

AFRICAN JOURNAL OF CHEMICAL EDUCATION
AJCE



Vol. 4, Number 3, May 2014

SPECIAL ISSUE: LECTURES IN CHEMISTRY EDUCATION (Part II)

SJIF Impact Factor Evaluation [SJIF 2012 = 3.963]



A Publication of

ISSN 2227-5835

www.faschem.org

AFRICAN JOURNAL OF CHEMICAL EDUCATION

AJCE

Editorial Board

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

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

Dereje Andargie
Institute of Education, Debre Birhan University
ETHIOPIA

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

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

International Advisory Board

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

© 2014 Federation of African Societies of Chemistry (FASC)

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

CONTENTS

EDITORIAL

- Lectures in chemistry education: Post-ACRICE-1 (Special issue, Part II)
Temechegn Engida 1

RESEARCH PAPERS

- Chemistry teacher professional development using the technological pedagogical content knowledge (TPACK) framework
Temechegn Engida 2
- Visualization of reaction mechanism by cg based on quantum chemical calculation
 An approach to electronic laboratory textbook
Akira Ikuo and Haruo Ogawa 22
- Empowerment of teaching and learning chemistry through information and communication technologies
Boshra Awad 34
- Small-scale chemistry for a hands-on approach to chemistry practical work in secondary schools: experiences from Ethiopia
Gebrekidan Tesfamariam, Annette Lykknes and Lise Kvittingen 48
- Opportunities and challenges in open distance post-graduate student training in chemistry: UNISA's experience
Fikru Tafesse and Malose J. Mphahlele 95
- To professionals: chemical safety and chemical security overview
Wafaa M. Abdou 110
- Measuring the effects of class scheduling on student success in secondary school chemistry using content-based versus logical thinking-based online commercial programs
Robyn Ford, Anna George, Cathy Molina, and Diana Mason 133
- Challenges left-handed students face in Kenyan girls' secondary school Science laboratories
Benerdeta Mwikali Malusi 150
- FEATURE ARTICLES ON ACRICE**
- ICT in teaching and learning chemistry: Activities on the ipad
G. Robert Shelton and Diana Mason 182
- GUIDELINES FOR AUTHORS** 189

EDITORIAL

**LECTURES IN CHEMISTRY EDUCATION
POST-ACRICE-1: SPECIAL ISSUE**

Temechegn Engida
Email: temechegn@gmail.com

Dear AJCE Communities,

As you all know we had a successful event back in December 2013 on the First African Conference on Research in Chemistry Education (ACRICE-1), held in Addis Ababa, Ethiopia. The Conference brought several chemistry education researchers and teachers from all over the world with the aim of creating a platform for understanding and enriching chemistry education for preparation of African citizens who are able to deal with local and global challenges.

At that moment the plenary speakers, keynote speakers and oral presenters agreed to submit their research papers to be published as a special issue of the African Journal of Chemical Education (AJCE), the official journal of the Federation of African Societies of Chemistry (FASC) that deals with educational issues.

As promised here is Part II of the Special Issue of AJCE entitled *Lectures in Chemistry Education*. Part I of the Lectures deals mainly with curricular, methodological and assessment issues in Chemistry. Part II focuses more on information and communication technologies (ICTs) in chemistry education.

We believe that readers will benefit a lot from the multitude of approaches discussed in the two parts of the Lectures in Chemistry Education by way of improving the approach to chemistry education of any level in their respective contexts.

SJIF IMPACT FACTOR EVALUATION [SJIF 2012 = 3.963]

CHEMISTRY TEACHER PROFESSIONAL DEVELOPMENT USING THE TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) FRAMEWORK

Temechegn Engida
UNESCO International Institute for Capacity Building in Africa (IICBA)
Addis Ababa, Ethiopia
temechegn@gmail.com

ABSTRACT

The knowledge base for teaching was considered to be the pedagogical content knowledge (PCK) conceptualized in the mid-1980s. But with the advent of modern technologies, information and communication technologies (ICTs) are becoming part of the day-to-day life of teachers and students. It was thus argued in the mid-2000s that the knowledge base for teaching in the 21st century is the technological pedagogical content knowledge (TPCK/TPACK). As such TPACK is not a professional development model; rather it is a framework for teacher knowledge. We have thus developed and validated an ICT-enhanced teacher development (ICTeTD) model and the corresponding standards and teacher training modules based on the TPACK framework. This paper demonstrates this innovative model with examples from Chemistry. [AJCE 4(3), Special Issue, May 2014]

INTRODUCTION

The development of ICTs in teacher education institutions has been one of the key strategic priorities of UNESCO-IICBA for Africa. With the advent of ICTs and the development of a knowledge-based society, IICBA firmly believes that teacher's role needs to be redefined in a way that meets the demands of 21st century education. To this end, IICBA looks beyond professional teacher development programs that merely focus on training teachers in the operation of computers and ICT literacy per se, and plans to work actively towards enabling African teachers to master ICT as an effective tool to improve teaching and learning and actually integrate their skills in day-to-day classroom instruction and beyond. The issue is no longer whether teachers should integrate technology in their practices, but how to use technology to transform their teaching with technology and create new opportunities for learning [1].

There have been many approaches to introduce ICT into education in general and teaching and learning processes in particular. In the past and even present time there have been five general approaches to technology integration in education. These are [2]:

1. *Software-focused initiatives* such as the mathematical learning and general problem-solving skill development through students' use of the programming language Logo and also the software-based integration attempts made use of integrated learning system software, which provides individualized instruction while tracking students' learning needs and progress.
2. *Demonstrations of sample resources, lessons and projects* such as classroom-based and student-tested examples of appropriate technology use with the assumption that successful use of instructional plans and educational resources is easily transferable among different classrooms.

3. *Technology-based educational reform efforts* such as the larger-scale, often grant-funded, projects that are usually organized around new visions for learning and teaching that are supported by the acquisition of hardware and software.
4. *Structured/standardized professional development workshops or courses* such as large-scale professional development initiatives that are structured either as cascading professional development or as a wide variety of licensed professional development courses to districts, regions, or states, so that teachers can pursue them in more individualized ways.
5. *Technology-focused teacher education courses*. Teacher education institutions, either colleges/universities or districts/regions working alone or collaboratively, offer educational technology courses to teachers, delivered online or face-to-face. These can serve as recertification courses taken on an unclassified student basis or as elements of graduate or undergraduate programs in education.

These technocentric approaches tend to initiate and organize their efforts according to the educational technologies being used, rather than students' learning needs relative to curriculum-based content standards, even when their titles and descriptions address technology integration directly [2]. In other words, they all lack proper consideration of the integration of content and pedagogy. However, in recent years, the technological pedagogical content knowledge (TPACK) framework has emerged as a representation of the knowledge required to use technology in an educational setting in ways that are contextually authentic and pedagogically appropriate [3].

THE TPACK FRAMEWORK

It is now well known, and perhaps well accepted, that the knowledge base for teaching in the 21st century is the technological pedagogical content knowledge (TPCK, later referred to as TPACK for ease of remembering it as a word). The framework was proposed [4] as depicted in figure 1.

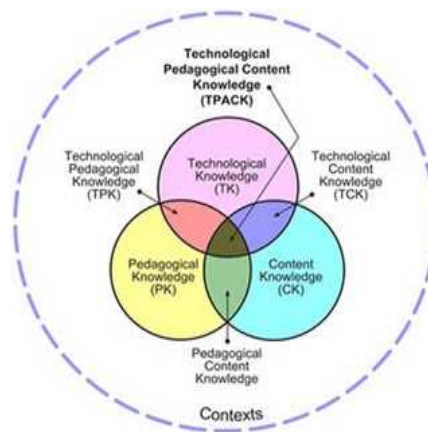


Figure 1. Technological Pedagogical Content Knowledge framework [4, p. 1025]

As Mishra and Koehler [4] argued “though Shulman’s approach [of the PCK as the knowledge base for teaching] still holds true, what has changed since the 1980s is that technologies have come to the forefront of educational discourse primarily because of the availability of a range of new, primarily digital, technologies and requirements for learning how to apply them to teaching” (p. 1023). It thus became natural to propose for the integration of technology with PCK, resulting in the amalgam knowledge called the technological pedagogical content knowledge (TPCK/TPACK). The TPCK framework “emphasizes the connections, interactions, affordances, and constraints between and among content, pedagogy, and technology. In this model, knowledge about content (C), pedagogy (P), and technology (T) is central for developing good teaching. However, rather than treating these as separate bodies of

knowledge, this model additionally emphasizes the complex interplay of these three bodies of knowledge” [4, p. 1025].

However, TPACK is not a professional development model; rather it is a framework for teacher knowledge [2]. Planners of professional development for teachers may use it by illuminating what teachers need to know about technology, pedagogy, and content and their interrelationships. More importantly, the TPACK framework does not specify how this should be accomplished, recognizing that there are many possible approaches to knowledge development of this type.

Some attempts were made to determine the effectiveness of the TPACK framework in teacher training programs. For instance, one study [5] examined the development of TPACK in four in-service secondary science teachers as they participated in a professional development program focusing on technology integration into K-12 classrooms to support science as inquiry teaching. The study introduced to the science teachers such tools as probeware, mind-mapping tools (CMaps), and Internet applications like computer simulations, digital images, and movies. The researchers then concluded that the intervention program had positive impacts to varying degrees on teachers’ development of TPACK. Contextual factors and teachers’ pedagogical reasoning affected teachers’ ability to enact in their classrooms what they learned in the program.

Another study [6] examined pre-service teachers’ perceived knowledge of TPACK and cyberwellness through structural equation modeling. The study also examined the relationships among Singaporean pre-service teachers’ perceptions of the constructs pertaining to TPACK, and their perceived ability to integrate cyberwellness knowledge when designing web-related learning. At the conclusion of the study, the researchers argued that the pre-service teachers’

confidence to integrate their cyberwellness knowledge into their teaching may play an important role in influencing how they plan and design web-based learning. Cyberwellness knowledge may be an important knowledge component to foster when considering the future development of teachers' TPACK for web-based learning.

There are, however, some theoretical arguments made by some researchers and practitioners who are not finding the TPACK framework completely effective in their work with teachers. Some among these are Krista Moroder [7] and those who expressed their agreement to her blog posted on 3 November 2013. Whereas Moroder agrees with the notion that TPACK looks at the collaboration between technology, pedagogy, and content and that teachers need knowledge of all three, she does not agree with how this framework is presented.

THE ICT-ENHANCED TEACHER DEVELOPMENT (ICTeTD) MODEL IN CHEMISTRY

The ICT-enhanced teacher development model [1] is thus developed as one of the approaches for the professional development of teachers at all levels (including higher education instructors) recognizing TPACK as the knowledge base for teachers and as the backbone of the ICTeTD. The ICTeTD model (figure 2) is expected to serve as the guide for the preparation of pre-and in-service teachers for the 21st century. The tetrahedral framework recognizes and indicates the progressive, transformed and dynamic nature of TPACK. It conveys the transformed nature of TPCK from its constituent content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (PK). Furthermore, the entire knowledge base for teachers is embedded within a context.

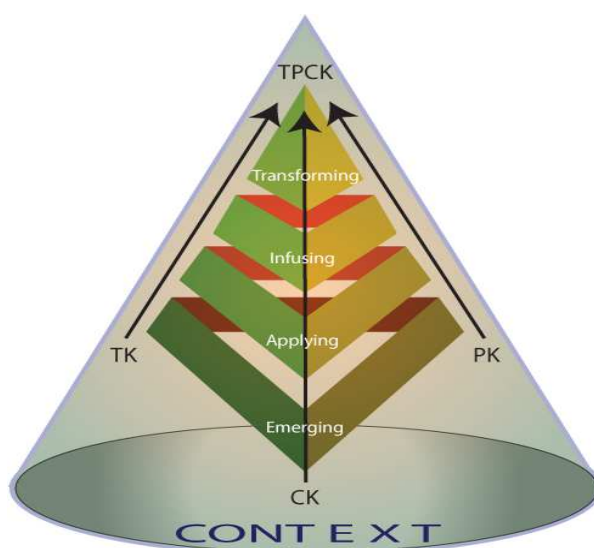


Figure 2. ICT-enhanced teacher development model [1, p. 19]

As can be seen from figure 2, TK and PK are in the plane of the page whereas CK is outward (towards the reader) of this page. All the three knowledge areas are at the same level of (have equal importance) forming the pyramid. The pyramid is made of ‘fleshes’ of TPCK--a transformed knowledge through proper interactions of CK, PK and TK.

The continuum of transformed knowledge (TPCK/TPACK) in figure 1 is categorized into four interrelated stages of development, namely *emerging TPCK*, *applying TPCK*, *infusing TPCK* and *transforming TPCK* [1]. It should be understood that each stage in the figure represents a continuum of triangular faces/planes of the pyramid parallel to its base, and that the space between successive stages is added merely for visibility of the three dimensional model.

Emerging TPCK in Chemistry represents an initial stage of TPACK development by chemistry teachers. Teachers at this stage are beginning to be aware of the nature and importance of TPCK in their social, personal and professional development. In accordance with the ICT-enhanced

teacher standards for Africa—ICTeTSA—[8], teachers at this stage are expected to be aware of the importance of a given TPACK chemistry activity (*knowledge*), to review various approaches to that given TPACK chemistry activity (*skills*), and to simply develop interest in using that activity (*attitude*).

The emerging TPCK stage in Chemistry can be applied using various technological tools like Microsoft word, Excel, PowerPoint, document camera, etc. Let's say that you have taught the States of Matter in the previous sections of your period and now it is time to teach (as per the Chemistry curriculum) the structures of simple organic molecules like methane, ethane, propane, etc. The usual way is to present the nomenclature and their structures on the chalk board (which is a two dimensional object—2D). It is, however, learnt through chemistry education research that most students could not understand the three dimensional (3D) nature of the structure of the molecules. Furthermore, it is time consuming for the Chemistry teacher to draw the structures every time he/she wants to teach/review the structures for different sections of a grade level.

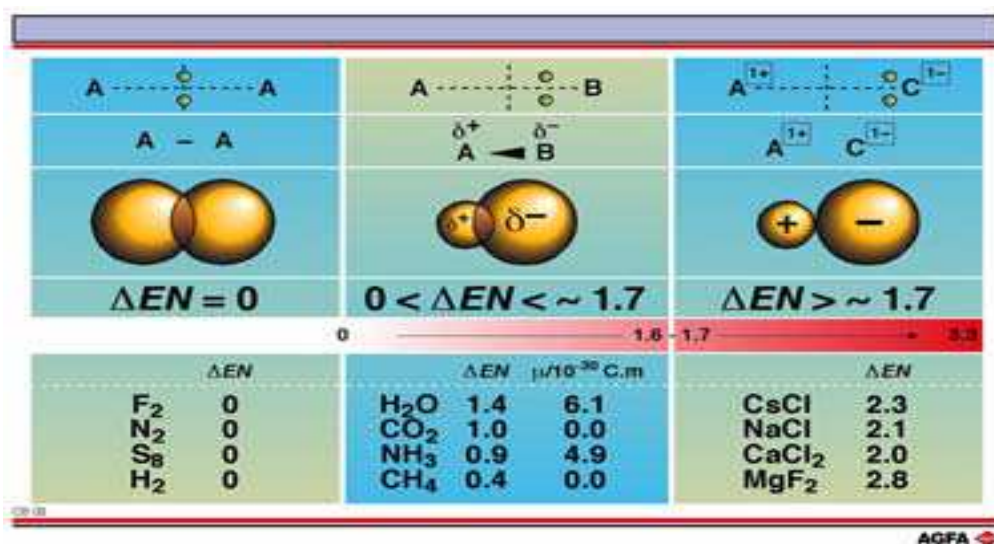
At the emerging stage, the teacher is expected to have the skills of preparing a powerpoint presentation (ppt) such as for simple organic molecules. The length of contents of the lesson can be increased at any time depending on the particular topic you are teaching. What is important here is that, when using the ppt (technological knowledge) in the classroom, you should point out that students usually misunderstand the structures drawn on chalk boards and in some textbooks as being 2D (pedagogical knowledge) rather than 3D (content knowledge).

It is also possible to prepare a ppt for use as an assessment tool. Let's assume that a Chemistry teacher wants to know to what extent his/her students understood the content he/she has taught them regarding the States of Matter. One way is to prepare a ppt involving pictures of actual objects and ask them to write down their responses on a sheet of paper when each slide is

shown to the whole class. Note that such an approach can accommodate a large number of students in one class as long as the ppt is visible to every student.

In addition, you can use transparencies prepared by others. One example is the UNESCO & IUPAC chemistry teaching material entitled DIDAC. See the following examples extracted from that material. These slides can be copied/ printed onto overhead transparencies and be used for teaching in the Chemistry classroom.

Example 1: The link between the differences in electronegativity and the type of bonding

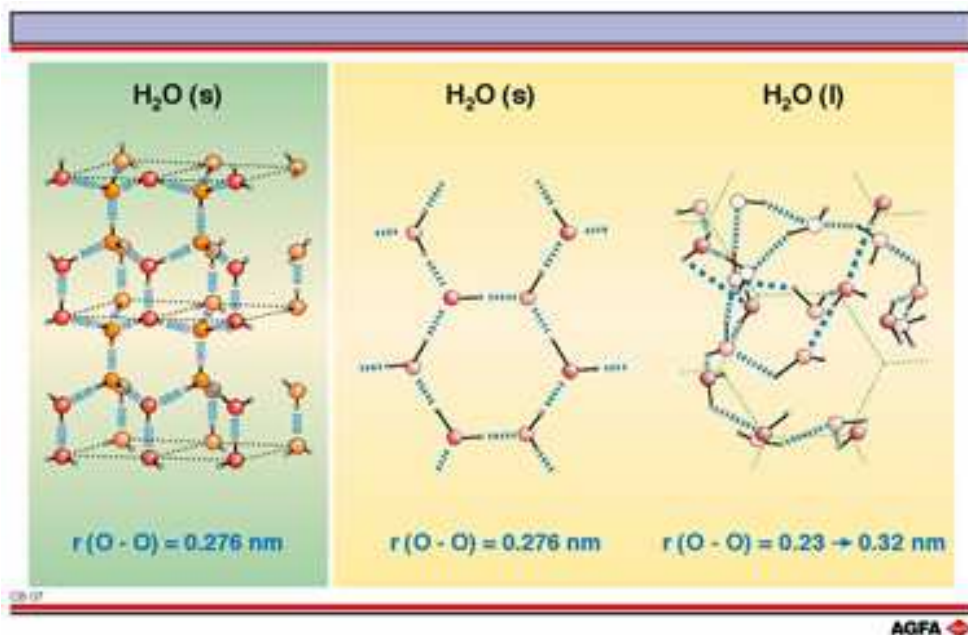


Beware!

- Substances built up of molecules which have clear polar bonds e.g. H₂O, NH₃, CO₂, CH₄ do not necessarily behave as polar substances.
- It is possible that the various polar bonds in a molecule cancel each other out, or as it were, “neutralize” each other.
- The direction and charge of the dipole moments generated by the polar bonds has to be taken into consideration, as does the resulting dipole moment for the whole molecule.

- CO_2 , for example, is an apolar molecule with two polar bonds between the C and O atoms, each having opposite dipole moments. H_2O and NH_3 are polar molecules, CH_4 is apolar.
- Nonetheless, all of these compounds contain polar chemical bonds.

Example 2: Structure of water as an example of hydrogen bonding



Left side, the three-dimensional representation of the structure of ice:

- The lattice contains a hexagonal structure. Each water molecule has four neighbors in a tetrahedral configuration.

