause of such misconceptions. Hence, in this study, it was aimed to diagnose both teachers’ and students’ misconceptions about five basic chemistry concepts (particulate nature of matter, physical state of matter, distinguishing differences of chemical and physical changes, phase changes and stoichiometry) and to examine the relevance and consistency of areas and intensity of students’ misconceptions with that of their teachers. As a result, a survey research method comprising of multi-tier chemistry misconception test (MTCMT) and an interview as data gathering instruments were employed by which eighth grade students and chemistry/science teachers from four second cycle primary schools found in Mettu Administrative Town were purposely selected as target populations. In the mean time, the MTCMT was administered for 64 students and 4 teachers as a pilot test, for 192 students and 6 teachers as a final version, and 32 students were finally interviewed to get detail information on their existing conception. As a result, many set of suspected and new misconceptions were found, and finally from the Pearson’s correlation, it was found that 90% of students’ misconceptions has a significant correlation with teachers misconceptions implying that teachers are responsible for most (90%) of their students’ misconceptions. [AJCE, 3(1), January 2013]
INTRODUCTION

Even though many students at all levels struggle to learn chemistry and feel its exact essence, they are often unsuccessful (1). Findings of many studies including (2) reveal that students’ performance on national and regional chemistry examinations had alarmingly been declining from year to year. In this regard, what findings of most studies identified is that the key cause of such failure to succeed especially in post primary and college education is formations of misconceptions towards basic chemistry/science concepts from the very beginning in primary education (3). It is clear that students use pre-existing conceptions constructed from reflection on previous experiences to reason about newly presented science concepts, and to make sense of their instructional science experiences (4).

If children could not develop the necessary understandings in basic scientific/chemical concepts from the very beginning, they couldn’t entertain more advanced concepts in a desired way later in high school and college (5). Because preconceptions are often incorrect from a scientific point of view they can interfere with students’ latter learning of science/chemistry concepts (6-7). Once misconceptions are created in students’ mind, they become very resistant to change and some of these students persist in giving answers consistent with their misconceptions even after large amounts of instruction (1). What a student learns results from the interaction between what is brought to the learning situation and what is experienced while in it (7). As a result, this aspect of chemical education has been given more emphasis in recent studies.

Basic and fundamental chemistry and science concepts, which are susceptible to misconceptions and misleading applications, have been considered in recent studies. More specifically, particulate nature of matter, physical state of matter, distinguishing chemical and physical changes, phase changes and stoichiometry are among the most frequent set of
Chemistry concepts studied (8-10), even though there is shortage of studies in our context. Still some researchers, based on their findings, argue that primary school science and chemistry teachers were also found to have such naïve ideas and misconceptions about basic chemical concepts (11).

However, what these studies couldn’t exactly figure out is all about the possible source and cause of such misconceptions. In this regard, it was hypothesized in this study that teachers could significantly be possible cause of students’ misconceptions. As a result, it was aimed to diagnose students’ and teachers’ misconceptions towards selected chemistry concepts, and correlate intensity and areas of students’ and teachers’ misconceptions

METHODOLOGY

In this study a survey research method was employed. The study comprised of two types of diagnostic tests which served as data gathering instruments. These are multi-tier chemistry misconception tests (MTCMT). The subjects of the study were 8th grade students and their chemistry/science teachers from four second-cycle primary schools in Western Ethiopia, Ilu Abba Bora Zone. From this zone second-cycle primary schools found in Mettu Administrative Town was selected using purposive sampling. These schools are Abuna Petros, Kidus Gebreal, Bubu and Nicholas Bohme Higher Primary School. In the first two schools there were respectively 146 (of which about 52% of them are females) and 280 (of which about 54% of them are females) eighth grade students. In the third and fourth schools there were respectively 135 (of which about 46% of them are females) and 146 (of which 52% of them are females) eighth grade students. On the other hand, there are 8 teachers teaching chemistry and basic science in the schools.
Three test groups were formed: pilot multi-tier chemistry misconception tests, revised multi-tier chemistry misconception tests and interview test groups. The purpose of the earlier was to examine standard of each item, while the last was employed to obtain in-depth information on students’ prior knowledge, logical reasoning, mental representation and confidence level.

In the course of the study, related literatures were exhaustively consulted to find existing students’ misconceptions towards the selected concepts. Next, a pilot multi-tier chemistry misconception test comprising of 14 main items was accordingly prepared and administered for 64 students and three teachers. Then its results were analyzed and some items were accordingly re-written, and the revised version was administered for 192 students and six chemistry/science teachers. Finally a semi-structured interview was prepared and administered for 32 students.

To simplify the task of data analysis, respective responses and answer were assigned in to three categories. These categories are responses showing correct or desired conceptions, alternative conceptions and missed understandings. Based on the respective values of these categories, proportions of students’ scores and teachers’ misconceptions were computed in terms of each concept, topics and sub-topics. Finally comparison of status and intensity of students’ and their teachers’ misconceptions was carried out to check consistency in terms of both frequency and areas of diagnosed misconceptions.

Regarding the drawing-based interview, categories of students’ responses and drawings were used. These categories are mostly assigned to five levels. The first category, level one, is only concerned with yes-or-no responses. The second level is all about non-representational drawings, while the third one represents drawings with misconception. The fourth and the fifth
levels are respectively concerned with partial drawings and comprehensive representational drawings.

According to these categories, drawings were evaluated. Based on this evaluation, students sketching drawings with misconception were additionally asked to give detailed descriptions on their own drawings. This was carried out to check validity of the interpretation of the drawings. Finally, obtained descriptions were compared with respective drawings.

RESULTs AND DISCUSSIONs

Diagnosed misconceptions and their categories

Information and data on students’ and teachers’ alternative conceptions were gathered through multi-tier chemistry misconceptions test (MTCMT) and interview. The MTCMT was employed for the matter of diagnosing, figuring out and computing existing alternative conceptions in a more quantitative manner, while the interview aimed at digging out in-depth qualitative information regarding mental representation, prior knowledge and logical reasoning with respect to selected chemical concepts. Anyway, data gathered through both instruments were categorized to and presented under the respective concepts, topics and sub-topics.

In addition, some new or unexpected misconceptions were also diagnosed in the course of this study. These misconceptions were said to be “new” or “unexpected” for being either completely new or ever appear in the addressed age, context and grade range of this study.

Particulate nature of matter

Regarding the nature and structure of an atom, about 72.9% of students perceive an atom as some kind of billiard object fully filled throughout by some other particles, while 66.67% of their teachers think so. Still about 58.33% of students and 50% of their teachers believe that an
atom of an element can be seen through microscope, have physical state and color like any other form of matter. From these students about 39.06% of them think physical state of an atom as it was liquid.

**Physical state of matter**

Regarding this chemical concept three multi-tier questions consisting of 9 items were employed to diagnose respective students’ and teachers’ misconceptions. The first question examines students’ and teachers’ conception of shape and structure of a single H₂O molecule. As a result, more than 41.17% of students and 16.67% (1 from 6 teachers) believe a single H₂O molecule has different shape and structure in solid, liquid and gaseous states. In their response to the second tier of this question, about 82.29% of students and 33.33% of their chemistry teachers inferred that river water and ice water are different in their chemical composition. Once again, 64.6% of students were found to think that molecules (particles) of water can experience motion only in liquid state; while still 17% of them think only gaseous particles or molecules can experience motion. However, most of their respective (about 83.3% of) teachers were found to have the desired conception. This implies students were led to such kind of misconception due to “flowing nature” of liquids.

Many recent studies shows that children usually think as a single molecule can have different shape, size, structure and even mass in different physical states. These children are of 9-12 years old. However, what makes this study special is that older students (aged 14 – 15 years) were found to share such alternative conceptions. From 32 eighth grade interviewed students, only 13 of them were found to think that the mass of a single H₂O molecule is constant in all three physical states, while the rest believe that a single H₂O molecule could be heavier in solid state (9 students) and in liquid state (10 students). In addition, in their response about the mass of
collected gaseous product from an engine of a car, about 21 of them inferred that it is less than that of liquid fuel found in the tanker of the car before burning. In their reasoning, more than 85% of them said something like “. . . because, gases are less heavy than liquids”.

Regarding size, all interviewed students believe that size of a single molecule, H$_2$O for example, will change as its physical state changes. From these students, 16 of them think a single H$_2$O molecule is larger in liquid state, while 12 and 4 of them respectively were found to believe that a single H$_2$O molecule is larger in solid and gaseous state.

Moreover, it was attempted to compare and contrast students’ diagrammatic representation of all the three states of water from their respective teachers’ drawings taken informally. In this comparison, it was found that among drawings of 32 interviewed students and 18 teachers, 17 of students’ and 16 of teachers’ belong to the following category. Drawings indicating correct and alternative conceptions are presented as follows.

![Figure 1: Teachers’ drawing showing correct conceptions](image-url)
For the matter of simplicity density related differences were deliberately ignored during evaluation of these for being unique for water. Interviewees were also informed during interview session to assume the amount of sample water as constant in all three states and all three containers as closed.
Figures 1 and 2 represent categories of students’ and teachers’ drawings showing desired conception. On the other hand, figures 3 and 4 represent teachers’ and students’ drawings indicating alternative conceptions, respectively. First, the size of corresponding circles or dots placed in an ice-representing one are larger than those of liquid water and vapor representing drawing. Second, these circles and dots in the first ice-representing drawing are larger than those of liquid water and vapor representing drawing. Such kind of representations could have two chemical implications—as \( \text{H}_2\text{O} \) molecule in ice could be broken into some kinds of other smaller molecules or particles and as number of molecules of water could increase in changing to liquid and gaseous states.

**Change of state, physical and chemical changes**

In this regard, different chemical events were given emphasis. Evaporation, cooling and heating of gaseous molecules, dissolving, rusting and burning of candle are among these events. Besides, some biased ways of lesson presentation and resulting conceptual perceptions were also entertained. Ways of explaining chemical compositions of simple molecules and compounds, for example, are among commonly miss-presented chemical topics. In this study too, about 48% of students and 16% of their teachers were found to use explanations like “. . . it [water] contain \( \text{H}_2 \) and \( \text{O}_2 \) in it”, as if oxygen and hydrogen molecules could independently exist in water.

i. **Evaporation**

Water was taken as first example and its change from liquid to gas (vapor) was given more emphasis. In the first tier of the diagnostic question, the entire respondents were found to be able to easily figure out this change as physical. However, on their response to what really happens to water during evaporation (in the second tier) a wide range of perceptions were found.
For example respondents believe that:

- The bond between O and H breaks (23.44% of students and 16.67% of teachers)
- Water changes to air (50% of students and 33.34% of teachers)
- Water disappears during evaporation (6.77% of students)
- Only intermolecular forces break during evaporation (18% of students)

From this distribution, it’s tangible that about 82% of students, except the last category were found to have set of misconceptions towards physical process of evaporation. The interview also revealed that more than 75% (24 out of 32) of students have such alternative conceptions. According to these students, water changes to hydrogen and oxygen gas on evaporation. The third tier of this question gives respondents the change to imagine a water sample being evaporated and think about chemical compositions of the bubbles formed in the mean time. As a result they think of the forming bubbles as:

- Dust particles (6.25%)
- Gases like O\(_2\), CO\(_2\) and H\(_2\) (79.16% of students and 50% of teachers)
- Just water (12.5%)

On the other hand, it should be noted that such kinds of naïve ideas are deep-rooted in that interview shows that about 65% (21 out of 32) of students believe spaces between molecules like H\(_2\)O in a water sample are filled with hydrogen, oxygen, carbon dioxide gases, dust and even germs and bacteria.

ii. **Heating and cooling of gases**

This aspect of chemistry/science education seems to be among hardly understood topics. Different studies revealed that children were mostly found to think mechanically about most of
scientific phenomena. Especially in earlier age, they were found to be led by what they have been seeing rather than by what they have been taught. They usually tend to think and feel macroscopically. As a result, for chemical process like diffusion, expansion, weakening of intermolecular attraction or repulsion they were found to use bursting, shrinking, growing, reproduction and so on.

In this study, too, more than 60% of students were found to have missed conceptions rather that alternative conceptions. However, about 18.23% of students and 16% of their teachers think that volume of gases increase up on heating because of the swelling of their molecules. Conversely, almost the same proportion of students and their chemistry teachers (respectively 21.35% and 16.67%) think volume of a gaseous sample decrease up on cooling because of shrinking of its molecules. No one seems to figure out the impact of temperature on intermolecular interaction, namely, attraction and repulsion between molecules of gas. In interview session also, when students were asked to remaining gaseous molecules in a partially evacuated cylinder, only about 12.5% (4 out of 32) of them were able to figure out and explain the spontaneously diffusing nature of gases. Students’ drawing showing desired conceptions (DC) and alternative conceptions (AC) are presented below (Figures 5 and 6).

![Fig 5: Students' drawing showing AC](image1)

![Fig 6: Students' drawing showing DC](image2)
iii. Dissolving

Among the total 192 students who took the multi-tier chemistry misconception test (MTCMT), about 87.5% of them agreed that dissolving some crystal of sugar as a physical change. In proceeding to the second tier of the respective question, which expose them to think about what really happens to the sugar during dissolving, most of them were found to raise different naive ideas. As a result about 26.56% of students and 16.67% of teachers believe that the sugar is lost or disappeared up on dissolving, while 60.42% of students and 50% of teachers believe sugar will be changed or transformed to water up on dissolving. Still 5.5% of students think sugar will decompose to its elements up on dissolving in water. Only 13.02% of students and 16.67% teachers were found to have the desired conception. From these students, in their response to the third tier which brings the events of dissolving to concept of conservation of mass and stoichiometry, about 49.47% of them were found to think that the mass of water remains constant whatever the mass of the sugar is, as the sugar is just disappeared or lost. Moreover, this figure reached 71% in the interview session. These students, in their reasoning said “. . . the mass of the solution will exactly equal to that of pure water because the sugar has just disappeared”.

iv. Rusting

Almost all students were found to have no problems of figuring out a chemical event happened when a nail is exposed to moisture and air. Because, only 5.2% and 2.6 of students and teachers respectively think the nail will melt and dissolve when exposed to moisture and air. However, different set of alternatives conceptions were found when this rusting issue is brought to the concept of conservation of mass or stoichiometry in the second tier. In this regard, only
30% of them were able to point out that the mass of the rust is greater than that of the nail due to combination of oxygen with the iron of the nail. The rest think the mass of the rust is:

- Greater than that of the nail due to addition of soil (12.5%)
- Less than the mass of the nail, because the nail itself is being eaten up (36.46% of students and 33.34% of teachers)
- Equal to the mass of the nail (35.42% of students and 16.67% of teachers)

v. Burning of a candle

Here the overall event of burning and lightening of candle was entertained as two separate processes. These are burning of the central part and the changes occur on the external part. More than 78% of students and 66.67% of their teachers identified the melting part of the candle as a physical change. The second tier of the question issued on this event offers students and respective teachers to think about the composition of the flame formed during burning of a candle. As a result, they were found to think it as:

- Just a flame (64.3% of students and 66.67% of teachers)
- Dust particles (5.22% of students)
- Right Conception; Hydrocarbon particles (13.02% of students and 16.67% of teachers)
- Oxygen and hydrogen gas (13.01% of students and 16.67% of teachers)

Stoichiometry

Under this chemical concept; balancing of chemical equations, analysis of reactant consumption and product formation proportion, the concept of limiting reactant and diagrammatic representations of atoms reacting and forming elements, molecules and
compounds were given more emphasis to diagnose alternative conceptions regarding conserving mass and difference between subscripts and coefficients. Most students and teachers have no problems of choosing the most possible numbers that kept a given chemical equation balanced. Significantly most of them were found to be unaware of the chemical meanings and implications of coefficient and subscripts, though they exactly know operational meanings of these terms.

Among the 156 students who were able to choose the right set of numbers of coefficients of simple chemical equation, such as reaction of oxygen and hydrogen to form water and reaction of nitrogen and hydrogen forming ammonia, only about 11.46% of them were found to be able to figure out the proportion of consumption of oxygen and hydrogen in the formation of water. About 50% of them think as all the reactant combine together whatever the proportion of reactant and ignoring the impact of limiting reactants. The rest 40% of them were found to have missed-understanding rather than missed conceptions.

Regarding diagrammatic representations of reacting and forming species, most teachers and students were found to have no clear mental representations of what they are teaching and learning, respectively. This is most probably missed-conceptions (lack of understanding) rather than alternative conception. For about 56.25% of students and 16.67% of teachers, for example, the following pictures are the same in every chemical and physical aspect. Moreover, this figure of students’ misconceptions and missed-understanding rose to 96.67% in the interview session. For instance,

\[ \text{\H}_{4} \quad \text{and} \quad \text{\H}_{2} \text{ as H} \text{ and} \quad \text{\H}_{5} \text{ as N} \text{ and NH}_{3} \text{ were considered the same.} \]

Such findings can be best amplified by the following attempts (drawings) of numerical and diagrammatical representation of balanced chemical equations of simple reactions.
Figure 7: Category of teachers’ drawing showing desired conceptions

Figure 8: Category of drawings (attempted only by teachers) showing alternative conceptions

Figure 9: Category of drawings (attempted by both teachers and students) showing alternative conceptions

Figure 10: Category of drawing showing alternative conceptions
Figure 7 from the above list represents a balanced and correctly represented chemical equation of a reaction by which water is formed. Unfortunately, none of the students attempted to represent such a balanced chemical equation using drawing. From the rest interviewed students, only one of them balance the chemical equation correctly and attempted to represent it using drawing, though the drawing falls to the alternative conceptions category of figure 9. As a result, only two students attempted to balance both numerically and diagrammatically. This implies that most students have no understanding in this regard, rather than alternative conceptions. Regarding teachers’ drawings informally obtained, 22%, 11%, 11% and 66% of them respectively fall to the figure 7, 8, 9 and 10 categories.

The next theme of stoichiometry brings students’ and their teachers’ attention to an event of burning a piece of wood. In the first tier of this theme, about 60.42% of students and almost all teachers have the desired conception in inferring that burning of wood can result in the formation of ash, soot, smoke and so on. The rest students were found to think only ash (9.89%), smoke (5.3%) and soot (19.79%) could be formed. However, surprisingly, about 68.23% of students think as the mass of all the products of a burning wood is less than that of the wood.

This implies that most of students have alternative conceptions and naive ideas about the stochiometric meaning of burning of wood. Similarly, during the interview, almost all students were able to figure out fuel burns in a car engine resulting release of gases. They were able to indentify this change as combustion reaction, a kind of chemical change. However, what these students respond differently on is the mass of collected gas. In this regard, about 62.5% (20 out of 32) of them think the overall mass of resulting gases will be less than that of the fuel. From these 62.5% of students, still about 18 of them believe that the mass of collected gases would be
less than that of liquid fuel. In their reasoning, they said “... because gaseous molecules are lighter than that of liquid molecules”.

On the other hand, about 83.33% of teachers didn’t agree with their students’ ideas. They believe the total mass of all products of a burning wood will exactly be equal to the mass of the wood. Still, such conceptions fall to the misconceptions categories because these teachers seem to forget the role, mass and addition of oxygen in the burning process.

**Correlation of students and their teachers’ misconceptions**

For better comparison, categories of alternative conceptions in terms of each concept and specific topic are presented below in table 1 with their respective frequencies.
Table 1: Correlations of frequencies of students' and teachers' misconceptions