⇒ A very open structure that has a very low density.

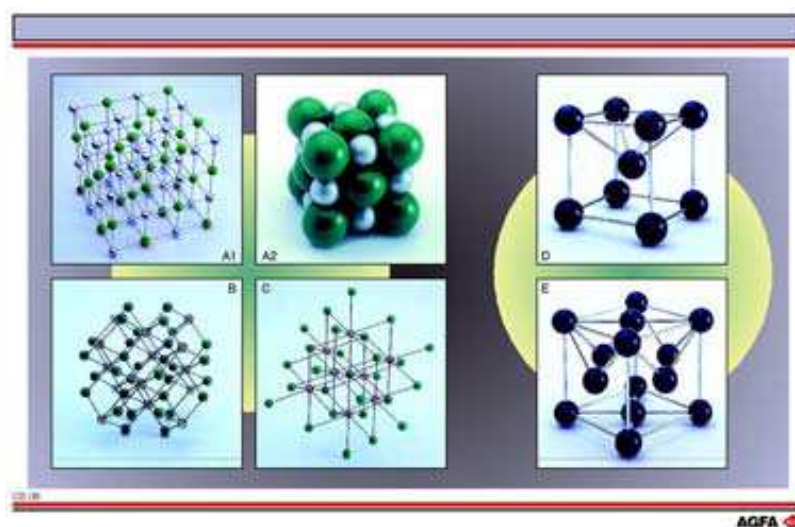
- When it is warmed (to 4°C) the hydrogen bonds are partially broken resulting in a denser structure. On further warming the thermal agitation of the water molecules increases and the density again decreases.

Right side compares the structure of ice with the structure of water at a given instant in time (computer simulation):

- The hexagonal pattern of ice is shown by a light green dotted line
- The blue dotted line represents the hydrogen bonds. The shorter the distance between the dots the shorter the hydrogen bond.
- The color of the oxygen atom indicates to what extent it is out of the plane: white atoms are in the plane whilst dark brown atoms are between 0.7 and 1.0 nm in front of the plane. The light pink and red atoms are at an intermediate distance; the darker the color the further the atom is in front of the plane.

Hydrogen bonds are essential for the spatial configuration of biologically important molecules such as proteins.

Example 3: Lattice Structures



Ionic Lattices

A1 = NaCl (open structure)

A2 = NaCl (close-packed structure)

B = CaF₂

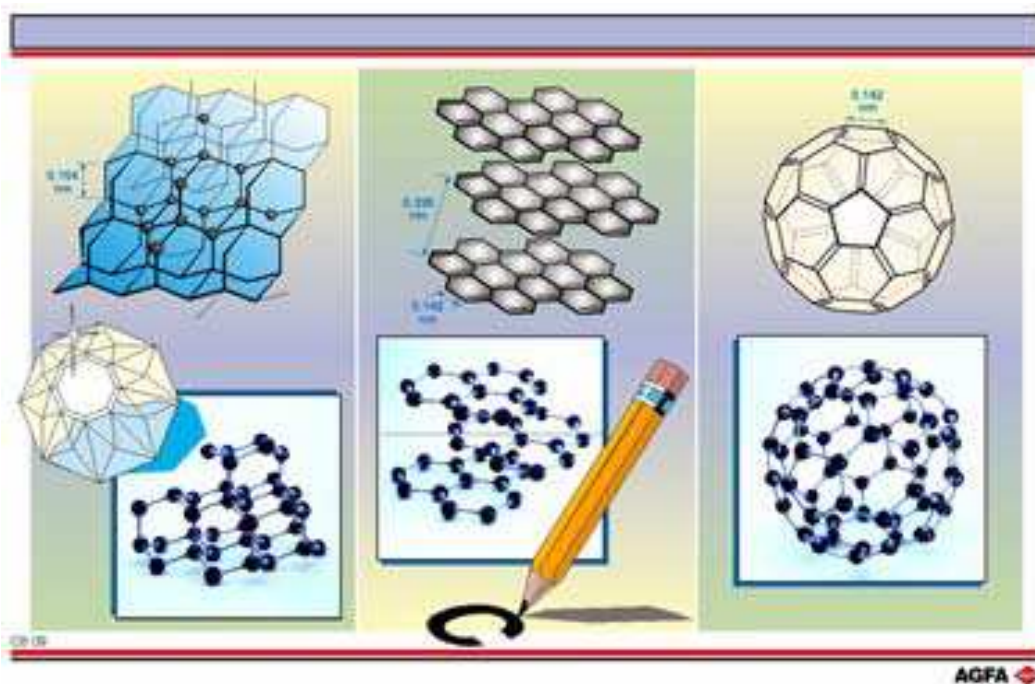
C = CsCl

Metal Lattices

D = Fe (bcc unit cell)

E = Cu (fcc unit cell)

Example 4 : Allotropes of Carbon: Diamond, Graphite and Fullerenes



Diamond (left):

- Each atom is bonded via sp^3 -hybrid orbital to four atoms in a tetrahedron.
- All four valence electrons are paired in bonding orbitals.

⇒ Diamond is stable, being an insulator with a high melting point and the hardest substance on earth. It is transparent and has a high refractive index.

Graphite (middle):

- Each atom is bonded to another three atoms by sp^2 -hybrid orbitals.

- Consists of layers of flat, hexagonal rings of carbon atoms. The layers are held together by London force. They slide easily over each other.

⇒ Graphite is a soft, black material and is used as a lubricant.

- Each atom contributes three valence electrons to the three s-bonds. The fourth electron forms a π -bond with a neighboring atom. This is not a localized bond but it moves freely throughout the π -system.

⇒ The electrical conductivity parallel to the layers is high, but is low perpendicular to the layers.

Fullerene, C₆₀ (right):

- This molecule consists of 60 carbon atoms divided into 20 six-rings and 12 five-rings, like a football.
- In 1996 Robert F. Curl, Sir Harold W. Kroto and Richard E. Smalley received the Nobel Prize for chemistry for this discovery.

Applying TPCK in Chemistry is characterized by teachers who started to use TPCK-based programs/lessons developed by others. Chemistry teachers at this stage also start engaging themselves in discourses among themselves about what it means to be a teacher of TPCK-based Chemistry curriculum, about their feelings and students' feelings while experiencing the TPCK-based curriculum, etc. In accordance with the ICT-enhanced teacher standards for Africa—ICTeTSA—[8], teachers at this stage are expected to recognize and describe the approaches for a given TPCK chemistry activity (*knowledge*), to use available approaches that are claimed by the authors for that given TPCK activity using ICTs in the specified chemistry area (*skills*), to evaluate the appropriateness of that given TPCK activity for their target learners (*skills*), and to

demonstrate positive attitudes in using that activity developed by others and that promote the standard in their subjects using ICTs (*attitude*).

In the applying stage teachers use ICT for professional purposes, focusing on improving the teaching of Chemistry so as to enrich how to teach with a range of ICT tools. The applying stage is linked with institutions in which a new understanding of the contribution of ICT to learning has developed. In this phase, administrators and teachers use ICT for tasks already carried out in institution management and in the curriculum. Teachers still largely dominate the learning environment.

Let's assume that you want to teach the topic Elements and Atoms to your students. Apart from preparing and using a PowerPoint presentation by yourself, as in the case of the emerging TPCK, you can also download from the Internet lessons that teach the topic and prepared with screenshot software and you can project it to the classroom. Such materials have also audio components that the students can listen to. You can stop the multimedia lesson at any time if you want to emphasize a certain point in the lesson and/or if you want to ask questions that the student could predict/hypothesize before listening and watching the next segment of the recorded lesson.

As part of the Chemistry teacher training lessons, a group of teachers separately watch the downloaded Chemistry lesson, compare and contrast the use of the lesson in a group-work-learning format, compare the pedagogical strategy and the specific technology used with their own practices in teaching the topic for the target learners. Such training activities constitute the knowledge component of the competencies expected of the teachers. With regard to the skills component of the competencies for the applying level of ICTeTSA [8], a group of Chemistry teachers can prepare lessons of their own on Elements and Atoms using a specific lesson plan

templates, incorporate the videos and slides of their own by recording their practices on a group of students using a video camera. The teachers could also develop positive attitude towards this particular TPACK activity by evaluating and discussing the lessons recorded by other course mates.

Note that you will be able to develop your own such lessons as your technological knowledge is advancing. Perhaps you will do so when you reach the infusing TPACK stage in teaching Chemistry, but for sure you can do it at the transforming stage.

Infusing TPACK in Chemistry represents a stage of TPACK development by teachers who started to modify, adapt and initiate their own TPACK-based materials/lessons/modules for diverse group of learners. Teachers at this stage have the capability to mentor/advise other teachers about what and how of TPACK-based chemistry educational programs. They can also comfortably adapt themselves to new situations in those programs. They can design and carryout TPACK-based inquiry/research activities to solve personal and institutional problems.

In the infusing stage, Chemistry teachers infuse ICT in all aspects of professional life to improve student learning and the management of learning processes. ICT enables teachers to become active and creative in stimulating and managing the learning process, by infusing a range of preferred learning styles and uses of ICT in achieving educational goals. Chemistry teachers are required to master authoring tools, animation tools and multimedia tools to develop instructional software in Chemistry. In accordance with the ICT-enhanced teacher standards for Africa—ICTeTSA—[8], teachers at this stage are expected to explain and criticize the pros and cons of various approaches for a given TPACK chemistry activity in terms of established theories, appropriateness of ICT tools, content requirements (pedagogical approaches) within a

Chemistry area and contextual factors (*knowledge*), to produce what is needed by the standard using ICTs for their subject areas and target groups (*skills*), to use one's produced standard-based TPACK chemistry activity for the target group (*skills*), to evaluate the effectiveness and efficiency of one's produced approaches for that given TPACK activity (*skills*), and to appreciate the care and rigor needed in implementing the standard for target learners using available ICT tools (*attitude*).

For instance, at the infusing TPCCK stage, a Chemistry teacher starts designing his/her own lessons by using free software available for educational purposes. One such software is the Advanced Chemistry Development (ACD/ChemSketch). As stated in the reference manual [9], ACD/ChemSketch is a chemical drawing software package from ACD/Labs designed to be used alone or integrated with other applications. ChemSketch is used to draw chemical structures, reactions, and schematic diagrams. It can also be used to design chemistry-related reports and presentations.

ACD/ChemSketch has the following major capabilities: **Structure mode** for drawing chemical structures and calculating their properties, **Draw mode** for text and graphics processing, and **Molecular Properties** calculations for automatic estimation of: Formula weight, Percentage composition, Molar refractivity, Molar volume, Parachor, Index of refraction, Surface tension, Density, Dielectric constant, Polarizability, Monoisotopic, nominal, and average mass.

ACD/ChemSketch can stand alone as a drawing package or act as the "front end" to other ACD/Labs software such as the NMR Predictor engines. Once ACD is installed in the computer (TK), the Chemistry teacher can follow the instructions/user manual for drawing and animating (PK), for instance, the structures of organic molecules (CK). The animated structures with

different models such as wire frame, sticks, ball and sticks, space filling, dots only, and discs can be used to challenge students' misconceptions about the structures of the molecules through the teacher's application of this particular TPACK activity.

Transforming TPCK in Chemistry is the highest stage of social, personal and professional development of 21st century teachers. Teachers at this stage are creative and innovative in that they not only develop new and appropriate TPCK programs for their institutions but also theorize about the nature and methodologies of TPCK. In accordance with the ICT-enhanced teacher standards for Africa—ICTeTSA—[8], chemistry teachers at this stage are expected to master the approaches and techniques that promote the given standard within and across grade levels of Chemistry as well as across the institute's/school's curricula using ICTs (*knowledge*), to demonstrate creativity in relation to that particular standard using ICTs in their institutions/schools and beyond (*skills*), and to demonstrate motivation, dedication and sensitivity to implementing the standard to various target groups using ICTs (*attitude*).

The transforming stage is linked with institutions that have used ICT creatively to rethink and renew their institute. ICT becomes an integral part of daily personal productivity and professional practice. The focus of the Chemistry curriculum is now much more learner-centered and integrates the subject in real-world applications, both in real and virtual environments. For example, students may work with community leaders to solve local problems related to water by accessing, analyzing, reporting, and presenting information with ICT tools. Learners' access to technology is broad and unrestricted. They take even more responsibility for their own learning and assessment. ICT is taught as a subject area at an applied level and is incorporated into all vocational areas. The institution has become a centre of learning for the community. Teachers

need to master special software, learning management system, simulation and modeling tools, networking and various web tools, in order to innovatively transform the teaching and learning system.

At this stage, the teacher is a creative and innovative person. He/she can design, implement and evaluate a range of technological tools in teaching Chemistry and across the curriculum. At this stage the teacher should be able to design Chemistry website at least using opensource software like Joomla. He/she should also be able to use the content management software like Moodle for wider and online learning.

SUMMARY

Base on the ICTeTD model [1] and the corresponding standards [8], we developed a training module for Chemistry (of course to other subjects like History, Geography, Biology, Mathematics, Physics, and Literacy (we can do so for any subject in the curricula of any level, K-University). The basic idea behind these documents is that (chemistry) teacher training in the 21st century needs to be designed in such a way that they develop technological, pedagogical content knowledge (TPCK/ TPACK) as one package if they are to be successful and effective teachers. In addition, as teachers and their contexts vary to a great extent, there is a need for a progressive development which we classified as *Emerging TPCK*, *Applying TPCK*, *Infusing TPCK* and *Transforming TPCK*.

The training of chemistry teachers will follow activity-based interactive lessons, with each lesson designed to implement the approach depicted in figure 3. Facilitators of the training of teachers will follow what is called the lesson study approach. Lesson Study is a teaching improvement process that has origins in Japanese elementary education, where it is a widespread

professional development practice. Working in a small group, teachers collaborate with one another, meeting to discuss learning goals, to plan an actual classroom lesson (called a "research lesson"), to observe how it works in practice, and then to revise and report on the results so that other teachers can benefit from it. The lesson study employs PDCA (plan–do–check–act or plan–do–check–adjust) approach which is an iterative four-step management method used in business for the control and continuous improvement of processes and products.

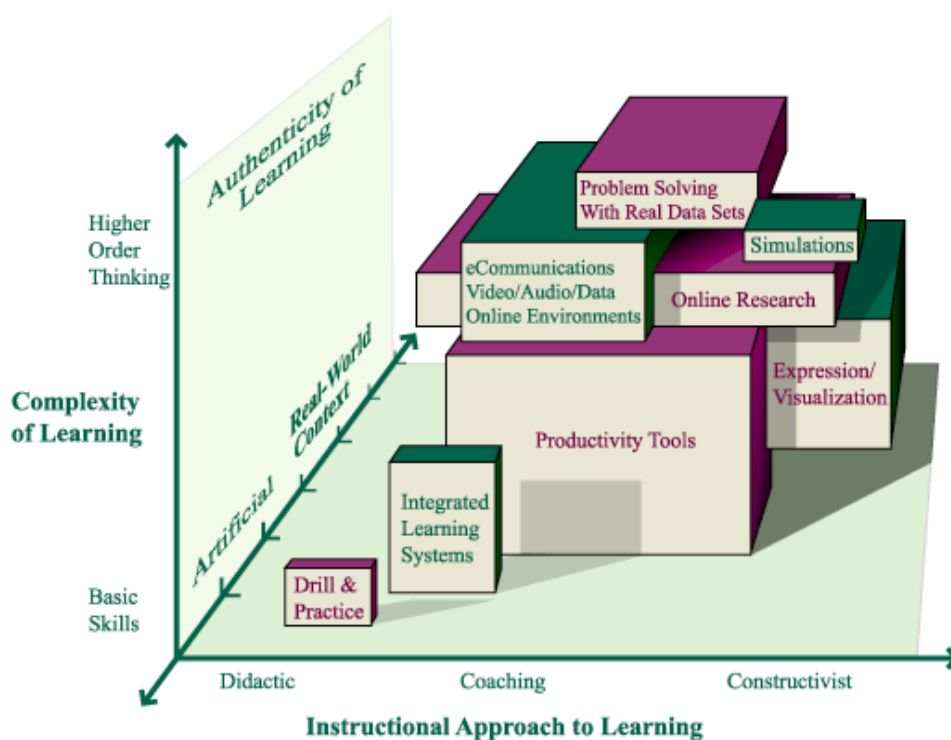


Fig. 3: A 3-D representation for gauging which instructional approach with ICT (X-axis) might support students' thinking (Z-axis) in authentic learning situations (Y-axis)[10]

REFERENCES

1. T. Engida, ICT-enhanced Teacher Development Model. Addis Ababa: UNESCO-IICBA, 2011. Available at <http://www.eng.unesco-iicba.org/sites/default/files/ICT-enhanced%20Teacher%20Development.pdf>
2. J. Harris, P. Mishra, and M. Koehler, "Teachers' Technological Pedagogical Content Knowledge and Learning Activity Types: Curriculum-based Technology Integration Reframed", *Journal of Research on Technology in Education*, vol. 41, no. 4, pp. 393–416, 2009.

3. J.T. Abbitt, “Measuring technological pedagogical content knowledge in pre-service teacher education: a review of current methods and instruments”, *Journal of Research on Technology in Education*, vol. 43, no. 4, pp. 281–300, 2011.
4. P. Mishra, and M. Koehler, “Technological pedagogical content knowledge: a framework for teacher knowledge”, *Teachers College Record*, vol. 108, no. 6, pp. 1017–1054.
5. S.S. Guzey and G.H. Roehrig, “Teaching science with technology: case studies of science teachers’ development of technology, pedagogy, and content knowledge”, *Contemporary Issues in Technology and Teacher Education*, vol. 9, no. 1, pp.25-45, 2009.
6. C.S. Chai, H.L. Joyce, H.N.J. Ho, and C-C. Tsai, “Examining pre-service teachers’ perceived knowledge of TPACK and cyberwellness through structural equation modeling”, *Australasian Journal of Educational Technology*, vol. 28 (special issue, 6), pp.1000-1019, 2012.
7. K. Moroder, “Ed Tech Frameworks: Why I Don't Use TPACK or SAMR with my Teachers”, <http://www.edtechcoaching.org/2013/11/ed-tech-frameworks-why-i-dont-use-tpack.html>, November 3 (Sunday), 2013.
8. T. Engida, *ICT-enhanced teacher standards for Africa*. Ababa: UNESCO-IICBA, 2012. Available at <http://www.eng.unesco-iicba.org/sites/default/files/ICTeTSA.pdf>
9. Advanced Chemistry Development, Inc., *ACD/ChemSketch Version 12.0 for Microsoft Windows: Reference Manual*. http://exordio.qfb.umich.mx/chemsk_r.pdf, 1997-2010
10. S. Majumdar, S., *Regional Guidelines on Teacher Development for Pedagogy-Technology Integration*. Bangkok: UNESCO-Asia and Pacific Regional Bureau for Education, 2005.