<table>
<thead>
<tr>
<th>Concept</th>
<th>Specific topics</th>
<th>Category of Misconceptions</th>
<th>Frequencies</th>
<th>Pearson’s Correlation Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate nature of matter</td>
<td>1. Atom is like some kind of billiard object fully filled throughout by some other particles</td>
<td></td>
<td>72.91</td>
<td>66.67</td>
</tr>
<tr>
<td></td>
<td>2. atom of an element can be seen through microscope</td>
<td></td>
<td>58.33</td>
<td>33.33</td>
</tr>
<tr>
<td></td>
<td>3. atom of an element have physical state and color like any other form of matter</td>
<td></td>
<td>68.75</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>4. Atoms of elements exist in liquid state</td>
<td></td>
<td>39.06</td>
<td>16.67</td>
</tr>
<tr>
<td>Physical State of matter</td>
<td>1. A single H₂O molecule has different shape and structure in solid, liquid and gaseous state</td>
<td></td>
<td>69</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>2. river water and ice water are different in their chemical composition</td>
<td></td>
<td>82.92</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>3. molecules (particles) of water can experience motion only in liquid state</td>
<td></td>
<td>64.6</td>
<td>16.66</td>
</tr>
<tr>
<td>Evaporation</td>
<td>1. The bond between H and O breaks during evaporation</td>
<td></td>
<td>23.44</td>
<td>16.67</td>
</tr>
<tr>
<td>Change of State</td>
<td>2. Water is changed to air during evaporation</td>
<td></td>
<td>50</td>
<td>33.34</td>
</tr>
<tr>
<td></td>
<td>3. Water disappear during evaporation</td>
<td></td>
<td>6.77</td>
<td>-</td>
</tr>
<tr>
<td>Composition of bubble, water</td>
<td>1. The chemical compositions of bubbles formed during evaporation of water are dust particles</td>
<td></td>
<td>6.25</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2. The chemical compositions of bubbles formed during evaporation of water are gases like hydrogen, oxygen, carbon dioxide and so on</td>
<td></td>
<td>78</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>3. Water contain H₂ and O₂ molecules in it</td>
<td></td>
<td>48</td>
<td>16.67</td>
</tr>
<tr>
<td>Heating and Cooling of Gases, properties of gases</td>
<td>1. volume gases increase up on heating because of the swelling of their molecules</td>
<td></td>
<td>18.23</td>
<td>16.66</td>
</tr>
<tr>
<td></td>
<td>2. volume of a gaseous sample decrease up on cooling because of shrinking of its molecules</td>
<td></td>
<td>21.35</td>
<td>16.67</td>
</tr>
<tr>
<td>Physical and Chemical Change</td>
<td>Dissolving</td>
<td>1. the sugar is lost or disappeared up on dissolving</td>
<td>26.56</td>
<td>16.67</td>
</tr>
<tr>
<td></td>
<td>2. sugar will be changed or transformed to water up on dissolving</td>
<td></td>
<td>60.42</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>3. sugar will decompose to its elements up on dissolving in water</td>
<td></td>
<td>5.2</td>
<td>-</td>
</tr>
<tr>
<td>Rusting</td>
<td>1. A nail will be melted when exposed to moisture and air</td>
<td></td>
<td>5.2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2. A nail will be dissolve when exposed to moisture and air</td>
<td></td>
<td>2.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3. The mass of the rust is greater than that of the nail because of addition of soil</td>
<td></td>
<td>12.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>4. The mass of the rust is less than that of the nail because the nail is just eaten up</td>
<td></td>
<td>39.56</td>
<td>16.67</td>
</tr>
<tr>
<td></td>
<td>5. The mass of the rust is equal to that of the nail</td>
<td></td>
<td>35.42</td>
<td>33</td>
</tr>
<tr>
<td>Burning of Candle (Composition of flame formed by a burning candle)</td>
<td>1. Just flame</td>
<td></td>
<td>64.59</td>
<td>66.67</td>
</tr>
<tr>
<td></td>
<td>2. Dust particles</td>
<td></td>
<td>5.2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3. Gases like Oxygen, hydrogen, carbon dioxide and so on</td>
<td></td>
<td>13.02</td>
<td>16.67</td>
</tr>
<tr>
<td>Stoichiometry</td>
<td>Subscripts and coefficient</td>
<td>1. 2H₂ and H₂ are the same in every aspects</td>
<td>56.35</td>
<td>16.67</td>
</tr>
<tr>
<td></td>
<td>2. 2NH₃ and N₂H₄ are the same too!</td>
<td></td>
<td>55.72</td>
<td>16.66</td>
</tr>
<tr>
<td></td>
<td>Limiting reactant and Stoichiometry</td>
<td>1. All the reacting species combine together whatever their proportion is</td>
<td>50</td>
<td>16.67</td>
</tr>
<tr>
<td></td>
<td>2. The mass of all products of burning wood is less than that of the wood</td>
<td></td>
<td>70.83</td>
<td>16.67</td>
</tr>
<tr>
<td></td>
<td>3. The mass of all products of burning wood is equal to that of the wood</td>
<td></td>
<td>28.12</td>
<td>83.33</td>
</tr>
</tbody>
</table>
As can be understood from table 1, intensity or frequencies of students’ and teachers’ misconceptions have significant (and even perfect) correlation for most concepts and specific topics. Only the correlation of diagnosed alternative conceptions of students’ and teachers’ about one concept (stoichiometry, specifically the concept of limiting reactants) shows negative correlation. As a result, frequencies of students’ and teachers’ alternative conceptions towards 9 specific topics categorized under selected five concepts were found to have significant correlations. This implies that teachers are responsible for almost all (90%) of their students’ misconceptions. From all specific topics, rusting was found to be less susceptible to misconceptions or alternative conceptions. On the other hand, particulate nature of matter, physical state of matter and stoichiometry were found to be the most alternatively perceived concepts.

**New or unexpected alternative conceptions**

For seven up to nine years children, as revealed by recent diagnostic studies, physical states could not only be three. For these children, being powder, jelly-like, soft moisture and hard are perceived as separate physical states (10). Such alternative conceptions were found to be vanished in late primary and junior education, though about 12.5% (4 out of 32) of interviewed eight grade students were still found to think so in that they inferred physical state of cotton as soft, flour as powder and so on. This is one aspect of unexpected alternative conceptions. The other concern soot formed from burning of different substances considering the gaseous nature of smoke which latter changes to soot. More than 19% (6 out of 32) of interviewed participants perceived physical state of soot as gas.
CONCLUSIONS AND RECOMMENDATIONS

Concepts and specific topics with the most frequency of students’ and teachers’ misconceptions were identified. Simultaneously, topics which are less subjected to misconceptions were also identified. From ten topics categorized under selected five concepts, only one (rusting) was found to be less susceptible to misconceptions implying that the rest topics are highly susceptible to both teachers’ and students’ misconceptions.

Generally, it was found that most of diagnosed students’ misconceptions have significant correlation with that of teachers. These correlations are significant for 90% (9 out of 10) of specific topics, while correlations are insignificant for the rest 10% (1 out of 10) of topics and concepts.

It is already found that teachers are responsible for most (90%) of students’ misconceptions with respect to specific topics, 80% with respect to selected concepts implying that most of these concepts were found to be highly susceptible to alternative conceptions. In such cases, challenging students’ conceptual change is highly dependent on teachers’ respective conceptual change. Therefore, it is recommended to give a direct, specific, applied and continuous training to chemistry teachers, focusing on subtopics on which significant correlation of students’ and teachers’ misconceptions were found.

However, such training could not independently bring promising solutions since other challenges related to ways of delivery, content nature and organization could have hindering impacts. For this matter, training sessions should be planned and implemented in such a way that appropriate ways and art of content delivery and materials organization will be simultaneously worked on.
REFERENCES


[SATLC- INITIATIVE]
USES OF SATL & MULTIPLE INTELLIGENCES [MI] FOR SECONDARY AND TERTIARY LEVELS
PART-I: BENZENE STRUCTURE ACTIVITY

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ABSTRACT

This paper focuses on the uses of Systemic Approach to Teaching and learning [SATL] and Multiple Intelligences [MI] in Chemistry. In this work we integrated both SATL and MI in teaching and learning Chemistry in secondary and tertiary levels. This activity was designed by making use of musical-rhythmic, bodily-kinesthetic, interpersonal intelligences to enhance logical-mathematical, visual-spatial intelligences in teaching and learning Chemistry. By implementation of benzene structure activity model we expected from our students to go in a deep understanding of benzene structure and its chemical bonding, create attitudes towards working in a team and gain the ability to plan and implement efficient and effective outdoor systemic activity models in Chemistry. So, we introduce this activity as an applicable outdoor model which displays innovations in teaching and learning and demonstrates one of the methods of surpassing the traditional indoor methods. It could be extended to other topics of organic chemistry or other branches of chemistry. [AJCE, 3(1), January 2013]

1 Presented at the 22nd ICCE & 11th ECREICA, July 15-22 2012, Rome, Italy
INTRODUCTION

It is well known that Chemistry is one of the most difficult and conceptually hard subjects in the school and university curricula. Many factors contribute to the complex nature of chemistry subject and much research work has been done in attempting to make conceptual chemistry easy to understand and more accessible for students (1). Much of the chemistry contents, at the secondary and tertiary levels, taught and assessed in terms of isolated facts and concepts without emphasizing conceptual understanding (2, 3). In the traditional linear way of teaching students are taught and assessed in many pieces of knowledge without any emphasis on connecting this knowledge into a functional framework.

Howard Gardner initially formulated a list of eight forms of intelligences (verbal-linguistic, logical-mathematical, visual-spatial, musical-rhythmic, bodily-kinesthetic, interpersonal, intra-personal, and naturalistic) (4, 5) or distinct areas of mental activities or skills, which are anatomically separate and can operate independently or in concert. Every individual is born possessing all the intelligences in varying degrees. These intelligences are dynamic in every student and can be strengthened or ignored and weakened. If it is strengthened in our chemistry students they will go in a deep learning of chemistry concepts.

Howard Gardner (6) suggests that the possibility of some students might have failed in certain school subjects such as chemistry or found the subject difficult because of a mismatch between their intelligences profile and the methodology used to teach the concepts of this subject to them. For example, a student high in bodily-kinesthetic and musical-rhythmic intelligences and low in verbal-linguistic and logical-mathematical intelligences could find it difficult to understand the topic of particle kinetic theory if the teacher presents this topic by using the didactic traditional methods only. Kornhaber (7) stated that Gardner theory validates educators’
everyday experience, and provides them with a conceptual framework for organizing and reflecting on curriculum assessment and pedagogical practices which make chemistry concepts more easily assessable. In turn, this reflection has led many educators to develop new approaches that might better meet the needs of a wide range of learners in their classrooms and make chemistry subject easy to learn.

Systemic approach meets the needs of both students and their teachers (8). Fahmy and Lagowski initially formulated systemic approach as one of the modern approaches that meets the student needs. Experimentation of SATL proved its effectiveness in both teaching and learning. SATL technique is a better instrument for making the teacher’s job easier, as it enhances their communication skills (9-11). Nazir and Naqvi (12) stated that SATLC is a worldwide derives towards concept building of young generation through this novel mode of teaching and learning. It was also stated (13) that, epistemologically, SATL can be considered as a hybrid approach that combines and uses features and ideas from systemics and constructivism adjusted in concept mapping procedures, and they also add that the originators of the SATL recognize the basic goal of this approach as “the achievement of meaningful learning by students” and suggest that this goal can be attained through the development of systems thinking, in a context of constructivist and systemic-oriented learning tasks (SATL techniques) (8,9).

Application of systemic approach to teaching and learning Linguistics and Math for the first three grades in the primary schools, proved the effectiveness in growing the skills for reading and writing and increases students’ learning achievements. This encourage us to integrate both SATL& MI in teaching and learning Arabic, English Languages and Math in the first three grades of the primary schools (primary level). This was done by designing systemic outdoor activities (14). It was experimented successfully in some primary schools in Egyptian
Governorates (Cairo, Alexandria, Quina). The obtained results from this study showed that learning was effective on increasing students’ learning outcomes.

In continuation of this work we integrated again both SATL and MI in teaching and learning Chemistry in secondary and tertiary levels. It is known that Chemistry represents one of the most difficult subjects because of a big number of abstract concepts and theories in its curriculum presented in a linear way of teaching. The topic covered in this model is the systemic study of the molecular structure of benzene correlated to covalent bonding, \( \sigma \) and \( \pi \) bonding, molecular shape and some electronic principles.

In this model all students exposed to a variety of experiences which stimulate the different intelligences in them and allow them to create rich environment for both teaching/learning. The staff members should design the presentation of the material in a way that engages most of the intelligences. The engagement of intelligences can take place at the end stage of the secondary level and the first year general chemistry of tertiary level.

The objectives of the present study are manifold and presented as below:

1. To use bodily-kinesthetic and musical-rhythmic, and interpersonal intelligences to enhance logical-mathematical, visual-spatial intelligences in learning Chemistry.
2. To enhance the quality of learning of molecular structure of benzene by presenting both Kekule structures and the resonance structures.
3. To change teaching/learning strategy of chemistry from a static mode inside the classroom (indoor) to an active dynamic mode (outdoor).
4. To build systemic relation between \( \sigma \) and \( \pi \) \( C-C \) bond orbitals and the molecular structure of benzene.
5. To perform subject materials taught in lectures.
6. To build up communication skills.
7. To create better environment for teaching and learning chemistry.
8. To promote understanding of the systemic relation between intelligences.
9. To create attitudes towards working in a team.
10. To enhance student’s appreciation towards chemistry subject.
11. To assess the systemic understanding of the model materials.

REQUIREMENTS FOR BUILDING SATL/MI ACTIVITY FOR BENZENE STRUCTURE

A. We ask our students to do the following jobs inside the classroom under supervision of Chemistry staff member:

1. Draw the two Kekule structures of benzene and its resonance structures.
2. Identify the chemical bonding in Kekule structure of benzene as $6\cdot C\cdot C \sigma$ bonds, $6\cdot C\cdot H \sigma$ bonds and $3\cdot C\cdot C \pi$ bonds.
3. Identify the chemical bonding in resonance hybrid structure of benzene as $6\cdot C\cdot C \sigma$ bonds, $6\cdot C\cdot H \sigma$ bonds and $6\cdot C\cdot C$ partial $\pi$ bonds
4. Identify that each bond represents bond orbital contains two electrons.
5. Identify that benzene C-skeleton as a regular hexagon with equal C-C bond distances.
6. Draw the carbon symbol [C] and hydrogen symbol [H] on a piece of hard paper.

B. The teacher of Sports draws the regular hexagon of benzene [C-skeleton] in the middle of the playing area or the Gymnasium of the school or faculty.
METHODOLOGY

Implementation of bodily-kinesthetic, musical-rhythmic and inter-personal beside logical-mathematical, visual-spatial, intelligences and systemic approach in designing benzene structure activity

This activity was designed and prepared on the basis of cooperation between Chemistry, Sports, and Music staff members inside the classroom and then performed on the playing area or gymnasium hall of the school or faculty. This means that staff members should design the presentation of the activity material in a systemic way that engages bodily-kinesthetic, musical-rhythmic and inter-personal beside logical-mathematical, intelligences as shown in the following systemic diagram.

Figure 1: Systemic Diagram (SD)
The above SD (Figure 1) shows the systemic relations between intelligences engaged in the benzene structure activity. The above mentioned intelligences could be used by students in harmony. Under this learning strategy the concept could have been better grasped and remembered.

**Scenario**

All the class students will participate actively in the preparation of the materials used (indoor) and in the performance (outdoor).

*First (Indoor)* Chemistry staff member asks the students to write the following on pieces of white hard papers or small flags:

1. [6-C] and [6 - H] letters
2. 6-e letters represent electrons
3. The following names and concepts **BENZENE, KEKULE-1, KEKULE-2,** **RESONANCE HYBRIDE**

*Second (Indoor)* Chemistry staff member asks the students to do the following:

1. One student raises **RESONANCE HYBRID** paper.
2. Six students raise six **Carbon [C]** papers.
3. Six students raise six **Hydrogen [H]** papers.
4. Six students raise six **Electron [e]** papers.

*Third (Outdoor)* Afterwards Chemistry staff member [CSM] in cooperation with Sport staff member [SSM] takes all the class students to the playing area or gymnasium hall of the school or faculty and then:
1. Sport SM asks all the class students to stand around the playing area.

2. Systemic [Fig.2] was constructed at the middle of the playing area by the aid of the sport SM.

3. Chemistry SM asks the BENZENE labeled student to stand at the center of the regular hexagon (Fig.2).

Fourth (Outdoor) Then Chemistry SM asks the students afterwards to do the following:

1. Six Carbon atom [C] labeled students to stand at the corners of benzene systemic (Fig.2). Each carbon labeled student is joined by hands to the two adjacent identical Carbon labeled students instead of one to form two identical sigma bonds.

2. Six Hydrogen [H] labeled students to stand beside the 6- carbon labeled students at the six corners of benzene systemic [Fig.3].
3. The above performances take place with the help of sport and music SM.

4. At this stage of performance, chemistry SM asks students around the playing area about:
   a. The number of sigma C-C & C-H bonds in the performed model by 12 students.
      - The students reply that there are 6 C-C Sigma bonds & 6 C-H sigma bonds.
   b. The reason for the regular hexagon of the C-skeleton of benzene.
      - The students reply that is due to the fact that all C-C sigma bonds are identical and then the bond lengths are the same.

**Fifth (Outdoor) Chemistry SM asks the students afterwards to do the following:**

1. Six electrons [e] labeled students to stand at three sides of benzene systemic (two on each alternating sides and connected by hands). This presentation shows alternating double and single bonds between carbon atoms of benzene.
2. Kekule-1 labeled student to stand beside the benzene systemic [Fig.4].

![Figure 4: The Benzene Systemic with Kekule-1](image)

3. The above performance movements accompanied by music and takes place with the help of sports and music SM.

4. At this stage of performance, chemistry SM asks students around the playing area about the number of $\pi$ bonds performed by 6 students in the performed model.
   - The students reply that there are $3 \, \pi$ bonds alternating with single bonds.
Sixth (Outdoor) Then chemistry SM asks the students afterwards to do following:

1. Six electrons [e] labeled students to move and stand at the other alternating sides of the benzene systemic (two on each alternating side and connected by hands).

2. The Kekule-1 labeled student to change the benzene structure by raising Kekule-2 instead of Kekule-1 [Fig.5].

![Figure 5: The Benzene Systemic with Kekule-2](image)

4. At this stage of performance, chemistry SM asks students around the playing area about the difference between Kekule-1 & Kekule-2 in the performed model.
   - The students reply that the difference is in the arrangement of the $3 \pi$ bonds in the regular hexagon of benzene.
Seventh (Outdoor) The Chemistry SM asks the students afterwards to do the following:

1. Kekule-2 labeled student to withdraw to the corner of the playing area.

2. Six electrons [e] labeled students to stand at all the sides of benzene systemic (one on each side and connected by hands) and move in a circular motion inside the benzene systemic.

3. Resonance hybrid labeled student to stand beside the benzene systemic diagram [Fig.6].

4. The above performances take place with the help of sport and music SM.

Figure 6: The Benzene Systemic with Resonance
5. At this stage of performance, chemistry SM asks students around the playing area about the difference between Kekule-2 & Kekule-1 structures & resonance hybrid structure in the performed model.

− The students reply that they differ in the arrangement of the \(3\pi\) bonds: In Kekule-1 and Kekule-2 the \(3\pi\) bonds are localized on the three sides of the benzene hexagon; however, in the resonance hybrid structure they are delocalized on all C-C bonds of the regular hexagon structure of benzene.

The systemic study of the benzene structure activity was presented by the systemic uses of the musical-rhythmic, bodily-kinesthetic, inter-personal, to enhance logical-mathematical and visual-spatial intelligences in teaching and learning chemistry.

*Eighth (Finally) The Chemistry SM announces the end of Benzene Structure performance, and asks the students of the class to withdraw from the playing area to the classroom by the aid of sports SM.*

**APPLICATIONS OF THE ACTIVITY MODEL**

This activity model could be used as an applicable model for benzene structure. The idea could be extended to cover other areas like electrophilic substitution reactions of benzene, stereochemistry, reaction mechanisms and types of chemical bonding.

By implementation of Benzene structure activity Model we expected from our students the following:

1. Go into a deep understanding of \(\alpha\) and \(\pi\) bond orbitals, localized and delocalized \(\pi\) molecular orbitals and their role in the benzene structure and reactivity.
2. Gain interpersonal skills, relating to the ability to cooperate with others and to work in a team.

3. Create better environment for both quality and quantity of learning.

4. Fostering the ability to explain scientifically and demonstrate knowledge and understanding of essential facts, concepts, and theories related to the benzene structure and reactivity.

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SYSTEMIC APPROACHES TO TEACHING AND LEARNING A MODULE OF BIOCHEMISTRY [SATL-BC]

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ABSTRACT

In this article, we introduce the application of SATL in the subject of medical biochemistry. The strategy of this method is based on the collection, organization, and presentation of the map of concepts through the interactive system in the module of which the relations between the concepts and issues will be clarified. The main structural element of the SATL is the systemic diagram which bears all the attributes of a closed concept map. The systemic diagrams are created on the basis of the combination of the concepts that students already have and what they acquire through the study of the modules. The construction of systemic diagram helps students to understand the conceptual framework of the subject. Through the application of systemic methodology, students will study not only concepts, principles, and various metabolic procedures that occur in the organism they will also understand the vital role of biochemistry in medicine and how biochemistry principles are applied in everyday professional practices. [AJCE, 3(1), January 2013]
INTRODUCTION

Methods and teaching techniques are standard procedures used by the lecturer in his/her interaction with students to introduce teaching materials and teaching activities to reach the goals and teaching objectives (1). For the diversity of the teaching methods, the lecturer should choose the one that makes teaching more efficient, more informative, more varied and more interesting.

There are several strategies that make teaching and learning much easier and understandable; the most important strategy is the systemic one which interlinks the lecturer, the student and the environment objectives. The systemic connections between the elements is displayed in the systematic diagram (Figure 1)

![Systemic Diagram](image)

*Figure 1: Systemic diagram between the lecturer, the student and the environment objectives.*

The factors that affect the selection of teaching and learning methods

- On the one hand, when the lecturer decides to define the method or the technique, he/she should consider students’ strongest abilities, knowledge, talent, intuition and personal experience. On the other hand, the lecturer should have confidence in the method or the technique that she/he selects. The lecturer should know for sure that the method he/she
selects will serve the students best. At the end, the method should prepare high qualified generations, capable of responding to the developments of the future society.

• The students enter the auditorium with their own interest, motives, needs, abilities, experiences and culture. The lecturer should consider students’ abilities and select the teaching method that will help the students to reach the expected results.

• Teaching should be oriented in such a way that it could reach the important goals and the objectives in class.

• The environment is important to help in the selection of the teaching and learning method. The lecturer always asks the question: “Is this the right environment for the selected method?”

METHODOLOGY

This study presents a method of explaining the module “Water and human metabolism” in the subject of medical biochemistry through systemic diagrams drawing and explaining. The method is applied at the University of Shkoder “Luigj Gurakuqi”, (Albania) in the Faculty of Medicine at the Department of Biochemistry with the students of the first study degree (BA), in the subject of medical biochemistry.