**VISUALIZATION OF REACTION MECHANISM BY CG BASED ON
QUANTUM CHEMICAL CALCULATION
- AN APPROACH TO ELECTRONIC LABORATORY TEXTBOOK -**

Akira Ikuo and Haruo Ogawa
Department of Chemistry, Tokyo Gakugei University, Japan
Corresponding Email: ikuo@u-gakugei.ac.jp

ABSTRACT

Visualization by computer graphics is great help for students to have images in the molecular level. In this work, the change in the molecular configuration in fundamental chemical reactions such as, $F + HCl \rightarrow HF + Cl$, $I + H_2 \rightarrow HI + H$, $OH^- + CH_3Cl \rightarrow CH_3OH + Cl^-$, and esterification of acetic acid and ethyl alcohol were visualized by the quantum chemical calculation MOPAC with PM5 Hamiltonian. The CG teaching material could simultaneously display realistic shapes and electrostatic potentials of reactants on the way of the reaction profile besides the ball-and-stick model. The CG teaching material could be an effective tool to provide information about the nature of the reaction. The teaching material was tried to combine with chemical experiments of student's lab used tablet PC for the purpose of making electronic textbook of chemical experiments, which integrates observable level, molecular level, and symbolic level. [AJCE 4(3), Special Issue, May 2014]

INTRODUCTION

Chemical education has the circumstances performed through an experiment. Understanding the observed phenomena, chemists use to imagine and explain observations in terms of molecules. Observed phenomena and molecular level models are then represented in terms of mathematics and chemical equation [1, 2]. Student's difficulties and misconceptions in chemistry are from inadequate or inaccurate models at the molecular level [3].

Visualization is great help for students to have images in the molecular level. It is our aim to produce computer graphics (CG) teaching material based on quantum chemical calculations, which provides realizable images of the nature of chemical reaction [4, 5]. If the CG teaching material is combined with chemical experiments of student's laboratory, students would observe the reaction from three thinking levels, namely, phenomena in the observable level and CG teaching material in the molecular level, and chemical equation in the symbolic level. Our ultimate goal is to produce such an electronic textbook that can be used in the experimental laboratory. This paper describes our approach to the electronic laboratory textbook of chemical experiments, which integrates the three thinking levels.

PROCEDURES

Quantum Chemical Calculation

The semi-empirical molecular orbital calculation software MOPAC [6] with PM5 Hamiltonian in SCIGRESS for Windows (FUJITSU, Inc.) was used in all of calculations for optimization of geometry, for search of potential energies of various geometries of intermediates, for search of transition state, and search of the reaction path from the reactants to the products *via* the transition state. The optimized structure of the transition state was verified by the

observation of a single absorption peak in the imaginary number by the use of the program Force in MOPAC for vibration analysis. If the peak was observed, Intrinsic Reaction Coordinate (IRC) [7] calculation was done and the reaction path was confirmed.

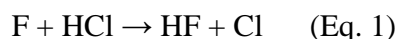
CG teaching material

A movie of the reaction path was produced by the software DIRECTOR (ver. 8.5.1J, Macromedia, Inc.) following the display of the bond order of the structure of the reactants in each reaction stage, which was drawn by the SCIGRESS. It was confirmed that the drawn CGs of the molecular models of reactants moves smoothly. The red ball, which indicates progress of the reaction, was arranged on the reaction profile and simultaneous movements of the ball and the reactants were confirmed. The movie file was converted to the Quick Time movie by the Quick Time PRO (ver. 7.66, Apple, Inc.) and was saved to iPad (Apple, Inc.) by using the iTunes (ver. 11.1.5, Apple, Inc.).

RESULTS AND DISCUSSION

Reaction of $F + HCl \rightarrow HF + Cl$

The study of simple reaction of two atoms molecule on the reaction of equation (Eq.1) was conducted by the calculation of potential energy (PE).



Changes of PE in the reaction have been reported experimentally [8] and theoretically [9]. However, the reaction has not been clarified enough in details such as PE surface in three-dimension (3-D). PE of 2-D and 3-D are shown in the Figure 1 along with structure of reactants

in the ball-and-stick model and the reaction profile, which demonstrates the degree of the reaction progress by the ball.

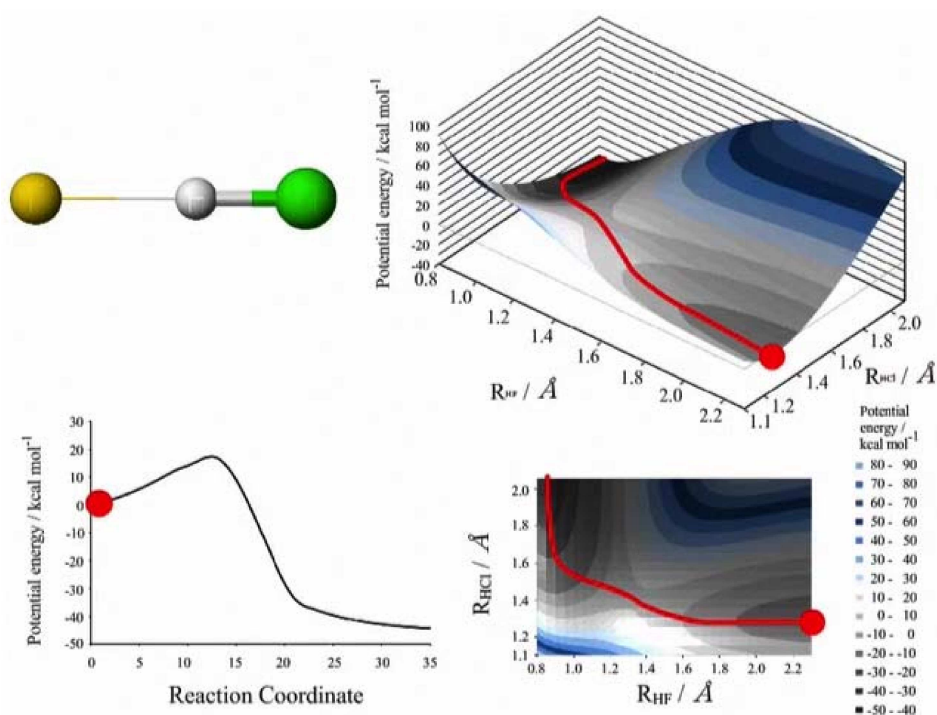


Figure 1 CG teaching material of $F + HCl \rightarrow HF + Cl$

The transition state is located near the point of H-F distance of 1.376 Å and H-Cl distance of 1.354 Å. The IRC method [7] supported the transition state. A single absorption peak in the negative region was found at -2858 cm^{-1} . The result indicates vibrational mode due to the decrease of potential energy for the direction of only one path *via* a true transition state at the saddle point. Energy between the initial state of reactants and the final state of products was $38.96 \text{ kcal mol}^{-1}$ [10]. The value was in fairly good agreement with an experimental [8] value of $33.06 \text{ kcal mol}^{-1}$.

The Figure 1 clearly shows these changes of PEs with display on PE surface in 3-D, which offers a bird-eye view of the reaction profile. Two Valleys of lower energies and hilltop on the transition state at the saddle point can be recognized boldly. Possible pathways of the reaction from the reactants of F and HCl to the products of HF and Cl *via* the transition state at saddle point can be readily traced. CG teaching material is able to provide information about change of the PE and structure of reactants in a certain state simultaneously.

Reaction of $I + H_2 \rightarrow HI + H$

We developed a CG teaching material of rearrangement by collision of diatomic molecule and one atom. The transition state of the reaction is located nearby the point of 1.6 Å of I-H distance and 1.8 Å of H-H distance [5]. The electrostatic potential on electron density (EPED) model and the ball-and-stick model of the intermediate, I-H-H, and the reaction profile were combined in the left side of the Figure 2 for easier recognition of those three.

The electrostatic potential [11] was calculated based on the coordinates of atoms from the IRC calculation[7] and superimposed on to the iso-surface of the electron density at the value of $0.01 \text{ e } \text{Å}^{-3}$ as shown in the upper left part of the CG. The values of electrostatic potentials were represented in different color on the model of intermediate on the way of the reaction, and figure legend of color boundaries for electrostatic potential was also listed. Distribution of the electrostatic potential among the intermediate can be seen by the colors. For example, right side of H_2 molecule is positively charged with relative value of +0.09 based on evaluation of energy of interactions of proton to the charge of iso-surface. The model by EPED provides information about electrostatic distribution in intermediate with realistic shape on the way of the reaction.

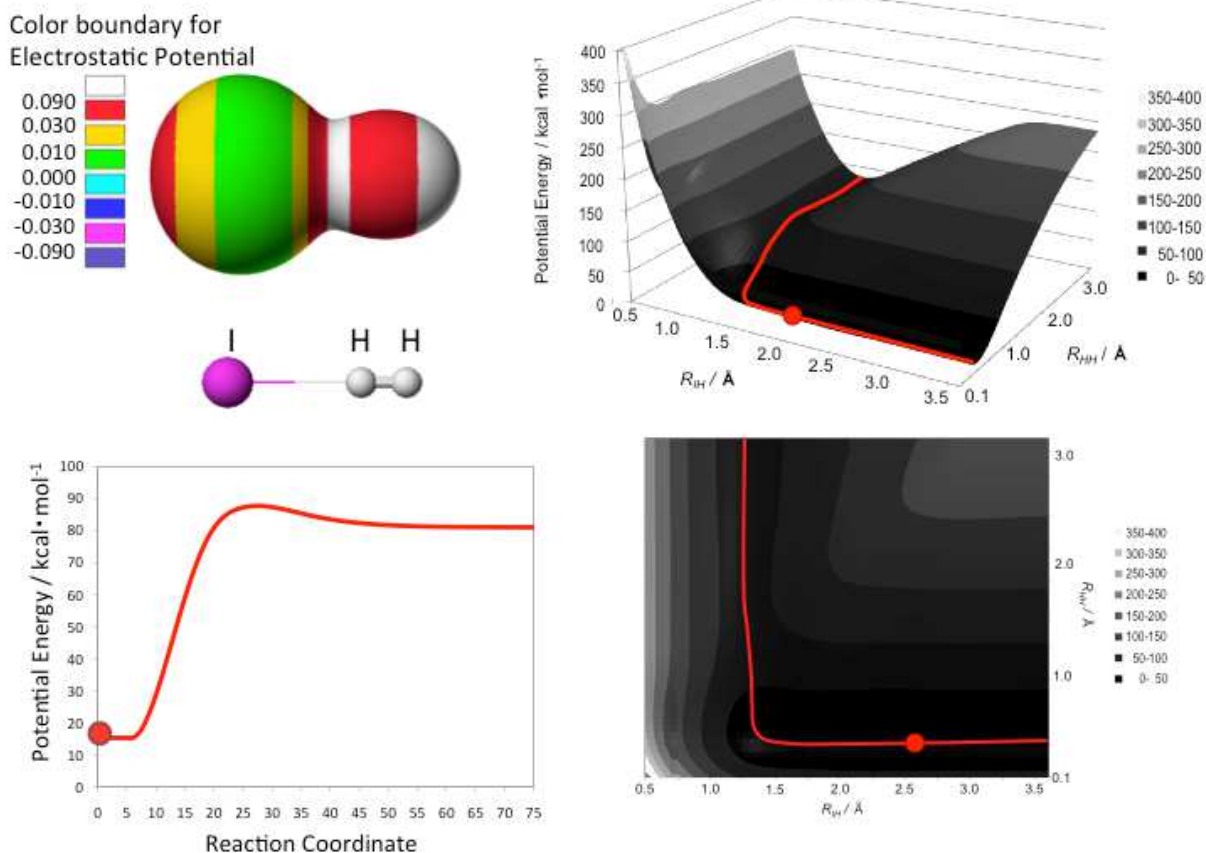


Figure 2 CG teaching material of $I + H_2 \rightarrow HI + H$

In the middle of CG, skeletal structure in the ball-and-stick model in which diameter of the stick reflects calculated bond order is shown. Lower left part of the CG shows PE vs. reaction coordinate, the reaction profile, which demonstrates the degree of the reaction progress by the ball. Student could correlate this reaction profile with the reaction path in the right side of CG. The left side of the CG is able to provide information about characteristics of intermediate of molecule in a certain state on the progress of reaction.

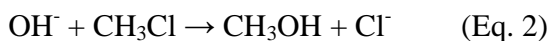
Form the survey conducted to the university student [12], the CG teaching material on the tablet computer (iPad) may creates positive attitude among the students toward the subject and it was effective to provide images of “Energy” change, “Structure” change, and “Migration of

Electron” during chemical reaction. Results of surveys suggested that the teaching material in the tablet computer could be an effective tool in laboratory class.



Walden’s inversion is one of important example of the bimolecular nucleophilic substitution reaction (S_N2 reaction), which inverse configuration of reactant. Therefore, the reaction is often adopted in teaching material on the curriculum of the university, including some appropriate schemes [13]. The schemes should be developed for student to acquire more realizable images of the nature of the reaction.

We developed CG teaching material for university student, concerned about reaction with drastic change of the structure of reactants in the reaction (Eq. 2) as a model of Walden’s inversion. CG teaching material could demonstrate dynamism of structural change.



The inter-atomic distances of C-Cl in CH_3Cl was calculated as 1.87 Å (1.87 Å) [14], and C-O in CH_3OH was 1.41 Å (1.43 Å) [15]. These values were in good agreement with the literature values in the parentheses. Energy between the initial state of reactants and the final state of products was 165.01 kJ mol⁻¹. The value was in fairly good agreement with literature [16] value of 162.90 kJ mol⁻¹.

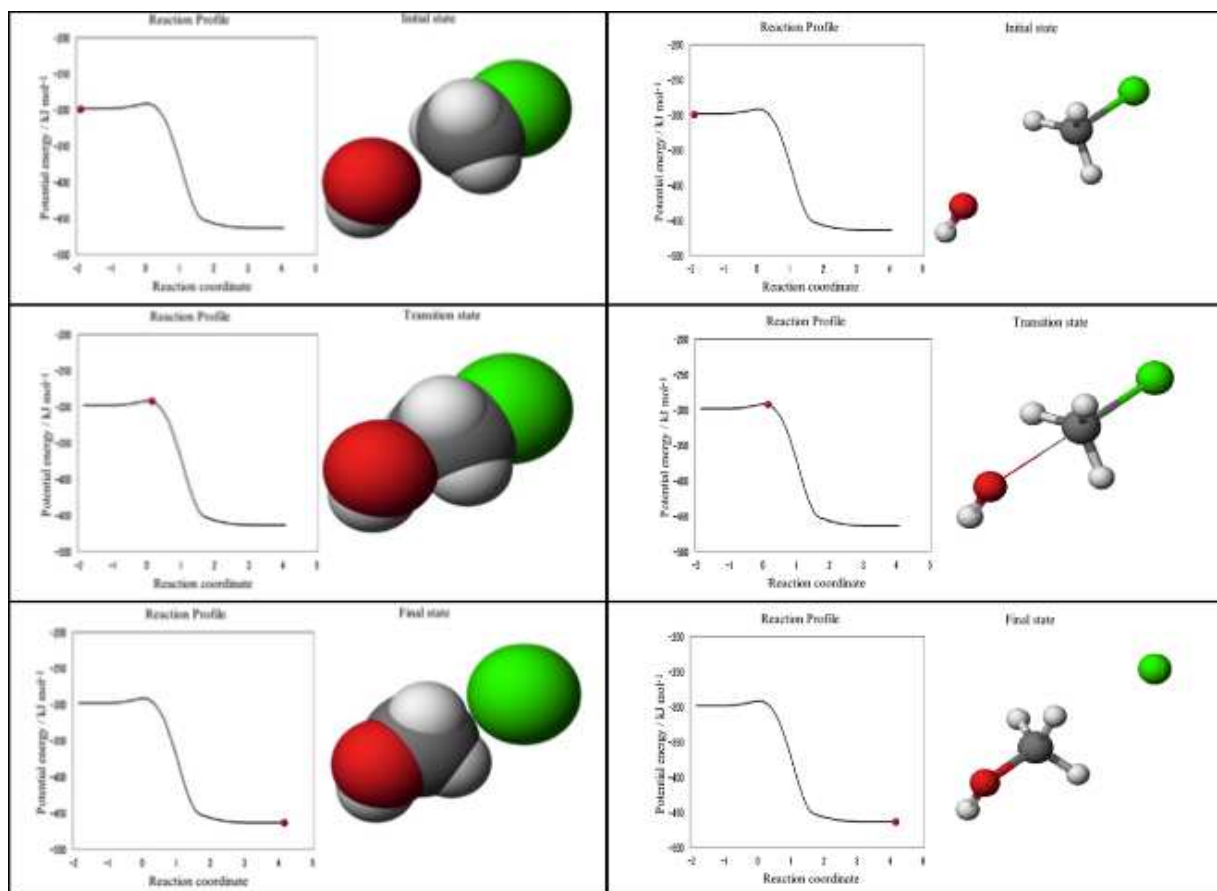


Figure 3 Selected picture from the CG teaching material

Selected picture of CG movies are shown in the Figure 3. The CG shows the reaction profile, potential energy vs. reaction coordinate, which demonstrates the degree of the reaction progress by the ball. Movies were made by using not only by the space filling model, which shows realistic shape, but also the ball-and-stick model, which shows change in molecular configuration easily.

A student is expected to obtain the image of an umbrella reversal like motion in Walden's inversion. In the space filling, the existence probability of the electron is 90 %. In the ball-and-stick, the thickness of stick changes by bond order. When the CG teaching material in the tablet PC is touched by student, the Quick Time control bar appears and the red ball can move by

student's choice. This manual control feature provides "Hands-on" feeling to student. This CG teaching material could provide not only images of energy change during reaction but also images of dynamical structure change during chemical reaction.

The CG teaching material could demonstrate the structural change of reactants with both the space filling and the ball-and-stick models along with the reaction profile, which can provide image of energy change during the reaction.

Esterification of acetic acid and ethyl alcohol

CG teaching material of the esterification of acetic acid and ethyl alcohol is shown in the Figure 4. The electrostatic potential [11] was calculated based on the coordinates of atoms obtained previously [4] and superimposed on to the iso-surface as shown in the Figure 4.

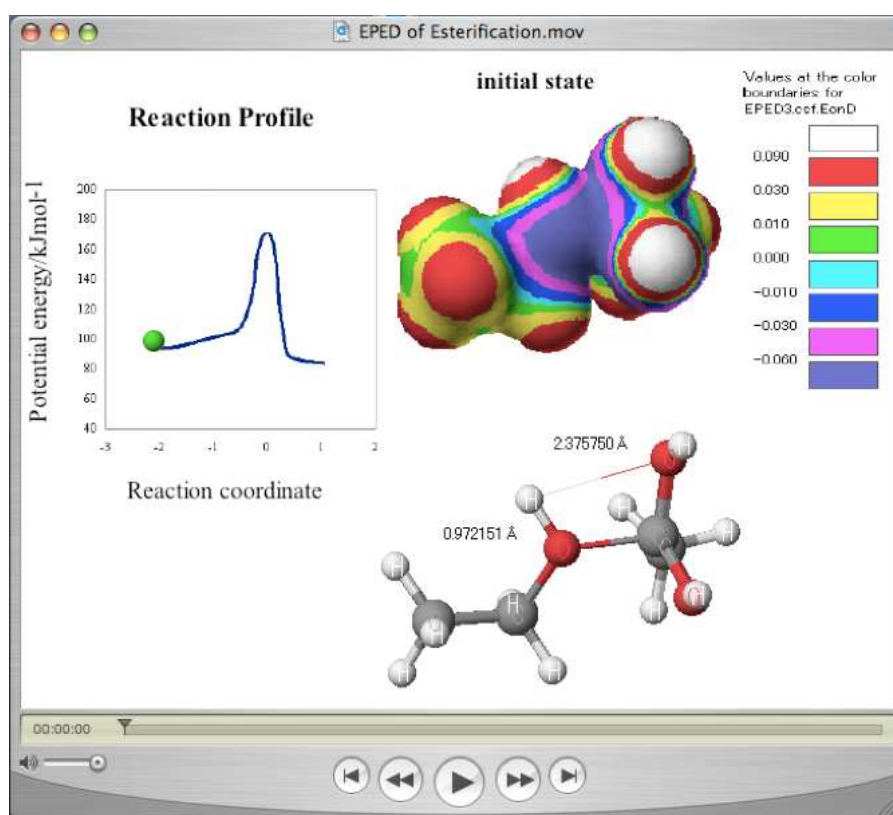


Figure 4 CG teaching material of the esterification

The values of electrostatic potentials were represented in different color on the model of intermediate in the transition state, and figure legend of color boundaries for electrostatic potential was also listed. Distribution of the electrostatic potential among the intermediate can be seen by the colors. For example, oxygen of ethanol is negatively charged with relative value of -0.06 based on evaluation of energy of interactions of proton to the charge of iso-surface and hydrogen of carbonium ion is positively charged with relative value of +0.09.

The model by electrostatic potential provides information about electrostatic distribution of the intermediate on the way of the reaction. The CG teaching material could simultaneously display realistic shapes and electrostatic potentials of reactants on the way of the reaction profile besides the ball-and-stick model as shown in the Figure 5.

The teaching material can play by student's choice of the way of automatic movement or manual movement. The CG teaching material can be loaded with note PC, tablet PC, and smart phone.

Prototype Electronic Laboratory Textbook

Produced CG teaching material could demonstrate the structural change of reactants in both the space filling with electrostatic potential and the ball-and-stick models along with the reaction profile, which could provide image of energy change during the reaction. The CG teaching material was integrated with electronic laboratory textbook for university student by means of iBooks Author (ver. 2.1.1, Apple, Inc.).

The laboratory textbook could display picture of apparatus and

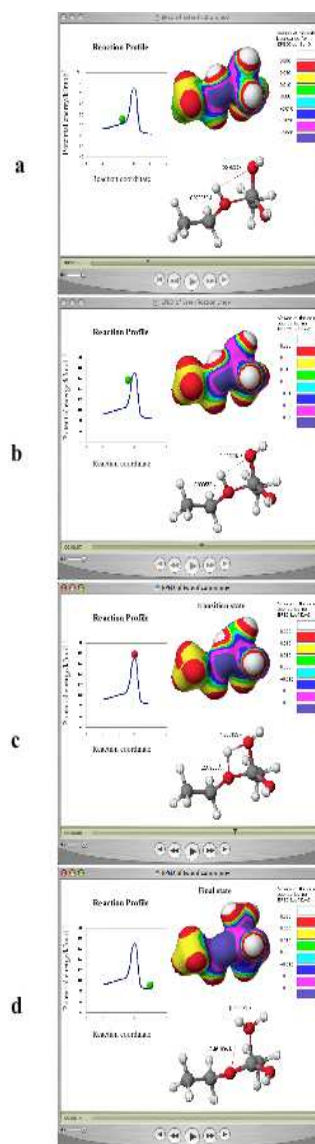


Figure 5 Selected picture of CG teaching material of the

flow-chart of small-scale experiment in addition to the CG teaching material of reaction mechanism.



Figure 6 Prototype electronic textbook

The CG teaching material was tried to combine with chemical experiments of student's lab used tablet PC for the purpose of making electronic textbook of chemistry laboratory. Prototype electronic textbook is shown in the Figure 6. The textbook provides images of experimental procedure in the form of flow chart and picture of apparatus, which can be enlarged by students touch.

CONCLUSIONS

In this work, the change in the molecular configuration in basic chemical reaction such as, $F + HCl \rightarrow HF + Cl$, $I + H_2 \rightarrow HI + H$, $OH^- + CH_3Cl \rightarrow CH_3OH + Cl^-$, and esterification of acetic acid and ethyl alcohol were visualized by the quantum chemical calculation. The CG teaching material could simultaneously display realistic shapes and electrostatic potentials of

reactants on the way of the reaction profile besides the ball-and-stick model. The CG teaching material could be an effective tool to provide information about the nature of the reaction. The teaching material was tried to combine with chemical experiments of student's lab used tablet PC for the purpose of making electronic textbook of chemical experiments, which integrates observable level, molecular level, and symbolic level.

REFERENCES

1. Gilbert, J. K., Treagust, D. F., in Gilbert, J. K., Treagust, D. (Eds.), "Models and Modeling in Science Education 4 Multiple Representations in Chemical Education", Springer, (2009), 333-350.
2. Tasker, R., Dalton, R., in Gilbert, J. K., Reiner, M., Nakhleh, M. (Eds.), "Models and Modeling in Science Education 3 Visualization: Theory and Practice in Science Education", Springer, (2010), 103-131.
3. Kleinman, R. W., Griffin, H. C., Kerner, N. K., *J. Chem. Edu.*, **64**, 766-770 (1987).
4. Ikuo, A., Ikarashi, Y., Shishido, T., Ogawa, H., *J. Sci. Educ. Jpn.*, **30** (4), 210-215 (2006).
5. Ikuo A., Nagashima H., Yoshinaga Y., Ogawa H., *Chem. Educ. J.*, **13**, Registration #13-2 (2009).
6. Stewart, J. J. P., *J. Comp. Chem.*, **10** (2), 209-220 (1989).
7. Fukui, K., *J. Phys. Chem.*, **74**, 4161-4163 (1970).
8. Martin, J. D. D., Hepburn, J. W., *J. Chem. Phys.*, **109**, 8139-8142(1998).
9. Deskevich, M. P., Hayes, M. Y., Takahashi, K., Skodje, R. T., Nesbitt, D. J., *J. Chem. Phys.*, **124**, 224303-1-224303-12(2006).
10. Ikuo, A., Nagashima, H., Yoshinaga, Y., Ogawa, H., in Gupta-Bhowon, M., Jhaumeer-Laulloo, S., Wah, H. L. K., Ramasami, P. (Eds.), "Chemistry Education in the ICT Age", Springer, (2009), 301-309.
11. Kahn, S. D., Pau, C. F., Overman, L. E., Hehre, W. J., *J. Am. Chem. Soc.*, **108**, 7381-7396(1986).
12. Ikuo, A., Nagashima, H., Yoshinaga, Y., Ogawa, H., in Werner, B (Ed.), "Proceedings 2012 7th IEEE International Conference on Wireless, Mobile and Ubiquitous Technology in Education.", IEEE Computer Soc. CPS, (2012), 82-86.
13. For example: McMurry, J., "McMurry Organic chemistry" Tokyo Kagaku Dojin, Tokyo (2001), 272.
14. Weast, R. C., "CRC Handbook of Chemistry and Physics" 63rd ed., CRC Press, Inc, Boca Raton, Florida (1982), F180-181.
15. Shida, S., "Kagaku jiten", Morikita Syuppan, Tokyo (1981), 1251.
16. Nihonkagakukai-hen, "Kagakubinran Kiso hen" 3rd. ed., Maruzen, Tokyo(1984), II-314 and 319.

ACKNOWLEDGEMENT

This work was supported by JSPS Grant-in-Aid for Scientific Research (C) (25350188).

EMPOWERMENT OF TEACHING AND LEARNING CHEMISTRY THROUGH INFORMATION AND COMMUNICATION TECHNOLOGIES

Boshra Awad

Faculty of Women for Arts, Science, and Education, Ain Shams University,

Asma Fahmy Street, Heliopolis, Cairo, Egypt

E-mail: boshra_awad@yahoo.com

ABSTRACT

There is an obvious growing of the importance of information and communication technologies (ICTs) in science education. It is used as a tool for designing new learning environments, integrating virtual models and creating learning communities (e-learning). However, e-learning used in teaching and learning chemistry, including informative material in electronic forms such as; www-pages e-mails, and discussion forums enhances teaching and learning chemistry. In addition to the material delivery and implementation of new electronic tools the e-learning process requires support in technical matters, especial activation of learning processes, and cooperation between teachers to exchange their experiences and ideas. It is very important to create e-learning in high quality that requires quality management to standardize approaches of e-learning. International cooperation would emphasize these requirements, and even more. In this paper I report experiences of developing a bilingual (English-Arabic) chemistry course in which web or virtual learning environment has been utilized. There is a need for increasing cooperation between teachers, in different countries web-based teaching and learning chemistry. Nowadays extremely actual and perspective educational technique is used, which is the mobile learning (m-learning). Mobile learning is the intersection of mobile computing (the application of small, portable, and wireless computing and communication devices) and e-learning (learning facilitated and supported through the use of information and communications technology). Mobile learning that provides learning is truly independent of time and place and facilitated by portable computers capable of providing rich interactivity, total connectivity, and powerful processing. In May 2005, Ellen Wagner, senior director of Global Education Solutions at Macromedia, proclaimed that the mobile revolution had finally arrived. *[AJCE 4(3), Special Issue, May 2014]*

INTRODUCTION

Information and communication technologies (ICTs) have become one of the fundamental building blocks of the modern societies. Many countries now regard the mastering of the basic skills and concepts of ICT as an inevitable part of the core of education. To this end, various new models of education into the teaching and learning environment, such as e-learning, m-learning, and other Web- based technologies. The effective integration of such applications however, depends to a large extent on teacher's familiarity and ability with the IT learning environment. However, 21st century declared to be the age of information and communication technology. We cannot work in the society without on-line technology. Online technology is also entered in the field of education. This article is about the integration of ICT as a tool with the overall aim of empowering teaching and learning chemistry.

WHY EMPOWER TEACHING AND LEARNING CHEMISTRY

Chemistry is considered as the central backbone for all the other scientific disciplines. It is a creative science essential for sustainability and improvements of our way of life. The aim is to outline the objectives and related activities of the ICT, such as e-learning and m-learning that empowers its education. Chemistry teachers need to know exactly how ICT is used as a teaching and learning tool, for their own purposes and to help students understanding.

One of the ICT opportunities in teaching and learning chemistry is to help students to visualize the spatial three-dimensional (3D) elemental and molecular structures, and allows collaborative interactions between teachers and students, and among students themselves, synchronously and asynchronously. ICT is considered as a veritable source of scientific data, theoretical information and offers a viable means to support authentic learning in chemistry. The

scope of information that are available over the Web and in other ICT- based cognitive tools, also virtual labs and simulations should be a part of teaching and learning chemistry at all levels, in order to enrich the understandings of its concepts and theories in different contexts.

WHAT IS THE ELECTRONIC LEARNING?

Electronic Learning is a subset of Distance Learning and Mobile Learning is a subset of E-learning. E-learning and m-learning have become extremely important buzz words of the education technology revolution each characterizing a whole raft of ideas and resources for teacher. But the two terms are not always used correctly; there is some confusion between them. However, differentiation between them can be particularly useful for teachers who use technology in the classroom, as it can help them to pick out which techniques are best for their education scenario. The present paper highlights the comparison of concept, characteristics, advantages, disadvantages, similarities and differences between E-learning and M-learning [1].

COMPARISON BETWEEN E-LEARNING AND M-LEARNING

E-Learning

E-learning refers to electronically supported learning and teaching using any form of digital communication, electronic devices or the internet. The learning process might be described as a form of e-learning, which also comprises education technology. E-Learning includes such processes as computer based learning and internet based learning, but it is important to remember that it does not necessarily require either a computer or an internet connection but only the use of electronics, such as a CD Rom, watching an educational television program, or computer conferencing.

It also includes delivering content via the Internet, intranet/extranet (LAN/WAN), audio and videotape, satellite broadcast, interactive TV, and CD-ROM. However, the advent of the internet is the real catalyst for many important advances in e-learning that allows internet-based educational activities such as collaborative online learning or interactive educational resources. It is a structured purposeful use of electronic system or computer in support of the learning process [2] to covers a wide set of applications and processes, such as Web-based learning, computer-based learning, virtual classrooms, and digital collaboration [3].

Benefits of E-Learning

E-learning is a fantastic resource for making chemistry lessons more interesting and interactive, using online learning platforms like Game Classroom or Quizinator to transform traditional classroom learning. It is also particularly effective for flipping the classroom. The ‘flipped classroom’ is a new model where teachers allow students to use their homework time to study new topics and learn the basic information they need to know, which they usually would have imparted to them in class. Class time is then used to go through activities and exercises to reinforce and test their understanding of the new concepts – an activity that usually forms the basis of homework. E-learning is fantastically effective on both sides of the flipped classroom, with great online resources like Chem Collective, allowing students unprecedented learning experiences in their own homes, whilst brilliant programs like Fifty Sneakers make testing and evaluation fun and exciting back in the classroom.

M- Learning

M-learning is an abbreviation of mobile learning, which means learning using mobile portable devices that allow the student to learn in different environments and while he is moving instead of being restricted to a place or tied to a PC or a laptop. Mobile learning is, of course, by its electronic nature, a subset of e-learning, but it refers far more specifically to these handheld devices and portable technology. The term has grown enormously in popularity in the past few years, with the advent of handheld wireless devices such as iPods, tablets and increasingly sophisticated mobile phones such as iPhones and android handsets expanding the potential applications of the concept exponentially.

However, there are many definitions for M-learning such as; the use of mobile or wireless devices for the purpose of learning while on the move, or any sort of learning that takes advantages of learning opportunities offered by mobile technologies, i.e. acquisition of any knowledge and skill through using mobile technology anytime, anywhere that result in alteration of behavior. M-Learning brings strong portability by replacing books and notes with small RAM's filled with tailored learning contents.

Benefits of M-learning

M-Learning is best used in scenarios where concrete benefits are gained from the potential for mobility. For example on class field trips, students who use mobile devices are keeping engaged and working whilst still giving the freedom to explore. It is also extremely effective to use m-learning in classroom environments where modern technology may not be available to all students, or in schools where there are not sufficient resources for all students to be able to use a device. In such a situation, using mobile learning device like a single tablet,

which may be passed easily from hand-to-hand or shared amongst a group of students, is a great way to ensure that pupils are still able to benefit from the diverse opportunities presented by education technology.

An app like [Mind Snacks](#), which presents language learning in simple, digestible chunks with fun, easy-to-use games, is a great example of m-learning solution that can be simply and quickly passed between students as they reach new levels to enable successful team-based learning. Mobile learning or M-learning is the idea that a student can learn from any place at any time using portable learning devices. This means that learning is accomplished with the use of small, portable computing devices, such as cellular phones, smart phones, palmtops, personal digital assistants (PDAs) and handheld computers; tablet PCs, laptops, and personal media players can also fall within this scope [4]. However, there is some debate on the inclusion of tablet and laptop computers.

Similarities between E-Learning and M-Learning

- Each of them needs an infrastructure and a wide community base in dealing with wire and wireless electronic computer technologies.
- Each of them needs a high cast technological system.
- Each of them provides students with digital literacy focusing on information processing.
- Students are centre of learning process in both models (Self- Learning).
- In both learning models students can access and surf the internet.
- Each of them allows communication between individual students and between students and teachers anywhere at any time locally and internationally.

- In each of them the learning content is delivered electronically, in the form of texts, images and video clips.
- Both learning models depend on developing problem solving and creative thinking skills among students.
- Both are capable of providing learning opportunities to many students.
- In both models learning material can be updated continuously in both learning models

Differences between E-Learning and M-Learning

- E- Learning uses fixed, wire devices such as PC's, but mobile learning uses wireless communication devices such as cell and smart phones, micro computers and personal digital assistants.
- In E- learning, access to the internet is achieved by the available telephone service, while mobile learning uses IR when accessing the internet anywhere at any time.
- In E- learning, messages are exchanged via the internet whereas in M-learning, MMS and SMS messages are used to exchange information between users.
- In E-learning, it is difficult to transfer books and files between individual learners, while in mobile learning, Bluetooth and IR technologies are used to exchange books and files among learners.
- Storage applications used in E-learning are more effective than ones used in mobile learning.
- Communication channels used in E-learning have low protection levels as learners use more than one device, whereas mobile learning provides users with more protection as learners use their own devices to connect with others.

- It is difficult to pass devices through learners in E-learning while these devices are easy to pass between learners in mobile learning.

Advantages of E-Learning

- Individualized instructions: E-learning provides individualized instructions suiting to the need, abilities, learning styles and interests of the learners. E-learning has much potential to make the education, instruction and learning opportunities provided to the learners adaptable to the need, local need and resources at their hands. Therefore, it is learner centered.
- Easy access: The learner gets access to learning by breaking all barriers of time, place and distance. The learners can access information and educational contents anytime and at anyplace. E-learning is available even in areas where there is no school or college. It can reach any remote or far off areas of the country or world.
- Qualitative: E-learning has a unique feature for allowing access to unlimited number of students the same quality of the content that a fulltime student has
- Effective media: E-learning can prove an effective media and tool for facing the problem so lack of trained teachers, shortage of schools and needed facilities for providing quality education to the number of students residing in far and wide corners of the country.
- Different learning styles: Unlike traditional classroom education, E-learning can cater to different learning styles and promote collaboration among students from different localities, cultures, regions, states and countries.

- **Flexibility:** The flexibility of E-learning in terms of delivery media (like CD, DVD, Laptops and Mobile Phones), type of courses and access may prove very beneficial for the learners.
- **Play-way spirit and learning by doing:** Learning experiences via simulated and gaming techniques may also provide the advantages of getting richer experiences on the useful pedagogical footings of play-way spirit and learning by doing or leaving.
- **Interesting and motivating:** E-learning may make the students more interested and motivated towards learning as they may get a wide variety of learning experiences by having an access to multimedia.
- **On-line, Off-line and live interaction:** The opportunities of having an on-line, off-line and live interaction between the students and teachers and among the students themselves may make the task of E-learning a joy and best alternative to the lively face-to-face interaction and real time sharing of the experiences in a traditional classroom settings
- **Self-learning and self-improvement:** E-learning leads to self-learning. It can be utilized for improving technical and vocational skills.
- **Evaluation and feedback:** E-learning can also provide opportunities for testing and evaluating the learning outcomes of the learners through teachers, peers and auto-instructional devices and software available with there a ding material online, or through the internet and mobile phone facilities

Advantages of Mobile learning

- **Increased mobility:** Learning is not restricted to fixed locations any more.
- **Mobile educational systems allow lifelong learning through distance learning.**

- The learning material is mostly colorful encouraging students to go back and forth and practice more.
- Learner gets stimulated in learning, convenient, and interesting.
- Time-saving: People can now study when they are commuting and traveling.
- Environmental-friendly: It is amazing to find out how much information a mobile device can carry despite its light weight. Less printing is required.
- Interactive: Mobile technology enables students to closely link with their peers, teachers, distant partners, and even interest groups worldwide.
- Use of relatively inexpensive everyday technologies.
- Better opportunities to acquire skills at one's own pace, with a degree of privacy that may be missing when using shared computer facilities or relying on equipment belonging to somebody else.
- Good support for preferred modes of interaction, e.g. accessing audio content or participating in social networks on the move.
- Catering for interests beyond what is provided in class, through access to additional content such as podcasts or free learning materials (e.g. Open Learn).
- Handheld devices are often an everyday part of business, so learning can contribute directly to enhancing employability, life skills and work practices.
- Opportunities for learners to give immediate feedback on their learning experience.
- Learning materials can become accessible to a larger audience, through podcasts, mobile applications, blogs and e-books, which are seen by potential students.
- Revitalizing the curriculum, rethinking teaching methods and implementing improved feedback to learners.

- Turning geographically dispersed learners into a valuable teaching resource by enabling them to contribute their local knowledge and research data more easily.
- Making the learning experience more tailored to the changing needs of individuals, encouraging learners to return for knowledge updating and further study.