Systemic Approach in Teaching and Learning (SATL) methodology is holistic in essence and encompasses delivery of facts, concepts and skills in one package (as displayed in figure 2). Teaching is carried out through communication. Learning process becomes pleasant if better communication skills of the teacher prevail upon the inherent inertia, associated with the students, while they focus upon a difficult subject. SATLC technique is a better instrument for making the teacher’s job easier, as it amply enhances the communication skills of the teachers.
This model displays innovations in teaching and demonstrates one of the ways of surpassing the traditional linear model. In this method the teaching process has two basic qualities, the indirect interaction student-knowledge, elaborated on the didactic side from the lecturer and the direct interaction with the knowledge. This SATL lesson would require the following multi step progress (2-4).

**Step 1. Goal: The role of water in human body.**

Objectives: To explain fluid compartments in the body,

To explain the four types of weak interactions that occur within and between biomolecules in an aqueous solvent,

To explain the miscellaneous functions of water,

To analyse the water source, water losses, and water requirement

**Step 2. Application of SALT in teaching the functions of water in the human body.**

Lecturers define the list based on the previous studies (molecular structure of water, form of molecules, ionization of water, the pH of water, specific heat, thermal conductivity, heat of vaporization, polarity, hydrogen bonds in water, composition of the cell, osmotic pressure, density, cohesion, dielectric constant, etc.) claimed for the creation of the lesson entity. Further to the salient features of the lesson that incorporate physical and chemical properties of water, biochemical reactions, functions of water, interrelationships and subsequent skills, accrued from the teaching and learning exercise, are underlined and elaborated. Students will be able to define the functions of water, from different aspects. The following issues are being addressed:

- Body water
- Water requirement
- Water source
- Water losses

**Step 3. Lecturers create the linear data list** (according to the second stage) with functions of water as a solvent, substrate, product, metabolic, lubricant, regulator, medium, etc. included in the lesson entity. Then, they draw the diagram (as displayed in figure 3). Afterwards, they illustrate the linear connections between the compounds that are introduced in the third stage:

![Diagram of Linear Connections between Functions of Water](image)

*Figure 3. Linear connections between function of water.*

Linear diagram describes miscellaneous functions of water in our bodies on the basis of these undertakings as reproduced below (5). Here, lecturers notice that the above connections are linear and independent from each other. While studying medical biochemistry, students are able to define the miscellaneous functions of water in human body. The water functions are listed below:

**Water as a principal fluid in human body.** It constitutes approximately 75 per cent of the total body weight. Almost all body fluids are present as water solutions. The human brain is made up
of 95% water; blood 82% and lungs 90%. The total amount of water in our body is found in three main locations; within our cells (two-thirds of the water), in the space between our cells and in our blood (one-third of the water).

**Water as solvent.** Water is the solvent of the body and it regulates all functions, including the activity of everything it dissolves and circulates. Water also serves as a solvent for waste product such as urea, carbon dioxide and various electrolytes that the body excretes. As a solvent contains these substances, water is necessary for transport to and from all cells of the body.

**Water as a medium.** Water acts as a medium in which various metabolic and biochemical reactions take place. It moves nutrients, hormones, antibodies and oxygen through the blood stream and lymphatic system. Water is the containing medium for electrolytes and all other ions throughout the human body. Some of these ions help to form electrical pathways for nerve functions (6). Water is the key element to acid-base neutrality and enzymes function. Water serves as medium for the transport of chemicals to and from the cells.

**Water as a lubricant.** Water lubricates the joints and internal organs. Water’s properties, specially its viscosity, make it a useful lubricant. Water based lubricating fluids include:

- Mucus- this is used externally to aid movement in animals, such as in nails, or internally, on the gut wall to aid the movement of food.
- Synovial fluid- this lubricates movement in joints.
- Leural fluid- this lubricates movement of the lungs during breathing.
- Pericardial fluid –this lubricates movement of the heart

**Water as a regulator.** Water regulates all functions, including the activity of everything it dissolves and circulates. Water is used to help in maintaining the body’s constant temperature. When the body needs to cool down, evaporation of water is used to cool the body off. This is
because to evaporate, the water removes heat from the body (7). The maintenance of a correct water balance (the net difference between water gain and water losses) is essential for good health. It is all the more essential as there is no real water storage in body; the water we lose needs to be replaced, and humans cannot survive more than a few days without water. Water is used to cool the body down through the reaction of perspiration. Water has high specific heat capacity which means it absorbs a lot of heat energy for its temperature rise, and loses a lot to cool. Water minimizes increase in temperature in cells as a result of chemical reaction. Enzymes, or proteins that act as catalysts to start chemical reactions, are heat-sensitive and will operate only at specific temperatures. Temperature regulation is vital for chemical reactions important to cellular activity, such as cellular respiration. Water has a large heat capacity which helps us to overcome the limit of change in the body temperature in the warm or in the cold environment. It allows the body to release heat when ambient temperature is higher than body temperature. The body sweats and the evaporation of water from the skin surface very efficiently cools the body.

**Water as a metabolite.** Cells work via chemical reactions. The sum total of chemical reactions within an organism is called metabolism. Water is a metabolite, or a chemical involved in these reactions. It is necessary for continued survival of the human body. Water aids in respiration. Water is used to split ATP in ADP and Pi (8). Cellular energy is released as a byproduct of this process.

**Water as a transport.** Nutrients and oxygen are transported throughout the body using water, and individual cells need water to bring the nutrients and oxygen into them.

**Water as a carrier.** Water is a carrier distributing essential nutrients to cells, such as minerals, vitamins, glucose and chemical energy.
**Water as a nutrient.** Water is clearly the most important nutrient and the most abundant substance in the human body (9). Hard water contains a larger number of minerals than soft water. Some of these minerals are calcium and magnesium, which the body can actually absorb.

**Water as a product.** Metabolic water formed in the body by oxidation metabolism of food such as carbohydrates, fats and proteins.

**Water as a support.** Water is not easily compressed and has important role in support. Water has a high specific tension and water molecules have cohesive forces holding them together, due to hydrogen bonding between water molecules.

**Water as a component of the digestion and constipation.** Water immediately passes into the intestine and is absorbed. The saliva that begins the process of digestion is partially made out of water, mixed with other enzymes. Water is used to ensure that the food easily slides down the esophagus. The digestive enzymes found in the stomach are also partially made out of water.

**Water in Sexual Reproduction.** During fertilization, a male sex cell (sperm) must reach a female sex cell (ovum) in order to fuse producing a zygote, which will develop into a new individual. The sperm is often transported in a fluid medium known as semen, which contains mostly water.

**Step 4.** Place the check mark [✓], in the chemistry knowledge from the previous studies. So, in this stage of study the linear relations [1-8] are known, but there are unknown linear relations [9-50] in which we placed the question mark [?]. So, the linear diagram figure 3 should be modified to diagram shown in figure 4.
Figure 4. The linear relations between concepts, some of these relations are known and some are unknown

Step 5. The diagram developed on the basis of suggestions in the previous step, outlines the linear relationships in an orderly manner. It modified to a systemic diagram. This can be done by placing the respective relations between the concepts as shown in the following systemic diagram (SD0).
Figure 5. Systemic diagram (SD-0)

This is the first diagram of its kind in a series of diagrams that the lecturer will draw during teaching and learning exercises. Let us call it (SD0). From the systemic diagram SD-0 one can notice the following (4, 10):

- The relations [1-8] in the diagram (SD-0) are known; therefore, the head of the arrows are in one direction and also carry the tick sign \([\sqrt{\text{v}}]\). Known reversible relationships are well illustrated in this diagram through one headed arrow. The unknown relationships of diagram (SD-0) bear the question mark sign [?] and carry double headed arrows.

- During the study of the metabolic processes, basic water balance, water absorption, intracellular and extracellular fluid, gastrointestinal tract, urinary tract, water intake, blood, the diagram above changes from a linear diagram (SD-0) to systematic diagram (SD-1) as a result of the connections in between the functions of water. The systematic
• The systematic diagram (SD-1) is the diagram that starts the studying of the systemic unit (see figure 6).

This diagram indicates unknown relationships of SD0, which are to be taught by the lecturer.

![Systemic diagram (SD-1)](image)

Figure 6. Systemic diagram (SD-1)

The diagram SD-1 is composed of two types of interrelationships, one which is known, as it is clearly taught by the lecturers and students have put on [✓] mark on the account of their understanding. The second component with sign [?] is still unknown and hence to be debated in the auditorium. The ensuing discussion, guides us to unfold secrets behind some more unknown. Following this auditorium discussion and resulting conclusions, some of the [?] marks are also replaced by [✓] marks and unidirectional arrows (→) also appear on the diagram to symbolize them as known. This debate in the auditorium about unknown concepts in relation to known ones will result in building new systemic relationships and also help the teacher to assess the systemic understanding of the proceedings part by part.
Step 6. In another stage of the study, the students learn the connections between functions of water and metabolism of proteins, lipids and carbohydrates. When the debate proceeds further, one can go deeper and deeper into the water metabolism and identify the newer relationships and add them to SD-1 (as displayed in figure 7). Afterwards, the DS-1 undergoes changes to the DS-2 with [9-40] known relations.

![Diagram](https://example.com/diagram.png)

**Figure 7. Systemic diagram (SD-2)**

A glance at SD-2 helps to appreciate and notice the following: All the relationships have been identified except 41-50 which have to be developed in the later stage of teaching the module. At this stage of study, the students are required to ponder upon the relationships developed during the debate and try to develop the remaining unknown relationships. In this stage of learning, students build several systemic diagrams of their own.
The systemic approach in teaching and learning medical biochemistry

Step 7. At the former stage of the study of the systemic module, the students learn the rest of the relations [41-50] based on the relations between body water, water source (drinking water, food, metabolic water, metabolic reaction, negative energy balance), water losses (urine, fecal, insensible water loss, sweat loss), water requirement (dietary factors, environmental factor, conserve water, physiological state, heat production, body surface area) that they learned previously. These changes are added to the DS-2 diagram; and modified to DS-3 diagram.

This is the final stage of teaching and learning of this systemic module (see figure 8). The diagram SD-3 is the terminal systemic diagram (4) and represents the end of teaching the module unites.

Figure 8. Systemic diagram (SD-3)
RESULTS

- Through the systematic diagrams, we managed to explain the maximum of the connections between function of water in human body, body water, water losses, water sources, and water requirements.
- The students are aware of the systemic way of teaching the unit from the beginning to the end of module.
- SATL units involve development of stage wise systemic diagrams (SD-0, SD-1, SD-2 and SD-3).
- These diagrams have SD-0 as a starting point and SD-3 as terminal point of the module, SD-1 and SD-2 are intermediary stages.
- The SATL teaching lessons are marked as SD-0, SD-1, SD-2 and the last SD-3. All of them are essentially similar except that they differ in the counts of tick signs [✓], the known relationships, and the counts of question marks [?], which represent the unknown ones. As the module progresses, the [✓] signs grow on the cost of [?]. This scenario is described in figure 2.

DISCUSSION AND CONCLUSION

- The application of the systemic method in teaching and learning medical biochemistry is successful.
- Systemic approach in teaching and learning allows students to create rich environment for both quality and quantity of information.
- Students have a research role in the learning process and they are able to give their own ideas and thoughts.
• In this method, knowledge is constructed and not transmitted.

• Students are motivated to learn. They identify and correct the prior inaccurate understanding.

• This method allows revising and expanding of the knowledge obtained in the previous lessons.

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SATL MODEL LESSON IN CHEMICAL KINETICS

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ABSTRACT

Studies in order to pursue kinetics and mechanism of chemical reactions are a vital component of chemical literature. SATL literature is still not available for promoting this vital aspect of chemistry teaching. A lesson pertaining to this important issue has been developed and various parameters of kinetic studies are explained therein. [AJCE, 3(1), January 2013]
INTRODUCTION

There are several strategies, through which teaching and learning of scientific subjects in general, and chemistry in particular may be made much easier to understand. Various teaching options continue to be reported in literature to illustrate the basics of chemistry in order to enhance its teaching and learning. In the past decade an innovative way of teaching and learning through systemic approach (SATL) has been introduced (1-4) for this end.

The basic goal of this approach is the achievement of meaningful (deep) learning by students. Meaningful (deep) learning was described by Amusabe (5) as the formulation of non-arbitrary relationships between ideas in the learners' mind. According to Novack (6) meaningful learning means that learners deal with a learning task by attempting to form relationships between newly and previously learned concepts. Michael (7) stated that meaningful learning occurs when the learner interprets, relates, and incorporates new information with existing knowledge and applies the new information to solve novel problems.

In Systemic Approach in Teaching and Learning Chemistry (SATLC) technique the concepts are positioned in such a way that the relations between a series of ideas and issues are made logical. In various publications it has been stated that systemic approach to teaching and learning (SATL) for discussing any issue initiates with the systemic diagram (SD0), which is based on the previous knowledge of students. After inclusion of similar systemics with known and unknown relationships (SD1, SD2, SD3 and so on) the unit ends at final systemic diagram (SDf) as in Figure 1). In (SDf) all the relationships between different concepts of the unit have been delivered to the students (8-9).
Several systemic diagrams on a variety of topics can be developed and finally all of these may be assembled together (Figure 2) (10).

**METHODOLOGY**

Chemical kinetics is one of the important branches of Physical Chemistry. It helps us to monitor the rate of the chemical reaction. This topic has been chosen to enlighten the effectiveness of systemic approach to teaching and learning (SATL) methodology in physical chemistry. SATL provides a matchless way to have deep understanding of chemical kinetics. Generally linear approach has been adopted to convey this subject matter. Figure 3 is based on the linear relationships among various factors involved in chemical kinetics. The relationships (1-7) are sequences of linear associations. Figure 3 can be transformed into systemic diagram SD0 as represented in Figure 4.
Figure 3: Linear relationships among different parameters occupied in chemical kinetics.

Figure 4: SD0
In systemic diagram (SD0) (Figure 4) all the relationships are unknown. Systemic approach will be implemented to interpret these relations. Following the clarification of role of temperature in a chemical reaction (1) and its connection with pH (8), which may also affect the rate of a reaction (2), SD0 can be renewed into another systemic diagram i.e. SD1 (Figure 5).

Figure 5: SD1

Still there are some links, in Figure 5 which have to be deciphered. After learning some of these connections Figure 5 will be modified to Figure 6 (SD2).
The remaining linkages of systemic diagram (SD2) relevant to the effect of medium (6) and the nature of reactants (7) in the kinetic study of a reaction and their association with each other (13) and with the temperature (14) can be worked out to attain final systemic diagram (SDf), Figure 7.
In the similar way several other systemic diagrams can be developed (Figures 8-11) in relation to the parameters involved in the chemical kinetics. Finally all these systemic diagrams can be linked to Figure 7 to provide a wide perceptive of this important field of chemistry.
Figure 9: Systemic linkages among the various properties of solvent or medium

Figure 10: Systemic diagram of various parameters of a reactant
SUMMARY

The implementation of systemic method assists to discuss the issue of chemical kinetics with SD0 as an initial point. Through the understanding of various linkages in SD0 stepwise, SDf can be acquired. Connecting different systemic diagrams (Figure 12) further clarify the topic.
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SCIENCE NEEDS AFRICA AS MUCH AS AFRICA NEEDS SCIENCE (1)
A CASE IN TANZANIA

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ABSTRACT
From 2003 until 2012 we visited several secondary schools around Moshi (Tanzania) and Mwenge University College of Education near Moshi, a teacher college which was founded in 2001. During our visits we found that the schools and the college were lacking of material for conducting experiments in an appropriate way, and teachers as well as lecturers were not well trained to conduct chemistry experiments. We recommend measures to improve the quality of science education at schools and colleges as presented in this paper. [AJCE, 3(1), January 2013]
Introduction

“One hundred Chemistry experiments to avoid chalk and talk” this was the headline for the project we realized in spring and summer 2003. With small boxes containing all materials for 100 Chemistry experiments we trained science teachers from the Kilimanjaro region in the laboratories of Vunjo Secondary School how to conduct chemistry experiments at Secondary Schools.

Science teaching in Tanzania – some personal impressions

During our stay in Tanzania in 2003 we observed lectures in some secondary schools, discussed with teachers how to conduct science lessons and met the Vice Principal of St. Joseph’s Teacher College near Moshi which now is Mwenge University College of Education (MWUCE).

From our observations in schools and discussions with science teachers in 2003 we found three main problems:

- The schools are equipped with laboratories for practical lessons but they are in a bad condition.
- The schools are lacking material for conducting experiments in an appropriate way.
- The teachers are not well trained to conduct chemistry experiments.

Background information of the partnership between GaM and Tanzanian schools

In 1992 Gymnasium am Mühlenberg (GaM) in Bad Schwartau (Germany) and Vunjo Secondary School (VSS) near Mwika (Tanzania) established a partnership which is based on

- regular exchange of letters between individuals (pupils, teachers) and also the committees of both schools
- mutual (exchange) visits
- the realization of different projects

From 2003 to 2005 three workshops for science teachers from the Kilimanjaro region have been realized at Vunjo Secondary School. The teachers mainly have been trained how to use experiments and models in chemistry, physics and biology lessons.

During our stays in Tanzania we visited Mwenge University College of Education (MWUCE) near Moshi and were asked to offer those workshops also for the college.
These observations are valid all over Tanzania and not only for the small number of schools, we visited. In connection with this problem Hamilton and co-authors found in 2010 with their study on the needs of science education in Tanzania (2, p. 12):

- “Resources are lacking in most every aspect of education, including insufficient numbers of qualified teachers of mathematics and science at the primary- and secondary-school level, inadequate equipment and materials, textbooks and facilities (i.e., laboratories and libraries). While resources needs are greater in rural areas, only a fraction of the needed resources is available in most every school in the country—regardless of the region.

- The quality of teaching is inadequate to meet the learning needs of students at all levels, in several respects. First, many primary school teachers lack the minimum academic qualifications — generally and in their subject matters in mathematics and science—to perform competently in the classroom. Second, teachers at both the primary- and the secondary-school levels are not well trained in the use of appropriate pedagogies. Whereas most teachers surveyed do know and report applying some context-based approaches, student performance in mathematics and science reflect neither thorough subject-matter knowledge nor adequate knowledge/application of the competency based approaches that are the basis of the science and mathematics curricula. Third, university students, employers and other participants in the study all report that education in mathematics especially—as well as science—do not provide graduates with the knowledge and the ability to apply it in the workplace. Fourth, while the teacher preparation curricula do, at the primary-school level, incorporate learner-centred approaches to teaching and assessment, the structure, organization and implementation of teacher preparation programmes are lacking in this respect. A complete assessment and overhaul of the current teacher preparation system is
needed, especially at the primary-school level, where children’s formative experiences with learning in mathematics and science have far-reaching effects upon students’ attitudes, knowledge and skills development.”

At Secondary and high schools in Tanzania practical tasks are an obliged part of the governmental examination in chemistry, physics and biology. To fulfil this requirement it is necessary that students are trained to do science experiments by their own and the teachers have to be trained how to conduct chemistry experiments in school lessons. Additionally the school laboratories have to be ready for doing experiments in the classes.

Teacher training workshops, as we practiced them between 2003 and 2005 at Vunjo Secondary School for science teachers from the Kilimanjaro region have been successful and the teachers told us that they profited very much from this work. In the following years from 2003 we noticed from discussions with teachers at secondary schools and lecturers at Mwenge University College of Education that teacher training alone is not enough. The student teachers leaving the college with a Bachelor degree are educated in Chemistry but they were not trained to conduct chemistry experiments at Secondary schools in a suitable way.

To minimize the problem of teachers with few or no experiences in conducting chemistry experiments, it is necessary to train pre-service teachers at Colleges and Universities in this field.
From our visits and discussions we know that this training only can be realized when the qualification of the lecturers is improved.

In spring 2012 we did the first step to reach the described goal when the principal of MWUCE asked for an expert in the following fields:

- Show the college lecturers, the students and some secondary school teachers how to conduct good chemistry experiments.
- Collaborate with them to develop experiments suitable for chemistry lessons at Tanzanian secondary schools and high schools.

In autumn 2012 the authors went to Tanzania to do the very first step fulfilling the given tasks. They took over lectures and workshops on models in chemistry, misconceptions and motivating experiments. Students and lecturers got an insight into latest results of research on using models in Chemistry and on misconceptions of secondary school students (3-4). We performed various experiments with different didactic functions which could be done with materials which are available in every laboratory. In addition to our performance of lectures we visited some Chemistry lectures and found that they did not meet all requirements of a University College.

The laboratories and lecture rooms were ready for groups of different size without using media like overhead projector or beamer. Overhead projectors and beamers, which were available on demand, could not be used at any time because of breakdown of electricity.
The Department of Chemistry has two Chemistry laboratories with basic equipment (e.g. flasks of different form, beakers, measuring cylinders, stands, Bunsen burners, balances and chemicals) which is required for almost basic experiments. Higher demanding experiments according to the standard of a College cannot be done. The laboratory was in a bad condition and it was very hard for the students to do their practical work according to a standard required for a college.

RECOMMENDATIONS

Hamilton and co-authors recommended based on their findings (2, p. 45) to:

- Establish and strengthen an effective system of teacher preparation, including pre-service and in-service training components at both the primary- and secondary-school level. This system would emphasize the use of context- and inquiry-based instructional methods in science and mathematics.