Pedagogical Implications of Mobile Learning

Mobile computing/communication devices offer a unique opportunity for teachers and students in different kinds of instructional settings to capitalize on the flexibility and freedom afforded by these devices. If appropriately facilitated, mobile learning can benefit learners by providing them the instructional materials and interaction through their mobile devices wherever and whenever they need it. Instructors also benefit where they can access services and interact with students while on the move. To keep up with this changing phenomenon and to effectively facilitate mobile learning, argued it is imperative that instructors learn about and adapt to the changing environments, when and where appropriate. We predict that mobile technologies will help in teaching and learning chemistry, especially in the rural areas, disables, etc.

The mobile educational revolution can be borderless through the cell phones, MP3 players, portable game devices, tablets, and laptops, especially students and teachers are increasingly connected and digitally communicating with each other in ways that would enhance teaching and learning chemistry, in the middle East.

However, we argue that mobile/electronic education should not replace traditional education with tutors and instructors, but support both student and teacher by providing services that facilitate teaching, learning and education-related administrative tasks. The basic approach is

integrative, combining a variety of devices (mobile and non-mobile) via a variety of transmitting techniques (wired and wireless).

TEN EASY STEPS KEY TO A SUCCESSFUL E- AND M-LEARNING

There are ten easy steps to help designers to construct pedagogically sound e-learning chemistry courses and related activities which are:

1. Well defined needs for the e-learning.
2. Well established infrastructure such as networking, Servers, e-classrooms accessed with PCs and Internet, communications, intranets, etc.
3. Development of e-learning according to the International standards
4. E-content matches to the curriculum
5. Well articulated e-content according to SCORM standards, that effectively designed to meet online delivery e- and M-learning goals and objectives, and students needs.
6. Well trained teachers and students.
7. Evaluation of using e- and M-learning
8. Sustainability of the system
9. Well established platform in which content is delivered (Internet, Intranet, LAN, Videoconference, satellite, Cloud, etc.)
10. Well established e-content developing and delivery centers including; development facilities, professional technical team, consultants, trainers, ongoing technical support, etc.

CASE STUDIES

A bilingual (English-Arabic) Chemistry course has been developed by Awad and Stovall [5] through the UNITWIN between UNESCO and University of Illinois (Urbana-Champaign) using WebCT software as a learning management system (LMS). It is deployed for e-learning in the Faculty of Women for Arts, Science, and Education, Ain Shams University. As a part of the e-learning process its impact on teaching and learning chemistry has been evaluated. Also M-learning has been deployed for teaching chemistry [6]. Moreover, 55 courses in other disciplines have been developed and delivered using Moodle as a LMS [6].

Impact of Teaching and Learning Chemistry Using E-Learning and Mobile-Learning

Study of the impact of using ICT on teaching and learning chemistry showed that it:

- Increases student's attraction and interest to learn chemistry
- Helps students to understand chemical education
- Supports students with the required memorization.
- Increases student participation in classroom activities with the increase of their understanding and skills, both in chemistry and IT.
- Enhances teaching of chemistry due to presence of the guided inquiry, 3D molecular structures, equations, graphics, animations, quizzes, etc.
- Helps in teaching and learning using virtual labs, where it reduce or completely eliminate the use or production of hazardous substances and chemical pollutions (green chemistry).
- Helps in assessment and assignments.

REFERENCES

1. Santosh Kumar Behera (2013) E- and M-Learning: A comparative study; International Journal on New Trends in Education and Their Implications, V(4), Issue: 3 Article: 08 ISSN 1309-6249.
2. Allen, M.W. (2010). Michael Allen's guide to E-learning. Hoboken, New Jersey: John Wiley & Sons, Incorporated.
3. Clark, R.C., Mayer, R.E.(2003). E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning. San Francisco, California: John Wiley & Sons, Incorporated.
4. Kukulska-Hulme, A., Traxler, J. (2005). Mobile learning: A handbook for educators and trainers, London: Routledge.
5. Awad B., Stovall I. (2000). Bilingual (English-Arabic) Online Chemistry Course. www.chem.uiuc.edu.
6. Awad B.; www.shams.asu.edu.eg

ADDITIONAL RESOURCES

1. Ally, M. (2009). Mobile learning: Transforming the delivery of education and Training. Athabasca.
2. Ellen W. (2005). Global Education Solutions at Macromedia.
3. Hall, B. (1997). Web-based Training. John Wiley & Sons, Inc., New York.
4. [Laura Bates; http://www.fractuslearning.com](http://www.fractuslearning.com)
5. O'Connor, C., McDonnell, C., Seery, M. (2007). Continuous Improvement in e-Learning: EdTech, DIT, Bolton St.
6. Traxler, J. (2005). Defining Mobile learning. Proceedings IADIA International conference on mobile learning, Malta. Pp – 261-266.

SMALL-SCALE CHEMISTRY FOR A HANDS-ON APPROACH TO CHEMISTRY PRACTICAL WORK IN SECONDARY SCHOOLS: EXPERIENCES FROM ETHIOPIA

Gebrekidan Tesfamariam, Annette Lykknes and Lise Kvittingen

Department of Chemistry, Norwegian University of Science and Technology, NTNU, Norway

Corresponding author email: gebrekidan.tesfamariam@ntnu.no

ABSTRACT

The purpose of this study was to investigate the possibility of using a small-scale chemistry (SSC) approach as a means of performing chemistry practical activities in Ethiopian secondary schools. A total of eight experiments from two topics, electrolysis and rate of reaction, in the Ethiopian grade 11 chemistry syllabus were modified into SSC for use with the MyLab Chemistry Kits (Northwest University, South Africa). The evaluation involved classroom testing of the SSC materials to investigate the effect of the approach compared to the regular teaching approach. Two comparable groups of Grade 11 science stream students (188 experimental; 195 control) and their chemistry teachers participated in the study. Triangulation procedures involving classroom observation of the use of the SSC approach in classrooms, student achievement tests (pre and post-test), questionnaires, and interviews were employed for data collection. Results showed that the SSC approach can increase students understanding of chemistry concepts. Furthermore, despite the presence of some challenges in operating the small-scale equipment, collecting quantitative data, and maintaining class discipline, the SSC approach was viewed by both teachers and students as cost and time saving, safer, easy to use and enjoyable. [AJCE 4(3), Special Issue, May 2014]

INTRODUCTION

Background

Practical work carried out by students themselves is an essential part of science education although critical views on its effectiveness also exist [1-2]. Many science educators and science education researchers believe that student practical work leads to better science learning. Hofstein and Mamlok-Naaman [3, p. 105], for example, stated that “laboratory experiences have been purported to promote central science education goals, including the enhancement of students’ abilities; scientific practical skills and problem solving abilities; scientific ‘habits of mind’; understanding of how science and scientists work; interest and motivation”. Layton [4] argued that chemistry without practical work was seen as a body of factual information and general laws, which conveyed nothing of lasting power to the mind. In this paper the term ‘practical work’, as it is commonly used in the science education literature, refers to any type of science teaching and learning activity in which students, working either individually or in groups, interact with materials to observe and understand the natural world.

In line with the above arguments, the education and training policy of Ethiopia [5] declares that science should be taught in a practical manner. The policy discourages rote and memory learning. In principle, the Ethiopian secondary (grade 9-12) chemistry curriculum focuses at enabling students to solve real life problems, and become independent and helpful citizens. Accordingly, central to the teaching-learning process in the secondary chemistry curriculum is practical work geared towards mastery of scientific skills: process skills, manipulative skills and thinking skills. More specifically, after completion of their upper secondary chemistry syllabi students are expected to use scientific methods in solving problems; and demonstrate an understanding of experimental skills, knowledge of laboratory procedure and

scientific enquiry skills including observing, inferring, predicting, comparing and contrasting, communicating, analysing, classifying, applying, theorizing, measuring; asking questions, developing hypotheses, performing and designing experiments, interpreting data, drawing conclusions, making generalizations and problem solving [6]. Although being good teaching ideals, as we shall see, in Ethiopia these expectations are hard to fulfil.

If implemented as intended, practical work in chemistry gives students opportunities to gain the above listed skills through scientific investigations and hands-on activities. Practical activities can also promote positive attitudes and provide students with opportunities to develop skills in cooperation and communication [7]. From a constructivist point of view, students need to be active participants in the learning process in constructing meaning and developing understanding [8]. In line with this, Bradley [9] and many others argued that practical work should involve active participation of students.

While practical work is considered essential in chemistry teaching, it is also associated with a number of burdens including high cost of equipment and chemicals, chemical hazard risk, and environmental pollution. Furthermore, practical work requires more time and the presence of qualified and experienced teachers and technical assistants. As a result, it is frequently missed from the real curriculum in schools around the world [9], especially where resources are scarce.

Though no extensive studies have been conducted on the situation of secondary science teaching in Ethiopia, the few available studies have demonstrated the lack of hands-on practical activities in schools. Bekalo and Welford [10], for example, reported that, for a number of reasons, secondary school students in the country were not getting science hands-on experiences as specified in the curriculum. Similar findings [11] had been reported in a study conducted to assess the overall quality of secondary science education in North Ethiopia (Tigray region) by a

team of science educators in which one of the authors of this paper was a member. Amongst the reasons mentioned are: absence of laboratory room, lack of equipment and chemicals, shortage of time, large workload, absence of laboratory technical assistants, fear of chemical hazards, teachers feeling inadequately prepared, lack of laboratory manuals, lack of basic facilities such as water or electricity, and large class size. It can also be argued that the problem has been worsened by the recently observed fast- growing student population in the sciences¹ not being matched with resources.

Some of the challenges associated with chemistry practical work may be overcome through the use of a small-scale/microscale chemistry experimentation approach. In this study, the approach has been tried out on two chemistry topics in secondary school classrooms in Ethiopia, and the effects have been evaluated.

Small-scale chemistry

Small-scale chemistry (SSC) is chemistry carried out on a reduced scale using small quantities of chemicals and often, but not always, simple equipment [12] with a shift from glassware to plastic materials [14]. Sing et al. [13] reckon that at the lower end of the scale, solids and liquids of 25–100 milligrams and 100–200 microliters respectively may be used without compromising the quality and standard of the chemical applications in education and industry [13]. In our experience even a tenth of this may be suitable in many experiments. The terms *microscale* and *small-scale* are often used interchangeably and refer to a similar scale of chemistry [12]. In this paper, the term *small-scale chemistry* (SSC) is used.

¹It is believed that the student population in the science streams of the secondary schools in Ethiopia has been increased abruptly since the implementation of the 70:30 policy. According to the policy which has been implemented as of 2008, 70% of the student enrolment in universities (and secondary schools alike) has to be in the natural science and technology related fields.

Reduction of waste production at the source was the main driving force behind the interest in SSC [12-13]. In the USA, for example, the National Microscale Chemistry Centre (NMCC) was established in 1993 to promote the use of microscale chemistry as a means of eliminating waste at the source [15]. Other motivations behind the move towards SSC include: the increasing cost of laboratory equipment and chemicals coupled with budget cuts, shortage of laboratory time [16], and the increasing application of safety legislation to educational institutions [12, 17].

The benefits of implementing SSC experimentation in chemistry teaching have been reported by many researchers [e.g. 12, 13, 18-30, 41]. Frequently mentioned benefits include: saves money and time, increases safety, is easy to use and environment friendly, instils ethics of resource conservation, enhances students' understanding of scientific concepts, maintains students' interest towards the subject, uniquely engage students in hands-on learning experiences, and experiments are perceived by students as easy and fun. Bradley [21] argues that the SSC approach can help address many of the challenges that teachers face when planning practical work including shortage of equipment and chemicals, lack of laboratory space, lack of laboratory assistants, shortage of time, and lack of confidence by teachers.

A few limitations of the SSC approach are also reported. Experiments which involve heating, the use of organic solvents or concentrated acids are unsuitable for the approach in which most of the equipment is made of plastic materials [22]. Nowadays, there are alternatives in which some glass equipment are included in the kits; the MyLab small-scale chemistry kit is one such example (31). Difficulties in getting accurate results for quantitative experiments and problems in handling some of the apparatuses are also reported as limitations [21, 30, 32] and are supported by our own experiences.

SSC experiences in Africa

Although small-scale techniques have been introduced in Egypt as early as 1924 [33], little progress was made in the rest of Africa for almost seventy years. It was only in the 1990s that such techniques were successfully introduced in South Africa by the Research and Development in Mathematics, Science and Technology Education (RADMASTE) centre, University of Witwatersrand, South Africa. The RADMASTE kits introduced with the aim of addressing the problems of science practical work in schools of disadvantaged communities mainly due to the efforts of John Bradley [34]. Since then, a number of African countries, being aware of the potential benefits, have implemented the new approach of science practical work in their respective education systems, and some others have been on the way [35]. Other kits, also of South African origin, are the MyLab small-scale science/chemistry kits which were designed in 2001 by Corrie du Toit, and his colleague, Marié du Toit of the Faculty of Natural Sciences, North-West University. These have also been successfully implemented in a number of South African schools and beyond [31].

A few studies have documented the effectiveness of the SSC approach in the African contexts [e.g. 24, 36-41, 52]. Bradley and Vermaak [52] reported knowledge gains and positive attitudes in a study on South African secondary school students after their involvement in microscale practical work. Also in teacher training institutions in South Africa this approach has been proven beneficial [36]. Madeira [40] studied the influence of microscale chemistry experimentation in Mozambican junior secondary schools and reported significant gains in chemistry achievement. Similarly, the impact of microscale on students' understanding of concepts and their attitudes towards the approach has been positively reported by Mafumiko [37, 38] in Tanzania. Cameroon, Uganda, and Kenya are other examples within Africa where SSC

has received very positive response from both teachers and students [43]. Not surprisingly, UNESCO [35] has reported a strong demand for introducing the SSC approach from countries like Sudan, Ethiopia, Tanzania and Gambia.

A positive feedback from students, teachers and school principals has been reported from a pilot introduction of SSC in two Ethiopian secondary schools [42]. No other empirical studies are, to our knowledge, reported so far on SSC experiences in the Ethiopian school context. This study, therefore, contributes towards filling the gap and thereby informing concerned parties regarding the strengths and limitations of the approach.

PURPOSE OF THE STUDY

The main purpose of the study was to explore the possibility of using the SSC approach as a means of performing chemistry hands-on practical activities in Ethiopian secondary schools, and thereby reducing the need for costly equipment and expensive laboratories. Specifically, the study aimed at evaluating the effectiveness of the SSC approach in supporting classroom implementation of chemistry hands-on practical work against the teaching approaches normally in use; assessing students' and teachers' perceptions towards the SSC approach; and comparing the chemistry performance of students taught using the SSC experimentation approach with those taught using the 'traditional' teaching approaches. The study tried to answer the following questions:

- i. What were the experiences when implementing hands-on chemistry practical work through the SSC approach in secondary school classrooms in Mekelle, Ethiopia?
- ii. What were the 'students' and 'teachers' reactions to the SSC experimentation approach?

- iii. What were the differences in the chemistry test performance of the two groups of students in the small-scale approach (experimental group) and the approaches normally used in chemistry classes (control group)?

METHODOLOGY OF THE STUDY

Research design

The procedure of the overall study, in which this paper is one part, consisted of three phases: The first was focused on front-end analysis (review of related literature and context analysis); the second involved development of SSC experimentation (acquisition of SSC kits and chemicals, and preparation of SSC laboratory manuals) based on the Ethiopian secondary chemistry syllabus; and the third evaluated the effectiveness of the SSC approach in some selected Ethiopian secondary chemistry classrooms. This paper focuses mainly on the latter phase in which a quasi-experimental design was used. The quasi-experimental design is commonly used in educational research when participants cannot be randomly selected and assigned to experimental and control groups [43, 44]. Consistent with this type of research design, in this study triangulation procedures involving chemistry concept understanding test, observation of the use of the SSC approach in actual classrooms by teachers and students, interviews and questionnaires, have been used to collect data.

Research participants

Participants consisted of 383 grade 11 (average age 17 years) science stream students from two selected governmental secondary schools (experimental and control schools): 188 of the students (88 males and 100 females) came from four intact classes in the experimental school

while 195 (91 males and 94 females) came from four intact classes in the control school. Both schools are located in the same city (Mekelle, North Ethiopia) and have more or less the same number of student and teacher population. Schools were selected based on purposive sampling (43) considering the willingness of the chemistry teachers and school principals; matching of the topic of investigation with the teachers' scheme of work; and presence of reasonable number of grade 11 science students in the schools. Both schools were interested in implementing the intervention; but were assigned as experimental and control schools using the lottery method.

The control school demanded to have the experiments afterwards if they were to participate, and were promised so. Participating teachers were those who were teaching the study classes. Thus, six teachers (four experimental and two control) participated in the study. All of the teachers had a Bachelor of Education degree in chemistry teaching² while one (teaching in the control class) had attained Master of Science degree in the same field. All of the teachers had 10-15 years of experience in teaching chemistry at the upper secondary level.

Implementation of the study

Two topics – electrolysis and rate of reaction –were selected from the Ethiopian grade 11 chemistry syllabus for the purpose of the study. Fourteen sets of MyLab small-scale chemistry kits were acquired from South Africa (Mylab project, Northwest University). The experiments included in the study topics were modified to the SSC approach for use with the kits. A two-days training workshop on the SSC approach was offered to the four experimental school teachers and a lecturer of chemistry from Mekelle University (Ethiopia). No such training was given to the

² Three years of in-service chemistry teacher education in Ethiopian teacher training institutions results in the award of 'bachelor of education degree in chemistry teaching' and qualifies for a lower secondary (grades 9-10) chemistry teaching

control school teachers; only a brief orientation regarding the study was offered just before the start of the implementation.

During the classroom implementation of the study, the experimental class teachers were required to implement the SSC experimentation approach in teaching the study topics i.e. they were required to conduct their lessons in a hands-on manner using the provided kits, manuals and other materials. Accordingly, each of the experimental classes carried out a total of eight SSC hands-on experiments during the implementation period. Students carried out the experiments in groups of 4-5, where a MyLab kit and two copies of the developed manuals, and other supplementary materials were provided for each group. In the curriculum, chemistry is given four periods (40 minutes each) per week. The experimental class teachers used two periods for teaching concepts and two periods for conducting the small-scale hands-on experiments. On the other hand, the control class teachers were requested to conduct their lessons on similar topics using their regular teaching methods. Both the experimental and control group teachers conducted the study lessons for over one month.

Data collection

Data were collected through four instruments: chemistry concept test, student questionnaire, individual teacher interview, and classroom observation. Chemistry pre-test and post-test consisting of fifteen multiple choice items and four short answer items were developed by the researchers. The test items were mainly composed of knowledge, comprehension and application questions and covered the two study topics: electrolysis and rate of reaction. Prior to administration, the contents of the test were validated by one university lecturer and two experienced upper secondary school chemistry teachers. The test was also pilot-tested in one

upper secondary school of the same grade level as students in the study school and improvements were made on the basis of the feedback. The internal consistency of the multiple choice test items was computed using Kuder-Richardson KR-21 and a reliability coefficient of 0.74 was obtained. For the short answer items an inter-rater reliability coefficient of 0.94 was obtained. The pre-test was administered to gauge the prior knowledge of students on the topics; while the post-test to measure their learning gains. Similar questions were administered both in the pre-test and post-test. Samples of the questions are given in appendix 1.

Data regarding student experiences and opinions about the SSC based lessons were collected using a semi-structured questionnaire adapted from one used by Mafumiko (38) in similar studies. Students of the experimental classes filled the questionnaire at the end of the classroom implementation of SSC based lessons. The questionnaire consisted of a total of 17 items: 14 close-ended items and 3 open-ended items. A scale of 1 to 5 was provided for each close-ended statement item (1=strongly disagree, 2= disagree, 3=neutral, 4= agree & 5= strongly agree) for the students to indicate their response about their perceptions in relation to SSC based lessons. The open-ended questions also focused on students opinions/perceptions towards the SSC approach; differences between the SSC approach and the usual/traditional teaching approaches normally used by teachers; and problems encountered with the SSC approach. The internal consistency of the questionnaire was estimated (using SPSS version 16.0 software) based on the close-ended component of the questionnaire and a reliability coefficient of 0.83 was obtained.

The feasibility of using the SSC approach in actual classrooms was evaluated by conducting individual interviews with the experimental class teachers. The interviews were conducted at the end of the classroom implementation of the SSC based lessons and were

focused on the helpfulness of the two-day training workshop on SSC offered to the teachers; the applicability of the SSC experimentation in actual lessons; how the SSC experimentation helped the teachers to instruct in a student-centered manner; and what problems were encountered during class room implementation of the SSC experimentation with students. All interviews were transcribed and the informants anonymized.

A 29-item classroom observation checklist adapted from previous similar studies (38, 45, 46) was implemented to collect classroom observational data. In the experimental classes, classroom observations were made aimed at observing how teachers and students were implementing the SSC experimentation approach in teaching the study topics using the provided materials (student worksheet, teachers' guide and small-scale chemistry kits). In the control classes the classroom observations aimed at observing how teachers were implementing the same topics in their lessons using regular teaching approaches. The same classroom observation checklist was used in both the experimental and control classes. However, in the control classes, only items applicable to the lessons were considered. In addition to this, to get insight into the overall situation of the classrooms, open notes were taken during the lesson observation.

Data analysis

An independent samples t-test was conducted to examine whether there was a significant difference between the experimental and control group students in relation to their understanding of chemistry concepts with $P < 0.05$ being considered as significant. Data from the close-ended questions (Likert-type items) of the student questionnaire were analyzed by computing the means, standard deviations, and the percentage of students who rated as "4=agree" or "5=strongly agree" for each of the items. Data from the open-ended questions of the student

questionnaire, individual teacher interview and classroom observation were reported qualitatively.

Informed consent

The project was both staged and undertaken logistically through the schools. Informed consents were obtained from local authorities, school principals, teachers and students themselves after information on the purpose of the project, as a trial introduction of small-scale chemistry with an evaluation and as part of a PhD thesis that should be made public afterwards. Participants were informed that the evaluation consisted of student questionnaires and chemistry tests, teacher interviews and classroom observation during lessons. Furthermore, participating students and teachers were informed that their class and group activities as well as individual interviews would be photographed and tape recorded. Due to the little sensitivity of the project and its evaluation, consents were made in an oral form. A letter of support was also produced from the education bureau of the Tigray region. The teachers and students participated voluntarily and were informed that they could withdraw from the project any time. The identity of the participants has been made anonymous throughout the project.

RESULTS AND DISCUSSIONS

Results from context analysis (Overview of the situation of secondary schools)

The education system in Ethiopia consists of eight years of primary education, divided into two 4-year cycles, and four years of secondary education, divided into two 2-year cycles (lower secondary education: grades 9–10, and upper secondary education: grades 11–12). The Education Statistics Annual Abstract of the Bureau of Education [47] of the Tigray region, where

the study was conducted, shows that there were a total of 24 secondary schools in the Mekelle city; 11 upper secondary, 13 lower secondary; 8 governmental, 16 private schools. In total there were nearly 22 000 students (almost 10,000 males and 12,000 females) and nearly 730 teachers (almost 600 males and 130 females).

According to the Education policy of Ethiopia, lower secondary school teachers are supposed to have a first (bachelor) degree, while upper secondary are supposed to have a second (masters) degree in the fields they teach. More than 90% of the teachers were first degree holders, and only very few of them attained their second degree. This shows that most of the upper secondary teachers had no sufficient qualifications as required by the policy. With respect to material resources, the problem seems even more severe: out of the 24 secondary schools, for example, two had no access to running water, four had no library, one had no laboratory room at all while five have only a shared one for the three science subjects, and 16 had no source of income of their own to spend on materials [47].

The results from the observational visit to the eight governmental schools in Mekelle city in the Tigray region (including the two which were selected for the SSC try-out) show that chemistry laboratories were at a very poor status. Most of the laboratory rooms were not to the standard (or not built for laboratory purpose) and lacked even the most basic facilities like running water, source of electricity; working tables, sinks, hoods, etc.. In some cases the rooms had broken windows, roofs, doors etc., and as a result were not secure places in which to keep materials. The rooms also lacked the required equipment and chemicals. In some of the older schools a considerable number of equipment and chemicals were present; however these have been kept idle for years. Consequently most of the equipment were broken and parts missing.

For the chemicals, many had expired and were clearly decomposed, stoppers were broken and labels had fallen off. These chemicals were therefore inadequate for teaching and in addition caused a waste problem. The teachers lacked the required qualification and skills, were overloaded with a number of assignments and, unsurprisingly, did not feel in a position to solve/handle the lab problems, and, even less, to explore innovative ways (e.g. low-cost and time saving approaches) of implementing chemistry hands-on activities in their classes. Administrators gave little or no attention to the complex problems associated with laboratory activities. In conclusion, in these schools, the possibilities for hands-on student experiences were very minimal. The teaching was dominated by the traditional ‘chalk and talk approach’ which is characterized by teacher and textbook domination, lectures, note giving, memorization, and lack of practical work; though the policy requires otherwise. The information obtained from teachers confirmed our observation.

During a discussion a teacher for example pointed out the problem saying;

Firstly, I do not believe I have proper training to implement chemistry practical work in my classes, secondly, I do not have sufficient time to engage my students in chemistry practical work, I am so loaded and just run for coverage only. In addition to this, the laboratory is not equipped with the required materials; no trainings are given to us on laboratory skills. In general, there is lack of attention.

In theory, the situation described only holds for Mekelle city in the Tigray region. However, there is no reason to believe that similar characteristics are not applicable in the rest of the country. Our observations and findings agree with reports from other studies in Ethiopia [e.g. 10, 48] and abroad [9, 49, 50]. Zymelman [49] and Lewin [50] reported that science education in developing countries is, amongst others, characterized by absence of hands-on practical

experiences and poor understanding of scientific methods. Cost, safety, waste disposal and teacher training issues were identified as the main reasons for the lack of science practicals [9].

Results from development process of the SSC experiments

The second phase of our study involved the development and adaptation of SSC experimentation for Ethiopian classrooms. Fourteen MyLab small-scale chemistry kits (Figure 1) and related teaching materials were acquired from the MyLab project of Northwest University, South Africa. The MyLab kits were selected as the authors have experienced their versatility in different school settings. The kits mirror the traditional chemistry lab, but in a miniature format. They are self-contained by including chemicals and equipment for the majority of experiments mentioned in the syllabi for secondary schools and through the first year general chemistry course at university level.



Figure 1 MyLab small-scale chemistry kit set

Analysis of the Ethiopian secondary chemistry [6] was carried out to examine the topics and nature of practical activities included. It was found that no less than 80 experiments were mandatory. These required at least 66 large-scale apparatuses (like digital pH meters, digital balances, different flasks etc.) and 85 different chemicals (see appendix 4) which is unrealistic given the existing Ethiopian school context. Each of these ‘large-scale’ experiments were studied and found to be adaptable to the SSC approach.

Based on the analysis and practical considerations, eight experiments from the two grade 11 chemistry topics (electrolysis and reaction rate) were selected³ and adapted into the small-scale approach for use with the MyLab kits (Table 1). Drafts of student worksheets and teachers' guide laboratory manuals were prepared using MyLab grade small-scale chemistry manuals [51] as main sources. The experiments were, then, self-tried repeatedly by one of the authors at the chemistry laboratory of Department of chemistry, Mekelle University (Ethiopia), and improvements were made.

Table .1 the developed SSC experiments

Experiment 1: electrical conductivity of ionic compounds

Experiment 2: effect of an electric current on water

Experiment 3: effect of an electric current on an aqueous sodium iodide solution

Experiment 4: effect of temperature on reaction rate

Experiment 5: effect of concentration on reaction rate

Experiment 6: effect of surface area on reaction rate

Experiment 7: effect of nature of reactants on the reaction rate

Experiment 8: effect of catalyst on reaction rate

A two-day training on small-scale chemistry was provided to four grade 11 chemistry teachers of the experimental school and instructed by one of the authors. During the training, teachers performed each of the small-scale experiments by themselves with a minimal help from the instructor and gave a number of suggestions which were used to improve the final versions of the teachers' guide and student worksheet materials thereby also developing an ownership to

³ Only experiments which were offered in the second semester (as in the syllabus) were considered. Experiments which need special equipment, not available in the MyLab kit, and those which need excessive heating were excluded. Accordingly, the experiments in the two topics (rate of reaction and electrolysis) were found suitable.

experiments that were to be undertaken in the classrooms. See appendix 2, and 3 respectively for samples of the materials. Descriptions of two of the developed SSC experiments (experiments 1 and 4) are presented here for the sake of illustration.

Experiment 1: Electrical conductivity of ionic compounds

The objective of this experiment was to test the electrical conductivity of the aqueous solutions of some common ionic compounds. The experiment was conducted using sodium chloride, copper sulphate, calcium chloride, and sodium carbonate. The apparatus required for the traditional set-up were; 9-volt battery, 6-watt bulb with a bulb holder, conducting wires, carbon rods, 250-mL beaker, spatula and stirrer. In the small-scale set-up MYLAB apparatus stand was used to fix the required apparatus (including the battery, battery connection, the electrodes, and the water bowl). The water bowl replaced the 250 mL beaker, and the light emitting diode (LED) replaced the 6-watt bulb. Light emitted from the LED was used as an indicator of the conductivity of the aqueous solution and the intensity (brightness) as an indicator of the strength as well as the degree of dissociation of the electrolyte (salt) used (Figure 2).

Obviously with the four ionic solutions a bright light was emitted from the LED. Similar tests carried with table sugar failed to give glowing of the LED; only a faint light was observed probably due to the presence of some ionic impurities.

Unlike the traditional set-up which needs some additional materials to support the bulb and the two electrodes, in the small-scale setup the LED is permanently fixed on to the Mylab stand, the electrodes are easily supported by the two multi-purpose holes which exist in the stand. This makes the setup easy to use. The traditional set-up, as indicated in the student textbook [6], does not specify the amount of the compound to be used in preparing the aqueous

solution, which may result in more waste of chemicals as students may use more than required. However, in the small-scale set-up, 4 micro-spatulas of each salt were sufficient to prepare the required solution. The time needed to perform the experiment was very short (not more than 40 minutes overall). The main reason for this saving in time was due to the fact that all apparatuses and chemicals were at hand in one kit.

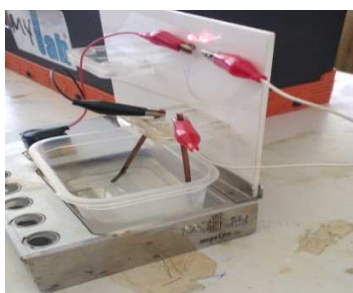


Figure 2. Small-scale setup (MyLab) for electrical conductivity test of ionic solutions

Experiment 4: Effect of temperature on reaction rate

The objective of this experiment was to study the effect of temperature on the rate of reaction between zinc and dilute hydrochloric acid (HCl). This was undertaken by using the specific gas units in the kits (in water baths of different temperature) and by measuring the volume of gas developed through downward displacement of water in a test tube. Two temperature conditions were used; one around 80°C ; and another around 0°C , using ice water, which was replaced by room temperature water (Figure 3). As these reactions were run in parallel, the difference in the rate of the two reactions was easily observed.



Figure 3. Effect of temperature on rate of reaction between dilute HCl and zinc

The experimental setup of this experiment could be a bit challenging for both inexperienced students and teachers. However, after some trials, it was hoped, they would manage. Getting ice in schools could also be a problem and the experiment was later changed so that the water bath held room temperature.

Results from classroom observation (classroom observation checklist)

Observation in experimental classes

Two lessons were observed from each of the four experimental classes. The results in Table 2 show that almost all of the SSC based practical lessons were implemented successfully as per the criterion indicated in the observation checklist. Teachers made all preparations in advance including grouping and sitting arrangements of students; and making the SSC kits, student worksheets, and other supplementary materials ready for use. Teachers started the first experiment by forming small-groups of 4-5 students in which members shared roles (e.g. chairperson, secretary) among each other. Following the instructions given in the teachers' guide, all teachers introduced the practical lessons/experiments by clarifying the purpose of the

experiments; and explaining how students obtain materials from the kits, and how to use them. They also strongly advised their students to read safety instructions carefully.

When it comes to the body of the lessons, the results show that teachers demonstrated the experiments to their students at the beginning of the experiment and in the course of the experiment when requested by students; and were moving around groups to give further help when students were engaged in the practical activities. During the activities, student-student and student-teacher interactions were very high, a situation, we believe, is not often encountered in most classrooms in Ethiopia. This could be due to the assignment of a separate SSC kit and a student worksheet to each group.

Working in small groups and performing experiments by themselves for the first time had also contributed to the high motivation and participation observed in all students. Most students demonstrated ability in using the apparatus and materials, and eagerly tried to follow the instruction provided in the student worksheets. Occasionally, when questions were asked, teachers were observed giving short presentations to the whole class. Their approach was friendly, and both they and their students were smiling, signs of their motivation and happiness of their involvement in the SSC based hands-on activities.

Table 2 results of classroom observation of the experimental classes

Criterion to be observed	experimental class lessons observed							
	ET1		ET2		ET3		ET4	
	L1	L2	L1	L2	L1	L2	L1	L2
Introduction to the lesson								
1. Teacher relates the lesson to previous learning/future activities	+	+	+	+	+	+	+	±
2. Teacher groups students for experimental work	+	+	+	+	+	+	+	+
3. Teacher introduces by an activity (e.g. pre-lab exercise)	±	±	±	±	±	±	+	+
4. Teacher makes connection between pre-lab activity and current lesson activities (if applicable)	±	±	±	±	±	±	+	+
5. Teacher explains clearly the purpose of student practical	+	±	+	+	±	+	±	+
6. Teacher explains how students will obtain materials	+	+	+	+	+	+	+	+
7. Teacher emphasizes students to read carefully safety instructions	+	+	+	+	+	±	±	+
8. Teacher asks group members to assign and share roles during activities (e.g. chairperson, secretary)	+	+	+	+	+	+	+	+
Body of the lesson								
9. Teacher explains how to use materials and equipment	+	+	+	+	+	+	+	+
10. Teacher demonstrates experiments to students	+	+	+	+	+	+	+	+
11. Students actively participate in doing hands-on activities	+	+	+	+	+	+	+	+
12. Teacher moves around groups to insure experimental set-up and safety	+	+	+	+	+	+	+	+
13. Students use information from the student worksheet	±	±	+	+	±	+	±	+
14. Students demonstrate ability in working with apparatus and materials	+	+	+	+	+	+	+	+
15. Students work cooperatively in small groups	+	+	+	+	+	+	+	+
16. Teacher circulates among groups asking/answering questions	+	+	+	+	+	+	+	+
17. Students seek help from the teacher during activities	+	+	+	+	+	+	+	+
18. Students discuss their experimental activities in the small groups	±	+	+	+	±	+	+	+
19. Students show interest in the experiments they are doing	+	+	+	+	+	+	+	+
20. Groups present observations to the whole class	±	±	±	+	±	+	+	+
21. Teacher and the students discuss the activities as a whole class	±	±	±	+	±	+	±	±
22. Teacher makes short presentation at different times during the activities to help students grasp major concepts	+	+	+	+	+	+	+	±
23. Teacher effectively manages timing of different activities	±	±	+	+	+	+	+	-
Conclusion of the lesson								
24. Teacher, together with students draws conclusions from the experiment	±	±	±	±	±	±	±	+
25. Teacher discusses with the students their procedures and results	+	±	+	±	±	±	±	+
26. Teacher guides students to understand differences in their results	+	±	+	+	+	±	+	+
27. Teacher helps students to relate the activity with theory	+	±	+	+	+	±	+	+
28. Teacher summarizes the main concepts learned from the activities	±	±	±	+	+	±	±	±
29. Teacher checks learning of students (e.g. by oral questions, class discussions, homework questions)	±	±	±	±	±	±	±	-

Note: plus (+) means the activity was observed, minus (-) means the activity was not observed and plus/minus (\pm) the activity was partially observed. ET1, ET2, ET3 and ET4 stand for experimental class teacher 1, 2, 3, and 4 respectively. L1 and L2 stand for lesson 1 and 2 respectively.

Some limitations were also observed during the practical lessons. Due to the high student' participation in the experiments and group discussions, it seemed that, teachers lost control of time for other parts of the lesson like encouraging small-groups to give presentations to the whole class; making students to compare their results; drawing conclusions and summarizing the concepts learned from the experiments; and in checking student learning. However, given the lack of practical experience in handling active classes, this is not unexpected. The teachers should also know that experienced lab teachers encounter this "lack of control", but that they regard most of the buzzing as positive. "Real" problems, such as for example time management will, nevertheless, be handled better as both teachers and students engage in doing more hands-on activities.

Observation in control classes

In the control classes only four lessons were observed i.e. one observation in each control class. The results in Table 3 show that, while introducing their lessons, teachers tried either to define the concepts directly or ask oral questions about the topic to students. They also tried to relate their lessons with previous lessons, and to clarify lesson objectives. While presenting the main body of the lesson, the main tasks of the teachers were lecturing and writing notes on the black board and the main tasks of students were listening and copying the notes. Teachers were observed circulating around the class to insure 'disciple'. No hands-on practical activities were offered to students and their participation was limited to answering orally asked questions in

between the lectures and written questions given in the form of class work at the end of the lecture. In general, the climate in the classrooms was passive. Because teachers were running the lessons at their own pace, they were good at managing and saving time for activities like checking student learning and summarizing the main points of the lesson.

Table 3 results of classroom observation of the control classes

Curriculum profile	Control class		lesson	
	CT1	CT2	L1	L2
Introduction to the lesson	L1	L2	L1	L2
1. Teacher relates the lesson to previous learning/future activities (e.g. checking home work)	±	+	±	+
2. Teacher organizes students for group activities	-	-	-	-
3. Teacher introduces the lesson by an activity	±	-	-	±
4. Teacher clearly explains objectives of the lesson	±	+	±	-
5. Teacher asks group members to share responsibilities during activities	-	-	-	-
Body of the lesson				
6. Teacher demonstrates experiments to students	-	-	-	-
7. Students actively participate in doing experiments / hands-on activities	-	-	-	-
8. Students work cooperatively in small groups	-	-	-	-
9. Teacher circulates among students/groups asking/answering questions	+	+	±	+
10. Students seek help from the teacher during activities	-	±	-	-
11. Students discuss their activities (exercises) in small groups	±	±	-	-
12. Teacher makes short presentation at different times during the activities to help students grasp major concepts	-	-	-	±
13. Teacher and the students discuss the activities (exercises) as a whole class	-	+	+	+
14. Teacher effectively manages timing of different activities	±	±	±	±
Conclusion of the lesson				
15. Teacher, together with students draws conclusions from the activity/ experiment	-	-	±	±
16. Teacher helps students to relate the conclusion of activity with theory	-	-	±	±
17. Teacher summarizes the main concepts learned from the activities	±	±	-	±
18. Teacher checks learning of students (e.g. by oral questions, class discussions, homework questions)	±	+	±	+

Note: CT1=control class teacher 1 and CT2= control class teacher 2

Comparison of the experimental and control classes

In general, the results of the experimental and control classes showed significant differences in the types of classroom activities, student-student and student-teacher interactions, and teaching styles. In the experimental classes students were active participants; using the opportunity to carry out a variety of hands-on activities by themselves, discuss in their groups and to interact with their teachers. On the other hand, in the control classes the information flow was one-directional. Thus, the classes were typically teacher-centered.