- Establish partnerships between Tanzanian industry, science and technology colleges and universities and similar institutions abroad. These partnerships could include advisory boards, activities for knowledge and technology exchange, workshops and student- or teacher-led action research projects to improve the quality of education in science, mathematics and technology.

As a consequence of our findings at MWUCE and at some secondary schools we suggest specific measures as follows:

- Redevelopment and reorganization of the chemistry laboratories according to the standards adequate to a college. Only if the laboratory is well equipped and well managed that qualified practical work can be done by the students.
• To improve the quality, the lecturers have to be trained on modern concepts of chemistry and how to perform chemistry experiments at the College and secondary schools. We suggest organizing a one week local congress for lecturers and teachers on science teaching in summer 2014. This congress will be organized in cooperation with German and African Universities, especially with the Federation of African Societies of Chemistry (FASC).

REFERENCES
SUCCESSFUL PRACTICAL WORK IN CHALLENGING CIRCUMSTANCES
LESSONS TO BE LEARNED FROM UGANDA

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Abstract

This article is written in support of the argument that to encourage practical work in chemistry in schools where previously little had taken place, teachers should be taught basic workshop skills that they can use to safely improvise equipment suitable for use in their own school environment. These skills include cutting and bending glass tubing, inserting tubing through bungs and soldering electrical components. With these skills, teachers can make equipment to prepare gases, make spirit burners, and complete electrical connections. By empowering the teachers with these skills, they can train enthusiastic students to assist as technicians and with the teachers, visit other schools to pass on these skills. This process will compliment any government initiatives in this field of professional development. Prior to our visit to Uganda we anticipated that there could be issues with equipment and laboratory services but were surprised by the poor quality of the chemicals we found in the schools. This would make teaching practical chemistry a challenge even with the right equipment. [AJCE, 3(1), January 2013]
INTRODUCTION

Jean Johnson (1) has been promoting chemistry practical work in the schools in Uganda which she visits regularly. Jean invited Bob Worley and Mary Owen from the United Kingdom to visit two of the schools she works with regularly. Bob and Mary have experience teaching practical skills to teachers and technicians in the UK through their work with CLEAPSS (2). The aim of the visit was to see if these skills and techniques could be transferred to the situation in the secondary schools of Uganda. The specific objectives were:

- To build and consolidate previous work carried out in visits and initiatives to these schools in alternative methods of practical chemistry including “drop chemistry” and the use of Petri dishes to work with toxic gases. In “drop chemistry” (3) the chemical reactions are not carried out in glass test tubes but in drops on a plastic sheet or folder with the instructions underneath (see Fig 1).
- To provide a range of simple, cheaper, safer yet effective experimental techniques for activities such as making and collecting gases.
- To provide training in the workshop skills needed to make simple apparatus, such as spirit burners, gas-making equipment and micro-electrolysis equipment, often from materials that are easily obtained locally.
- To introduce teachers to more micro and small scale practical chemistry techniques to manage the activities involving toxic gases required by the syllabus safely without the need for expensive fume cupboards
- To encourage the teachers to spread their skills and expertise to other schools in the area.
GENERAL COMMENTS

We were told and we expected to find challenging conditions in Uganda when compared to the UK where every secondary school has several laboratories dedicated to the teaching of science and sourced with chemicals, equipment, dependable supplies of water, gas and electricity and a fume cupboard. All the teachers in the UK are expected to carry out practical work with their classes and to do demonstrations at regular intervals (weekly) assisted by technicians.

1. Equipment in the school laboratories

The schools visited in Uganda do have one or two rooms dedicated to science. There is equipment in these rooms, usually charitable gifts, but much of it is unsuitable. These donations should not stop, example burettes, pipette, conical flasks, etc are always useful. However, donations of redundant or over-complicated electrical equipment that can only be repaired at great expense and by an experienced engineer should be discouraged. We noticed that as equipment was at a premium it is only used when it has to be and there was anecdotal evidence that the students did not get to practice with it themselves beforehand.

As we were preparing the course, two articles in the African Journal of Chemical Education (4-5) served to confirm our initial ideas for our workshops suggesting that teachers making their own equipment and having pride in their creative abilities was important spur that could built on. The articles showed that much of the chemistry can be carried out with equipment that was obtainable for domestic use. For instance, the crown bottle top used as a deflagrating spoon (Fig. 2) to burn sulphur in oxygen. We had been using crown bottle tops for several years as a substitute for crucibles (6-7) (Fig. 3).
New electrical equipment is often better designed and relatively inexpensive compared to equipment used several years ago. For example, “pocket” digital balances weighing to 2 decimal places (Fig 4) can be obtained online for less than 10GBP whereas traditional laboratory balances were 20 times that value.

Plastic lab ware is now overtaking glass in many areas. Many traditional chemists are still suspicious that the volume measurements are not as “accurate” as in glass. Any lab ware which provides measurement should have International Standard Organisation marks (ISO) on it so that chemists can depend on the accuracy of the equipment. However, if the item is just being used to store water on the bench, cut-off plastic bottles can be used instead of expensive lab ware.

11. **Chemicals in the school laboratories**

This was a source of great concern. Some of the chemicals supplied to the schools were of very poor quality. Iron filings were unsuitable bits of rusty iron of various sizes; the local iron wool from the supermarket was far superior. The so-called marble chips turned out to be quartz.
The hydrogen peroxide solution from suppliers was useless (it does not store well) but the hydrogen peroxide in smaller bottles from the local pharmacy was excellent. Some powdered calcium carbonate did not fizz with acid and appeared to be more like talc. Calcium hydroxide had chemically changed to calcium carbonate under storage. Clear vinegar on sale locally was 1M ethanoic acid and can be used. In contrast, in the UK, much of the vinegar sold in shops comes from fermented sugars and so is not a suitable substitute.

In the UK it is recommended not to store chemical solutions in plastic water bottles. The reason is that if this bad practice was transferred to homes or industry with a bottle of an unlabelled toxic, the chemical could be mistaken for a bottle of water, with tragic consequences. However financial constraints may compel teachers in Uganda to use this practice so there must be real care over the correct labelling of bottles and the drinking of any water should take place outside of the laboratory.

12. Services in the school laboratories

The schools use LPG as a fuel but many cases the burners supplied (as charitable gifts) were designed for methane gas. The jet for a methane burner has a wider diameter and so, if LPG is used, the flame is dangerously high and it is difficult to obtain the classic hot flame with the air hole open. In one school, the LPG container was used inside the classroom. This is dangerous (because of possible leaks leading to explosive air/mixtures) and would not be acceptable in the UK.

Water supplies will depend on where the school is located. If practical exams are set, the intention is that solutions should be made with good chemicals using pure water, however examiners should realise that this might not be always possible. In Thailand there is an excellent organic chemistry kit which uses a pump to re-circulate the water through the condensers as an
alternative to a continuous flow of fresh water which is a best wasteful and in many situations not possible at all. CLEAPSS has made use of this approach to solve specific water supply issues in the UK.

13. **The chemistry syllabus and examination**

The syllabus that the students are required to study requires students to memorise observations from chemical reactions which they can only access via dictated notes or text books (see Fig 5). Students and teachers can only access the answers to this question using a text book. They cannot experience the chemistry directly as the traditional equipment requires the use of a fume cupboard which the majority of schools do not have.

Curiously, bleach is readily available in the local shops yet the reaction between bleach and acid to produce chlorine, which the teacher could demonstrate, is not required by this question. There is nothing to relate chemistry to the local environment, surroundings or living experience of the students and teachers. Uganda has limestone deposits, cement production, copper and cobalt mining, salt lakes, water purification plants and yet there is no reference to any of this in the examination syllabus.
14. **Technician support**

Adult technicians were very poorly paid and, in most cases, did not stay at the post for more than a few weeks. One school used students who were in their final two years to provide technical support. They had an enthusiasm for the subject and were extremely good at their work, for which they received a small reward. This approach does require good supervision by the science teacher as they have the duty of care to the student.

6. **The Teachers**

Teaching teachers (even in the UK) is not always easy. Some expect that having been trained, that is it; nothing more needs to be learned. However, we were overjoyed with the attitude of the teachers we met. Teaching the workshop skills to the teachers struck a chord with them.

**PRESENTING AND ORGANISING WORKSHOP SKILLS**

This was a complex visit to plan. We spent several hours of discussion and conducting practical trials in the CLEAPSS laboratory in the UK after having been warned of the practical challenges we might encounter.

Once in Uganda we allowed one day setting up equipment before the 2 days of courses and this proved essential. The preparation day was more exhausting than the teaching! We had to improvise quickly and safely and this can only be done by very experienced visiting technicians and teachers. The problems with the chemicals took longest to solve.

Although we took small laptop computers with PowerPoint presentations and videos, we found it impossible to adequately display the material because of lighting and sighting problems. We decided this was over-complicating matters. Fortunately we had taken paper copies of slides
on which the teachers could write. In the end we used the time honoured teaching method of demonstration followed by hands on practice and it seemed that it worked.

The essential workshop skills

Using 6 mm (outer diameter) medium-wall borosilicate glass tubing

Even in the UK, those ordering equipment try to cut corners by buying cheaply. It is a false economy. Glass equipment is a good example. Soda glass is cheaper than borosilicate glass but it easily cracks when subjected to thermal shock and the sharp edges can cause nasty cuts. Borosilicate glass many be more expensive but its lower coefficient of expansion means it withstands thermal shock and will survive much longer in a school laboratory.

Borosilicate glass tubing softens in a Bunsen burner flame but does not collapse as soda glass tubing does. As the tubing bends in the hot flame, the outer curve becomes thinner. Using medium wall glass ensures that it does not become so thin that it shatters on cooling or in use.

Cutting glass tubing (less than 10mm outside diameter)

- Wear eye protection.
- Place the glass on the bench protector and measure the length of glass you require.
- Using a file:-with one bold stroke (if possible) make a mark. (There is no need to mark right round the glass.) You should be able to see the mark and hear the grinding of glass.
- If a glass knife is used, score about a third of the way round the glass.
- Keep looking at the mark and wet the mark, this is said to give a smoother break.
- Turn the glass slightly so that the mark is pointing away from the body. Pull the tube apart while at the same time exert slight pressure behind the scratch with the thumbs. It will break cleanly!
• Examine the glass to see if there are any sharp points. If there are, just rub the end of the glass tubing with gauze. Do the same to the other piece.

*Flame (or fire) polishing to ensure there are no sharp edges*

• This is very important as it ensures there are no sharp edges on the cut ends of the tubing.
• Wear eye protection
• Hold the glass with a tongs if it is short. Place the other end of the glass at the top of the roaring Bunsen flame and lower it down so it is just above the blue cone.
• Rotate (if it is held with fingers) and keep it there until the end of the glass just melts.
• If the glass is short, place the glass on a heat proof mat to cool, otherwise, turn the tubing round and “fire polish” the other end.
• Leave the tubing on the bench protector to cool.