Thus, from the results of the classroom observation, it is possible to conclude that apart from the obvious benefit to implement hands-on chemistry experiments, this approach also promoted active learning. The results are consistent with the findings of Mafumiko [37-38] from Tanzania. Just like us, he observed that this approach, as fringe benefit, promoted active learning.

The impact of the SSC approach on students' understanding of chemistry concepts (results of pre-test and post-test)

To examine whether there was a significant difference between experimental and control class students in their academic performance in relation to understanding chemistry concepts, pre- and post-tests were administered to both groups. Data obtained were analysed using the SPSS (statistical package for social sciences) version 16.0 software. Comparison of the pre-test scores of the two groups by an independent t-test (Tables 4 and 5) revealed the absence of a statistically significant difference in the academic performances of the two groups: experimental group (mean = 7.97, standard deviation = 3.29), control group (mean = 7.82, standard deviation = 3.56); and the t-value is equal to 0.421 which was not significant at $P < 0.05$.

Table 4 : comparison of the pre-test scores for experimental and control classes (group statistics)

The group to which the respondent belongs		N	Mean	Std. Deviation	Std. Error Mean
Pretest result	Experimental	188	7.97	3.287	.240
	Control	195	7.82	3.561	.255

Table 5 : comparison of the pre-test scores for experimental and control groups (Independent Samples Test)

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Pretest result	.079	.779	.421	381	.674	.148	.351	-.542	.837
Equal variances assumed			.421	381	.674	.148	.351	-.542	.837
Equal variances not assumed			.422	380.2	.674	.148	.350	-.541	.836

Tables 6 and 7 below show a comparison of the post-test scores for the experimental and control groups in the chemistry concept understanding test. The test scores revealed the presence of a statistically significant difference between the academic performance of the two groups: experimental group (mean=13.37, standard deviation = 4.52), control group (mean = 9.49, standard deviation = 4.11); and the t-value is equal to 8.51 which was significant at $P < 0.05$. The mean score of the experimental group was significantly higher than that of the control group. The findings show that the SSC hands-on practical activities could contribute to enhance students' understanding of chemistry concepts. The findings are in agreement with the results obtained from classroom observation, and teachers' and students' evaluations. Furthermore, the findings

are in line with the findings of other researchers (e.g. 24, 30, 32, 37, 38, 40, 52, 53) who demonstrated that the small-scale/microscale approach can enhance students' understanding of chemistry concepts; and increase their interest and motivation towards the subject.

Table 6: comparison of the post-test scores for experimental and control groups (group statistics)

The group to which the respondent belongs	N	Mean	Std. Deviation	Std. Error Mean
Post-test result out of Experimental	172	13.37	4.520	.345
25 (total) Control	185	9.49	4.107	.302

Table 7: comparison of the pre-test scores for experimental and control groups (Independent Samples Test)

	Levene's Test for Equality of Variance		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Postest result	2.106	.148	8.509	355	.000	3.886	.457	2.988	4.784
Equal variances assumed									
Equal variances not assumed			8.479	345.23	.000	3.886	.458	2.984	4.787

Students' opinions about the SSC approach

Students' perceptions towards the SSC hands-on activities (close-ended questions)

The close-ended questions were administered to estimate the perception of students towards the SSC approach of performing chemistry hands-on activities. This part of the questionnaire consisted of 14 Likert-type items with a scale of 1 to 5 where “1=strongly disagree”, “2=disagree”, “3=neutral”, “4=agree”, and “5=strongly agree”. The internal consistency of the items was estimated to be 0.84 (Cronbach’s alpha, $\alpha=0.84$). Data was analyzed by computing the means, standard deviations, and the percentage of students who rated as “4=agree” or “5=strongly agree” for each of the Likert-type items. The results are summarized in Table 3.4 below

Table 8: Students’ perceptions towards the SSC hands-on activities

Did you feel that the small-scale chemistry practical activities:	N	Ave	Stand. Dev.	% of A/SA
1. Were linked into other parts of chemistry	144	4.3	0.81	88
2. Helped you understand more about electrical conductivity of solutions of different compounds, electrolysis and rate of reaction	146	4.7	0.58	97
3. Made you feel like learning more about the subject	146	4.5	0.67	94
4. Helped you prepare for other topics in the text (syllabus)	145	4.4	0.84	88
5. Clarified some of the concepts that you have difficulties with	145	4.4	0.80	88
6. Made you enjoy your chemistry classes	146	4.5	0.75	89
7. Made your head think	145	4,6	0.69	96
8. Have given you confidence to carryout experiments by yourself	145	4.7	0.63	97
9. Provided you with opportunity to use materials and equipment	146	4.7	0.61	96
10. Made you feel working like a chemist	145	4.4	0.86	87
11. Made you actively participate in the lesson	146	4.6	0.69	95
12. Increased your cooperation and sharing ideas with fellow students	145	4.5	0.76	92
13. Made you feel very responsible about safety and environment	145	4,5	0,75	94
14. Exposed you to an easier way of doing experiments	143	4,6	0,55	97

Note: N: number of respondents per item; Ave: average score per item; %A/AS: percentage of students who rated as Agree or Strongly Agree.

As can be seen from the Table 8 about 146 students filled this part of the questionnaire. The mean scores of the items ranged from 4.3 and 4.7 and the overall mean was about 4.5. In general, the very high mean scores with small standard deviations show that the students' opinions about the SSC approach were highly positive. These findings are supported by many other researchers in similar studies [30, 37, 38, 52-57].

The strong positive perceptions were also reflected in the high ratings of each of the items. Most students indicated that performing the SSC hands-on activities by themselves enhanced their understanding of chemistry concepts: 97% believe (agree or strongly agree) that the activities helped them understand more about the topics (electrolysis and rate of reaction); 88% perceive that the activities helped them clarify some of the concepts that they had difficulties with; and 88% felt that the activities prepare them for other topics in the syllabus. In addition to this, students believed that the SSC practical activities made them feel like learning more about chemistry (94%), enjoy chemistry as a subject (89%), and feel like a chemist (87%). Furthermore, most students indicated that the SSC practical activities not only helped them enhance cooperation with their fellow students (92%) and made them actively participate in the practical lessons (95%) but also provided them with the opportunity to use and manipulate materials and equipment (96%). This is to be expected as students were performing the hands-on activities by themselves in small groups. Another result worth reporting was the great confidence students got as a result of exposure to SSC approach; 97% of them indicated that the SSC hands-on activities gave them confidence to carry out experiments by themselves.

Students' opinions about the SSC hands-on activities (open ended questions)

Aspects of the SSC experiments which students liked most

In general, the students who did SSC hands-on practical activities were positive to this approach. They had actually not conducted any experiments before; and most likely any practicals would have been received with acclamation. Students indicated that their involvement in the SSC practical activities gave them the opportunity to manipulate materials and learn from their mistakes. This in turn, students said, build their confidence, enhanced their practical skills and increased their interest towards science in general and chemistry in particular.

Most students also reported that they liked working in small groups. They mentioned that they were afraid to perform experiments by themselves. At first, some were reluctant even to touch the materials. However as some group members push ahead every group member followed and fear subdued. In addition, students commented that the group work enabled them to share ideas. A student, for example, expressed his satisfaction over the group work saying that 'the most joyful was to work in groups helping each other without fear'.

In addition to this, a majority of the students mentioned that they found the SSC kits and experiments easy to use and swift to conduct, safe and economical. They liked the way the materials and chemicals were arranged in the kits enabling them to easily find each apparatus or chemical without wasting time. The fact that students were getting positive results from the experiments also contributed for their positive view towards the SSC approach. Some of the positive comments forwarded by students include the following;

- *Everything was around us. No going here and there, it was easy to use and time saving.*
- *There was no wastage.*
- *I do not have words, but I want to say it was enjoyable.*
- *I love MyLab.*

Asked which experiments they liked most, majority of students mentioned that they liked the experiments on electrical conductivity of aqueous solutions of compounds and the effect of catalyst on the rate of a reaction. The most frequent reasons mentioned included the setting up of the experiments was easy, the results (changes) of the experiments were easy to observe, and the experiments helped them to verify and prove some of the difficult concepts that they had difficulties with. One student put it like this:

When we react [mix] copper with dilute HCl solution, there was no change. But there was a change [reaction] when zinc was mixed with HCl; the reaction between zinc and HCl become even faster when we conduct it in the presence of copper. That means the copper increased the rate of the reaction. Copper as a catalyst. I like this part very much.I was so confused when I learn [sic.] the theory on factors affecting the rate of reaction but when I do it practically, everything become clear. I investigated myself.

Difference between the SSC practical lessons and the regular chemistry classes

In general, students mentioned, not surprisingly, that they witnessed a big difference between the SSC based lessons and their regular chemistry classes, and commented in favor of the new approach. They explained that in their regular chemistry classes they were passive listeners while the SSC experiments enabled them to actively participate in different activities including finding the materials from the kits, setting up of apparatus, operating the experiments, observing and reporting results, using the worksheets, answering questions, cleaning working tables and other materials used in the experiments; and arranging all the materials to their original places in the kit. Clearly not all of this would give improved results in a typical "classical chemistry test".

However there is little of the above, which does not fall under an experimentalist's normal tasks. Therefore in order to transpire part of the tacit knowledge of experimental chemistry, these activities are worthwhile. The SSC provided an opportunity to read formulas

and names of chemicals on the vials, to deduce explanations of results etc. In short, the students were active, both manually and mentally, and the approach made them think chemistry non-stop.

Asked to forward final comments regarding the small-scale approach of chemistry practical work, a great majority of the students stressed that the SSC approach should be implemented across all schools in the country. Others suggested that a similar approach should also apply for biology and physics classes. Some even suggested for production of the kits in Ethiopia. Though most students were reluctant to indicate drawbacks of the SSC experimentation, a few highlighted problems such as breakage of glass materials (e.g. beaker, test tubes, glass rod), insufficient information before the start of the experiments, lack of clarity in some of the instructions (procedure) of the experiments, lack of previous practical skill of the students themselves, that the teachers were not able to give sufficient support to all groups, some disorder, fear of chemicals, shortage of chemicals in some experiments, and lack of positive results in some experiments.

Some of the problems mentioned were a result of lack of experience of teachers and students on chemistry hands-on activities and could be improved overtime as they make more practice. However, it should be recalled that even laboratories prepared to the teeth may not run smoothly. That experiments seldom are successful at first attempt must be considered a useful experience that contributes to a more realistic understanding of how science develops. Breakage of tiny glass materials, fear of some chemicals, lack of class discipline etc., for example, will never be fully avoided. The way out could be to make advance preparations to tackle the problems. It is of paramount importance for the schools to have a stock of replacement for broken/lost/non-functioning equipment or chemicals, but with more experience, less will be broken.

Teachers' evaluation of the SSC approach (interview)

The interviews were focused on the two-day SSC training, the applicability of the SSC approach in actual lessons and how the approach helped the teachers instruct in a student-centered manner, and what problems were encountered. As a whole, teachers' opinions towards the SSC approach were highly positive. As a result of their participation in the two-day workshop and in the study in general, teachers felt that their scope of practical work had been increased. The new approach enabled them to do practical work using minimum resources even with large number of students, up to fifty students in ten groups. Most of the SSC hands-on activities can be completed in a shorter time (within the forty minutes class period), which is also an advantage mentioned by the teachers.

The approach helped the teachers promote active learning in their lessons. Timid and shy students who seldom participated in the regular classes were observed participating in their groups during the SSC experiments; in particular girls' involvement was enhanced. The safe and easy to use nature of the SSC kits encouraged participation even further. Students were observed to be highly excited and happy, hardly surprising as this study gave the students a first opportunity to conduct experiments themselves. The teachers emphasized that the SSC approach helped the students develop confidence and an 'I can do' attitude.

All the teachers expressed strong positive views with regard to the importance of the SSC hands-on activities in enhancing students' practical skills, understanding of concepts and in developing positive attitudes towards the subject (chemistry). They expected the impact of the sessions to be long lasting, even having an effect on the students' future careers.

With regard to safety and suitability of the SSC approach for use in classrooms, a teacher put it as follows:

In the small-scale, my students had to use only very small amounts of chemicals. They can use proppets and syringes to transfer liquids. In addition, most of the apparatus are plastic materials; the reagent bottles are very small. Everything was safe. This gave confidence to me and my students to perform the experiments without fear. Furthermore, in this approach everything was ready; the kits were compact and portable and contain almost everything in the same box. There is no wasting time in searching reagents from shelves or stores. Solutions were ready. The manuals give step by step guidance. Everything was ok.

Another teacher also commented that the approach helped to facilitate students' understanding of concepts as follows:

Previously when I was teaching the topic of electrolysis (what is electrolysis? what is cathode? what is anode, what is preferential discharge etc.,) it was very difficult for me to transmit my ideas. But using the SSC, it became easy. I was able to physically show them the anode and the cathode; students were able to see the flow of electricity [glowing of the LED] and the reactions [bubbling of gases] that were taking place at the electrodes by their naked eyes. The same was true with factors affecting rate of reaction; it was difficult for me to convince students whether 'a catalyst facilitates a reaction without undergoing any change for itself'. But using the small-scale experimentation, students had proved that for themselves. You can see the students becoming very happy when they confirm the theory with their own experiment.

Asked to give final comments regarding the SSC approach, all teachers strongly recommended the implementation of the small-scale approach in their schools and in the country as a whole. As one of the teachers expressed it,

This SSC approach must be introduced to all schools in the country. I am sure, if they try it, they will like it.

A number of other studies have reported similar positive views of teachers towards the small-scale approach [e.g. 23, 24, 30, 32, 37, 38, 58]. Mohamed et al. [30], for example, reported that teachers strongly supported the approach saying that it is easier, time saving, can increase class interactions and can enhance the students' performance in various aspects of learning chemistry.

No significant problems were reported. The few mentioned will necessarily be improved as both students and teachers make more practice. The teachers experienced problems identifying some of the equipments in the kit, difficulties fitting some of the equipment, problems cleaning of some of the plastic apparatus, breakage problems in some glass equipment, and problems in getting accurate results. The lack of accurate results were partly due to fact that the the MyLab kit did not include analytical balance and hence measurement of mass in most of the experiments was just an estimation. In addition to this, some reactions were too fast to make accurate observations. Consequently, the results were affected.

Nevertheless, as any experimentalist knows, accurate results are rarely achieved the first time, materials break and stains stubbornly persist. This is part and parcel of doing experimental work – even for SSC. Lack of discipline, that is too much noise and disorder in the room, was also reported as a problem. Teachers who have been educated using an authoritarian style may avoid engaging students in hands-on practical activities simply for the discomfort and insecurity they feel due to the loss of ‘control’ in their classes. This part of practicals should be addressed parallel with the training in manipulating the SSC sets.

CONCLUSIONS AND RECOMMENDATIONS

This study explored the possibility and effect of using the SSC approach as a means of implementing chemistry hands-on practical activities in Ethiopian secondary classes without the need for expensive ‘traditional’ laboratories. Classroom experiences throughout the study period indicated that the approach was helpful in addressing some of the bottle necks that schools and teachers face when trying to implement chemistry practical work. With the SSC MyLab kit, everything the teachers and students needed were at hand and only small amounts of chemicals

were consumed, reducing these costs and waste. In addition, it was observed that the SSC approach led to intense interaction both among the students themselves and between the students and the teacher, thereby providing a positive learning ambience. Indeed, significant difference in chemistry achievement was observed between the experimental group that was taught using the SSC hands-on approach and the control group that was taught with the traditional approach in favor of the experimental group ($p < 0.05$).

Not surprisingly, the teachers and students regarded the SSC as an effective approach in teaching and learning chemistry. The teachers reported that their participation in the study had broadened their scope of practical chemistry work and that such activities can be performed with minimum resources. In the teachers' opinion, the approach allowed students to carry out experiments by themselves, promoted active learning by enhancing class interactions, and made chemistry class interesting and enjoyable. Both teachers and students appreciated that the SSC was easy to use, safe and less costly.

From the above-mentioned results, it is plausible to conclude that the SSC approach is a commendable option for the Ethiopian secondary chemistry classes. It may enable implementation of chemistry practical work by addressing some of the bottlenecks and thereby enhancing the quality and relevance of secondary chemistry teaching in the country. However, the need for good planning and extensive follow-up must not be underestimated. Training in the use of the kit, monitoring the implementation, continuous support to teachers and a steady system for acquiring spare parts are key factors in the successful implementation of the SSC approach in schools. In addition, attention should be given to time allocation, class size, and workload calculation of science practical classes. Future work shall focus on familiarizing the small-scale approach throughout schools and higher learning institutions in the country.

REFERENCES

1. Abrahams, I. and Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science, *International Journal of Science Education*, 30(14), 1945–1969.
2. Millar, R. and Abrahams, I. (2009) Practical work: making it more effective. *School Science Review*, 91(334), 59–64
3. Hofstein, A., & Mamlok-Naaman, R. (2007). The Laboratory in Science Education: The State of the Art. *Chemistry Education Research and Practice*, 8(2), 105-107
4. Layton, D. (1990). Student laboratory practice and the history and philosophy of science. In E. H Hegarty (Ed), *The student laboratory and the science curriculum*. London and New York: Routledge.
5. Federal Democratic Republic Government of Ethiopia (1994). *Education and Training Policy*. Addis Ababa
6. Ministry of Education (2010). *Chemistry grade 9-12 student text*. Federal Democratic Republic of Ethiopia, Addis Ababa
7. Hofstein, A. (2004). The laboratory in chemistry education: thirty years of experience with developments, implementation and research. *Chemistry Education Research and Practice*, 5(3), 247-264.
8. Jenkins, E.W. (2000). Constructivism in School Science Education: Powerful Model or the Most Dangerous Intellectual Tendency? *Science & Education*, 9, 599-610
9. Bradley, J.D. (2001). UNESCO/IUPAC-CTC global program in microchemistry. *Pure Applied Chemistry*, 73(7), 1215-1219.
10. Bekalo, S. & Welford, G. (2000). Practical activity in Ethiopian secondary physical sciences: implications for policy and practice of the match between the intended and the implemented curriculum, *research paper in education*, 15(2), 185-212
11. Mekelle University (2010). *Research review day, internal report*. Unpublished.
12. Skinner, J. (Ed.). (1997). *Microscale chemistry*. Royal Society of Chemistry.
13. Singh, M.M., Szafran, Z. & Pike, R.M. (1999). Microscale chemistry and green chemistry: complementary pedagogies. *Journal of Chemical Education*, 76(12), 1684-1686.
14. Bhanumati, S. (1997). Innovative tools in small-scale chemistry. *International News of Chemical Education*, 45, 11-15.
15. National Microscale Chemistry Centre. [Online] 3/08/2013. <http://www.microscale.org/>
16. Ciardullo, C. V. (2000). *Micro Action Chemistry: Teacher's edition*. Vol. 2. Flinn Scientific Catalog number AP8623
17. Breuer, S. W. *Microscale practical organic chemistry*. Lancaster: Lancaster University, 1991
18. Mayo, D.W., Pike, R. M. and Butcher, S. S., *Microscale Organic Laboratory*, John Wiley and Sons, New York, 1986.
19. Wood, Clair G. (1990). *Microchemistry*. *Journal of Chemical Education*. 67(7): 596-597.
20. Penn, J.H. (1999). *Microscale Chemistry in the U.S.A*. *Educacion Quimica*, 10(2), 107-113.
21. Bradley, J. D., Durbach, S., Bell, B., Mungarulire, J., & Kimel, H. (1998). Hands-On Practical Chemistry for All: Why and How? *Journal of Chemical Education*, 75, 1406 - 1409.
22. Bradley, J.D. (1999). Hands-on practical chemistry for all. *Pure Applied Chemistry*, 71(5), 817-823
23. Kelkar, S.L. & Dhavale, D.D. (2000). Microscale experiments in chemistry: the need of the new millenium. *Resonance*, 5(10), 24-31.