*Bending glass tubing*

• Wear eye protection.
• Light the Bunsen and adjust the flame to the non-luminous flame.
• Hold the glass rod or tube in both hands over the top of the flame and lower it until it is just above the blue cone (Fig 6).

• Turn the glass slowly.

• When the glass begins to soften, stop rotating and, if possible, let the glass bend under its own weight (Fig 7).

• Anneal the glass by turning the Bunsen collar so the flame is yellow and let the bend “cool” until carbon is deposited on the glass.

• Remove the glass and place it on the heatproof pad to cool.

• If the bend is close to the end of the tube, then use a spatula, tweezers or a cork borer to gently and slowly bend the softened glass. However, it may be better to make the bend in the middle of the tubing and then cut to the required length.

• Do not take the bend more than 90°. This avoids the glass becoming too thin on the outer radius. For a U bend make two right angle bends close together.

If time allows, the cooling of glass should be as slow as possible. This annealing process produces fewer strains in the bends so the glasswork is tougher. With the glass bend still in the flame close the air-hole on the Bunsen. Leave the glass in this cooler flame and finally remove and leave to cool to room temperature.

Inserting tubing through bungs

• Cork borers are required for this but copper piping inserted in cork or cloth can be used.
• Wear eye protection.

• Place the bung with a hole though it on the bench protector with the larger-diameter end on the mat.

• Choose the cork borer that is just big enough to fit over the tube or thermometer you intend to fit in the bung.

• Dip the cork borer into detergent or soap solution.

• Insert the borer all the way through (Fig 8), (you may need to choose a smaller cork borer first and insert this into the other side of the bung, then insert the larger one over the top of the smaller one starting from the opposite direction).

• With the cork borer still in the bung inset the glass tube through the borer. You may need to adjust the length to which the tube is inserted (Fig 9).

• Withdraw the cork borer leaving the glass tube or thermometer inserted through the bung. Adjust as necessary and wash any excess washing-up liquid from the object.

• This procedure, if performed carelessly without the use of the oversize borer, can produce some very bad accidents. The worst being glass tubing piercing the hand and coming out the other side.

• Removing tubing or thermometers from bungs can also give rise to accidents. First attempt to remove the tubing/thermometer bung by using a cork borer that is slightly bigger than the tube/thermometer. You can carefully insert a small screwdriver between the tubing and the bung, carefully working it around to break the seal. If this will not succeed easily – for example because the tubing/thermometer has been in the bung for a
long time, sacrifice the bung by cutting it away with a sharp knife or similar – this is far preferable than breaking the tubing/thermometer with the potential for injury that carries.

MORE TOOLS USEFUL FOR MAKING EQUIPMENT

In addition to the tools already cited in the previous section, the following can be added: The hand drill (Fig 10) can be used to drill holes through solid bungs and crown bottle tops. The glue gun (Fig 11) is especially useful for sealing objects together and the soldering iron (Fig 12) for firmly connecting electrical contacts but make sure you obtain rosin-free solder.

<table>
<thead>
<tr>
<th>Fig 10</th>
<th>Fig 11</th>
<th>Fig 12</th>
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<tbody>
<tr>
<td>Hand drill</td>
<td>The glue gun</td>
<td>Soldering iron</td>
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Making your own gas collecting apparatus (Fig 13):

![Fig 13](image)
Preparing the trough

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Mark and cut a 2.5L plastic container 8cm from the bottom. Cut the top piece in half (Fig 14).</th>
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<tbody>
<tr>
<td></td>
<td><img src="image1.png" alt="Figure 14" /></td>
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<tr>
<td>Step 2</td>
<td>Using the glue gun, overlap the two pieces and glue together (Fig 15).</td>
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<td></td>
<td><img src="image4.png" alt="Figure 15" /></td>
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<tr>
<td></td>
<td>Roll a square piece of plastic into a tube shape around a boiling tube so that will fit in the neck of the cut down container. Glue into shape. Glue tube into container neck (Fig 16).</td>
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<tr>
<td>Step 3</td>
<td><img src="image7.png" alt="Figure 16" /></td>
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Making your own gas generator (Fig 17)

- Glue guns get very hot when used. Switch the glue gun off after use. Wear eye protection.
- Wear eye protection
- Cut two lengths of 6mm borosilicate medium wall glass tubing, one 20cm long and one 8cm long. Flame polish all four ends of the pieces.
• Take the 8cm piece and make a right angled bend two thirds along. (You may need to use tongs or forceps to hold one end in the flame.)

• Choose a bung that fits your boiling tube.

• Insert the 20cm straight piece of tubing through the rubber bung. The straight piece should reach almost to the bottom of the boiling tube when inserted.

• Insert the bent piece of tubing into the rubber bung. The bent piece should reach just below the bottom of the bung when inserted.

• Cut down a dropper bottle or syringe so that it fits snugly over the straight piece of tubing. Glue in place with the glue gun if required.

• Attach a 12cm piece of rubber tubing to the right-angled tubing.

• Insert the bung into your boiling tube.

• Place this into the tube in the trough you made earlier (Fig 13).

• Assemble your gas apparatus and fill trough with water.

Making a home-made spirit burner and crucible (fig 18)

The spirit burner in Fig 18 is heating a crown bottle top crucible. The container for the spirit burner can be obtained from online shops (used for individual honey and jam portions in hotels of the UK) but we have also made one from a glass salt cellar that was bought in a hardware shop. The crucible is made by first heating the crown bottle top in a hot Bunsen flame to remove the plastic insert. A hole is drilled in the middle and a nut and bolt inserted so it can be held easily in a clamp or tongs.
Making the spirit burner (Fig 19)

- Wear eye protection
- Cut a 5 cm length of 6mm medium-wall borosilicate glass tubing.
- Flame polish both ends.
- Using a hand drill, drill a 6.5mm hole in the middle of the jar lid to take the glass tube (Keep the lid on the jar and ask a colleague to hold the jar in place. They must wear gloves).
- Drill a small 2mm air hole to one side of the main hole as above.
- Neaten the edge of the larger hole with a small file.
- Insert the glass tubing into the hole and glue in place using a glue gun
- Insert a string wick.
- Use propan-2-ol as the fuel.

A micro-scale approach to producing toxic gases

It is possible to see the reactions of toxic gases such as chlorine, hydrogen sulphide and ammonia on small scale in a plastic Petri dish. The gases (only 5cm$^3$ needs to be made) diffuse within the Petri dish to react with solutions placed as drops inside the dish (Fig 20).
This approach can also be applied to electrolysis. The picture (Fig 21) shows the apparatus made by one of the teachers in Bukinda. A hot needle is applied to the sides of a plastic Petri dish to melt the plastic and make small holes through which the electrodes are pushed. The electrodes in the Fig 21 are carbon fiber rods, obtained from online kite shops but straightened paper clips can be used.

There are drops of potassium bromide solution (which turns yellow when reacting with chlorine), potassium iodide solution (which turns dark brown), universal indicator solution or moist blue litmus paper which goes clear (bleaches) along with a Ugandan flower (which was originally blue). The electrodes are connected to a low voltage source. The teachers on the course used soldering ions to make leads for use with low voltage power packs but you could attach battery connectors (Fig 22) to crocodile clips to connect to a 9 volt battery.

CONCLUSIONS

Teacher trainers should provide instruction either at University or to groups of teachers in schools in practical workshop skills that will enable them to make simple equipment to enrich chemistry lessons. Those delivering these sessions will need to allow time on site for a lot of rehearsal. Preparation for the course will need to take place in the room where the course is to be delivered.
Teachers who receive such instruction should be encouraged to train other teachers in their immediate area, perhaps by establishing local self-help groups. These would complement existing or future government schemes. Wherever possible local education departments should cover travel expenses for teachers to meet together and share practice. Teachers who receive such instruction should also be encouraged to train enthusiastic and competent students in their schools to act as technicians on a rolling two-year basis. The student technicians could receive small financial rewards or special privileges within the school.

Syllabuses from examination boards should reflect the conditions; equipment and chemicals the teachers and pupils have available to them. Syllabuses in chemistry should reflect the industry, commerce and general daily life of the country.

University chemistry departments, professional groups of chemists and local industries often refer to tertiary education in their mission statements but often neglect to mention secondary education from where they will obtain their next batch of students. Lectures, simple demonstrations and discussions at local schools would help to inspire students and teachers in their work.

Teachers should examine the quality of chemicals. Chemicals should come with proper assay and hazard warnings on the label. Any equipment that has been sent to the school from abroad (and not been used for 5 years) should be recycled as it may be more suitable for a local University or Industry or disposed of in the correct manner.

ACKNOWLEDGEMENTS
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helped to organize the courses at the schools, the assistance from the senior staff at the Apostles of Jesus Bukinda Seminary, Kabale Diocese and St Teresa Girls’ College, Kanungu District of Uganda who made us so welcome (Fig 23).

Fig 23

REFERENCES

1. Jean Johnson has, for several years, supported teaching in a number of schools in Uganda. She has already with the help of funds from Royal Society of Chemistry and the Institute of Physics provided a laboratories, books, equipment and training for the teachers in these schools and the surrounding areas. See http://www.rsc.org/images/RSC-IOP%20Teachers%20Training%20Report_tcm18-156864.pdf and http://www.panafricachemistrynetwork.com/files/PACN%20course%20Uganda.%20Aug %2009.ppt

2. CLEAPSS (www.cleapss.org.uk) is an organisation to which the virtually all schools in England, Wales and Northern Ireland subscribe. It advises teachers, technicians and any others connected with science in schools with all aspects of practical work including chemicals, equipment, plants, microorganisms, laboratory design. The UK Health & Safety Regulations do not stop teachers, technicians and students performing chemical procedures in schools but they do require risk assessments and wherever possible the use of safer alternative procedures. The latter requirement has led CLEAPSS to develop many small and micro-scale approaches as safer alternatives to traditional procedures handed down from text book to text book and generation to generation.

3. http://www.youtube.com/watch?v=sk3ZolhPyWM&list=UU2ZRkBjqUw5-CW7vB- g0Xcw&index=31&feature=plcp (Other useful videos can be found on the CLEAPSS YouTube channel)


6. http://www.youtube.com/watch?v=d8QWXCaXfSs

7. http://www.youtube.com/watch?v=3b1V38YV0wo
The African Journal of Chemical Education (AJCE) is a biannual online journal of the Federation of African Societies of Chemistry (FASC). The primary focus of the content of AJCE is chemistry education in Africa. It, however, addresses chemistry education issues from any part of the world that have relevance for Africa. The type of contents may include, but not limited to, the following:

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

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

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