24. Vermaak, I. & Bradley, J. (2003). New technologies for effective science education break the cost barrier, paper presented at the British Educational Research Association Conference, Heriot-Watt University, Edinburg, Scotland, 11-13 September 2003
25. Tallmadge W., Homan M., Ruth C. and Bilek G., (2004), A local pollution prevention group collaborates with a high school intermediate unit bringing the benefits of microscale chemistry to high school chemistry labs in the Lake Erie watershed, *Chem. Health Safety*, 11, 30-33.
26. Mattson, B. (2005). Microscale gas chemistry. *Educación química*, 16(4), 514-528.
27. Tantayanon S. (2010). Small scale chemistry: experiences for developing countries. Simposio Microquim 2010 Universidad Iberoamericana, Mexico.
28. Orna, M.V (2010). Small-Scale chemistry, a sourcebook module, version 3.0 2010. ChemSource, instructional resources for pre-service and in-service teachers. <http://dwb4.unl.edu/ChemSource/ChemSource.html>
29. Poppe, N., Markic, S., & Eilks, I. (2011). Low-cost-techniques for the science classroom. Bremen: SALiS Project.
30. Mohamed, N., Abdullah, M., & Ismail, Z. Ensuring Sustainability through Microscale Chemistry. *Green Chemistry for Environmental Remediation*, 119-136.
31. MyLab school chemistry and science kits. [Online] 15/08/2013 <http://www.mylab.co.za/>
32. Abdullah, M., Mohamed, N., & Ismail, Z. H. (2009). The effect of an individualized laboratory approach through microscale chemistry experimentation on students' understanding of chemistry concepts, motivation and attitudes. *Chem. Educ. Res. Pract.*, 10(1), 53-61.
33. IUPAC (2001). *Chemistry International* 23 (4), 97 – 128
34. Ibanez, J. G. (2012). Miniaturizing Chemistry the Ecological Alternative. *African Journal of Chemical Education*, 2(1), 3-9.
35. UNESCO (2011). Small is beautiful. *A World of Science*, 9 (3), 17 – 19
36. Bradley, J. (2000). The Microscience project and its impact on pre-service and in-service teacher education. Washington, DC: The World Bank.
37. Mafumiko, F. (2008). The Potential of Micro-scale Chemistry Experimentation in enhancing teaching and learning of secondary chemistry: Experiences from Tanzania Classrooms. *鳴門教育大学国際教育協力研究*, (3), 63-79.
38. Mafumiko, F. S. M. (2006). Micro-scale experimentation as a catalyst for improving the chemistry curriculum in Tanzania. University of Twente.
39. Sia, L. (2002). UNESCO-IUPAC Global project: Microscience experiments. An African example. A paper presented at the conference of the Ministers of Education of African Member State. Dar es Salaam, Tanzania. 2- 6 December, 2002.
40. Madeira, A.C.P., (2005). The influence of practical work on chemistry teaching and learning- an approach using microchemistry kits in Mozambican Junior Secondary Schools, Unpublished M.Sc. Thesis, Faculty of Science, University of the Witwatersrand, Johannesburg
41. <http://www.radmaste.org.za>
42. Tesfaye, T. & Hussien, S. (2011). Pilot introduction of small-scale chemistry kits into two Ethiopian secondary schools.
43. Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education*. Routledge.
44. Wiersma, W. & Jurs, S. (2005). *Research Methods in Education*. USA: Pearson Education

45. Tilya, F. N. (2003). Teacher support for the use of MBL in activity-based physics teaching in Tanzania. University of Twente.
46. Ottevanger, W. J. W. (2001). Teacher support materials as a catalyst for science curriculum implementation in Namibia. Universiteit Twente.
47. Bureau of education (2012). Education Statistics Annual Abstract. Mekelle, Tigray Region, Ethiopia
48. Asfaw, E., Otores, D., Ayele, T., Gebremariam, Z., (2009). Science and mathematics secondary education in Ethiopia. An Option paper presented at the Technical Workshop on Science and Mathematics Secondary Education in Africa (SEIA) Follow-up Program. January 29 – February 06, 2009, Tunis
49. Zymelman, M. (1990). Science, education and development in sub-Saharan Africa. World Bank, Washington, DC.
50. Lewin, K. (1992). Science education in developing countries: issues and perspectives for planners. International institute for educational planning: Paris.
51. MyLab (2012). *Small scale chemistry grade 10-12 worksheets*. Northwest University, Potchefstroom.
52. Bradley, J. D & Vermaak, I. (1996). Proceedings of 14th international conference on chemical education (pp. 100 – 107). Brisbane, royal Australian chemical institute.
53. Abdullah, M., Mohamed, N., & Ismail, Z. H. (2007). The effect of microscale chemistry experimentation on students' attitude and motivation towards chemistry practical work. *Journal of Science and Mathematics Education in Southeast Asia*, 30(2), 44 – 72.
54. Carnduff, J., & Reid, N. (2003). Enhancing undergraduate chemistry laboratories: pre-laboratory and post-laboratory exercises. Royal Society of Chemistry.
55. Zakaria, Z., Latip, J., & Tantayanon, S. (2012). Organic Chemistry Practices for Undergraduates using a Small Lab Kit. *Procedia-Social and Behavioral Sciences*, 59, 508-514.
56. Vailikhit, V., Changto, W., Janthondee, S. (2013). Bringing Affordable experimental chemistry to rural Thai government high schools. International conference “New Perspectives in Science Education”, 2nd Edition, 14 - 15 March 2013. Florence, Italy
57. Abdullah, M., Mohamed, N., & Ismail, Z. H. (2013). Introducing Microscale Experimentation in Volumetric Analysis for Pre-service Teachers. In *Chemistry Education and Sustainability in the Global Age* (pp. 311-320). Springer Netherlands.
58. Vermaak, I. (1997). Evaluation of cost-effective microscale equipment for a hands-on approach to chemistry practical work in secondary schools. University of Witwatersrand. Bradley, JD. 1999. “Science Education at the RADMASTE Centre: The role of a University in Development.”. In Sylvia Ware, ed, *Science and Environment Education: Views from Developing Countries*. Washington, DC: World Bank: 141- 150.

Acknowledgements

This paper is based upon work supported by the Institutional Collaboration between MU-HU-UMB project (NORAD III) under grant number MU-UMB/CNCS/03/2003. Thus, the authors would like to acknowledge the financial support by NORAD III. The authors also thank Roger Aarvik for the technical support at the Department of chemistry, NTNU, Norway. Similar thanks also go to the Department of chemistry, Mekelle University, Ethiopia for material and financial support. Last but not least, great appreciations go to chemistry teachers and students of the participating secondary schools.

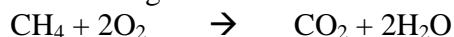
Appendix 1**Student pre- and post-tests questions***Time allocated: 90 minutes*

Name _____ Class and section _____ Sex _____ age _____

Part I: Choose the correct answer and circle the letter of your choice (1 mark each)

1. Solid sodium chloride is a bad conductor of electricity because;
 - A. It contains only molecules
 - B. It does not possess ions
 - C. The ions in it are not free to move
 - D. It does not contain free molecules
2. In the electrolysis of sulphuric acid using platinum electrodes
 - A. Hydrogen is evolved at the cathode
 - B. Ammonia is produced at the anode
 - C. Chlorine is obtained at the cathode
 - D. Sulphur dioxide is produced at the anode
3. It has been observed that gaseous hydrogen chloride is a very poor conductor of electricity but a solution of hydrogen chloride gas in water is good conductor of electricity. This is due to the fact that
 - A. Water is good conductor of electricity
 - B. Hydrogen chloride gas in water solution ionizes
 - C. A gas is non-conductor but a liquid conducts electricity
 - D. None of the above
4. The aqueous solution of which of the following compounds is decomposed on passing an electric current?
 - A. Cane sugar
 - B. Urea
 - C. Methanol
 - D. Potassium iodide
5. The electric conduction of a salt solution in water depends on the
 - A. size of its molecules
 - B. Shape of its molecules
 - C. Size of solvent molecules
 - D. Extent of its ionization
6. The rate of a chemical reaction can be expressed in
 - A. Grams per mole
 - B. Energy consumed per mole.
 - C. Volume of gas evolved per unit time.
 - D. Moles formed per litre of solution
7. Consider the following reaction:
$$2\text{N}_2\text{O}_5 \rightarrow 4\text{NO}_2 + \text{O}_2$$
At a certain temperature the rate of decomposition of N_2O_5 is 2.5×10^{-6} mol/s. The rate of formation of NO_2 is:
 - A. 1.0×10^{-5} mol/s
 - B. 1.3×10^{-6} mol/s
 - C. 2.5×10^{-6} mol/s
 - D. 5.0×10^{-6} mol/s

8. Consider the following reaction:



At a certain temperature, 1.0 mol CH_4 is consumed in 4.0 minutes. The rate of production of H_2O is

- A. 0.25 mol/min
 - B. 0.50 mol/min
 - C. 2.0 mol/min
 - D. 8.0 mol/min
9. Which combination of factors will affect the rate of the following reaction?
- $$\text{Zn(s)} + 2\text{HCl(aq)} \rightarrow \text{ZnCl}_2(\text{s}) + \text{H}_2(\text{g})$$
- A. temperature and surface area only
 - B. temperature and concentration only
 - C. concentration and surface area only
 - D. temperature, concentration and surface area
10. Magnesium metal reacts rapidly with hydrochloric acid in an open beaker to produce aqueous magnesium chloride and hydrogen gas. Which of the following could be used to measure the rate of this reaction?
- A. the volume of the solution
 - B. the colour of gas produced
 - C. the concentration of the chloride ion
 - D. the mass of the beaker and its contents
11. Consider the following factors:
- I. Concentration of reactants.
 - II. Temperature of reactants.
 - III. Surface area of reactants.
- The factors that affect the rate of a chemical reaction between two gases are
- A. I and II only.
 - B. I and III only.
 - C. II and III only.
 - D. I, II and III
12. To increase the rate of a reaction, there must be
- A. A decrease in the frequency of collisions.
 - B. An increase in the frequency of collisions.
 - C. A decrease in the frequency of successful collisions.
 - D. An increase in the frequency of successful collisions.
13. Which of the following statements about catalysts is true?
- A. Catalysts work by increasing the temperature of the reaction
 - B. Catalysts can be recovered chemically unchanged after the reaction
 - C. Catalysts increase the energy required for the reaction to take place
 - D. Catalysts are always powdered solids
14. If we increase the concentration of a reactant, what happens to the collisions between particles?
- A. There are fewer collisions
 - B. There are the same number of collisions but they have less energy
 - C. There are the same number of collisions but they have more energy
 - D. There are more collisions

15. Why does the rate of reaction increase when powdered calcium carbonate is used instead of cubes of marble?
- There is an increase in concentration
 - There is an increase in temperature
 - There is an increase in surface area
 - Powdered calcium carbonate is a catalyst

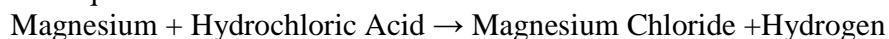
Part II: Answer the following questions in the space provided

16. An aqueous solution that contains positive and negative ions can conduct an electric current. Write down the chemical formulas for the ions formed in aqueous solution by the following compounds. (2 marks)

e.g. NaCl (aq) →	Na ⁺ (aq) + Cl ⁻ (aq)
Compounds in aqueous solution	The ions formed in aqueous solution
a) KCl (aq) →	
b) Na ₂ SO ₄ (aq) →	

17. Define electrolysis (1 mark)

18. An experiment was carried out to look at the reaction between magnesium and hydrochloric acid. The word equation for this reaction is:



- a) What would you observe when this reaction is taking place? (1 mark)
- b) Give three ways in which the rate of reaction could be increased (3 marks)
- _____
 - _____
 - _____
19. You are provided with a piece of zinc metal (zinc granule), zinc dust; dilute HCl, ice-bath, test tubes, water bath, burner. Using the materials provided, devise an activity to study the factors affecting the rate of the reaction between zinc and dilute HCl (3 marks)

Appendix 2

SSC student worksheet manual (for experiment 1)

Experiment 1: electrical conductivity of ionic compounds

Objective: To test the electrical conductivity of the aqueous solutions of some compounds

Apparatus: MYLAB apparatus stand, water bowl, spatula, 9-volt battery, set of conducting wires (connecting wires), battery connection, two copper electrodes, and glass stirring-rod

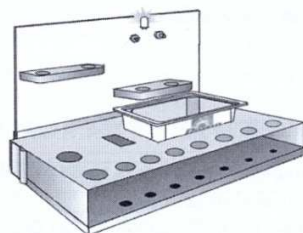
Chemicals: Distilled water, sodium chloride, copper sulphate, calcium chloride, sodium bicarbonate, iron (III) chloride, table sugar, Na₂CO₃.

Safety

- Sodium carbonate (Na₂CO₃) is an irritant. It is irritating to the eyes. In case of contact with the eyes, rinse immediately with plenty of water and seek medical advice. Do not breathe the dust.
- Copper (II) sulphate (CuSO₄) is harmful if swallowed. It is irritating to eyes and skin. Do not breathe the dust.

Procedure

- Set up the apparatus as shown in the sketch



Source: MyLab (2012)

2. Fill the water bowl with water to the brim
3. Add four spatulas of NaCl into the water in the water bowl and stir it with a glass rod until the salt dissolves
4. Follow the steps below (step 5-8) to complete the apparatus setup.
5. Place two electrodes (copper electrodes) in the water and connect them as shown in the sketch
6. Connect the red (positive) conducting wire of the battery connection to the red or positive terminal of the LED (light emitting diode).
7. Connect the black (negative) conducting wire of the battery connection to the end of the electrode protruding from the water.
8. Use another separate conducting wire to connect the end of the other electrode (also protruding from the water) to the black or negative terminal of LED. Note your observations
Note: Use the signs of the battery terminals to determine which is the positive and which is the negative electrode in the water bowl
9. Repeat the experiment using the following compounds: distilled water only, sodium carbonate, copper sulphate, calcium chloride, sodium bicarbonate, iron (III) chloride, table sugar. Note your observations

Observations and analysis

1. In step 8 above, what do you observe when you look at the LED? Explain your observation
2. In step 9 above, the aqueous solutions of some of the compounds conduct electricity while others do not? Explain why.
3. Classify solutions of these compounds as electrolytes and non-electrolytes
4. An aqueous solution that contains positive and negative ions can conduct an electric current. Write down the chemical formulas for the ions formed in aqueous solution by the following compounds.

e.g. NaCl (aq) →	Na ⁺ (aq) + Cl ⁻ (aq)
Compounds in aqueous solution	The ions formed in aqueous solution
KCl (aq) →	
MgCl ₂ (aq) →	
Na ₂ SO ₄ (aq) →	
5. What is an electrolyte?
6. When is a compound a strong electrolyte and when is a compound a weak electrolyte?

7. Will KCl(aq) , $\text{MgCl}_2(\text{aq})$, and $\text{Na}_2\text{SO}_4(\text{aq})$ be strong or weak electrolytes? Explain your answer.

8. What do you learn from this experiment?

Clean up time

MYLAB apparatus	Waste disposal
Wash and clean apparatus according to instructions	
Wash test tubes with test tube brush and rinse well. Dry or place upside down in apparatus stand	Dilute the waste with lots of water before disposing of the waste in the outside drain or on the ground
Close lids of chemicals properly and put back in the correct place	
Pack set according to packing instructions	
WASH HANDS on completion of experiments!!!	

Source: MyLab [2012]

Appendix 3: SSC teachers guide manual (for experiment 1)

Experiment 1: electrical conductivity of ionic compounds

Objective: To test the electrical conductivity of the aqueous solutions of some compounds

Apparatus: MYLAB apparatus stand, water bowl, spatula, 9-volt battery, set of conducting wires (connecting wires), battery connection, two copper electrodes and glass stirring-rod

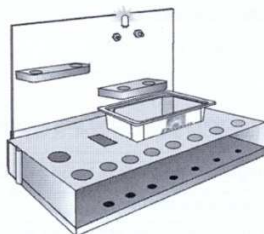
Chemicals: Distilled water, sodium chloride, copper sulphate, calcium chloride, sodium bicarbonate, iron (III) chloride, table sugar, Na_2CO_3 .

Safety

- Sodium carbonate (Na_2CO_3) is an irritant. It is irritating to the eyes. In case of contact with the eyes, rinse immediately with plenty of water and seek medical advice. Do not breathe the dust.
- Copper (II) sulphate (CuSO_4) is harmful if swallowed. It is irritating to eyes and skin. Do not breathe the dust.

Procedure

1. Set up the apparatus as shown in the sketch



Source: MyLab (2012)

2. Fill the water bowl with water to the brim
3. Add four spatulas of NaCl into the water in the water bowl and stir it with a glass rod until the salt dissolves
4. Follow the steps below (step 5-8) to complete the apparatus setup.

- Place two electrodes (copper electrodes) in the water and connect them as shown in the sketch
- Connect the red (positive) conducting wire of the battery connection to the red or positive terminal of the LED (light emitting diode).
- Connect the black (negative) conducting wire of the battery connection to the end of the electrode protruding from the water.
- Use another separate conducting wire to connect the end of the other electrode (also protruding from the water) to the black or negative terminal of LED. Note your observations
Note: Use the signs of the battery terminals to determine which is the positive and which is the negative electrode in the water bowl
- Repeat the experiment using the following compounds: distilled water only, sodium carbonate, copper sulphate, calcium chloride, sodium bicarbonate, iron (III) chloride, table sugar. Note your observations

Observations and analysis

- In step 8 above, what do you observe when you look at the LED? Explain your observation.

The LED burns brightly which shows that an aqueous solution of NaCl conducts electricity strongly.

- In step 9 above, the aqueous solutions of some of the compounds conduct electricity while others do not? Explain why.

Yes, aqueous solutions of sodium carbonate, copper sulphate, calcium chloride, sodium bicarbonate, iron (III) chloride conduct electricity strongly. On the other hand table sugar do not conduct electricity because it is a non-ionic compound

- Classify solutions of these compounds as electrolytes and non-electrolytes

Electrolytes: aqueous solutions of sodium carbonate, copper sulphate, calcium chloride, sodium bicarbonate, iron chloride

Non-electrolyte: aqueous solution of table sugar

- An aqueous solution that contains positive and negative ions can conduct an electric current. Write down the chemical formulas for the ions formed in aqueous solution by the following compounds.

e.g. NaCl (aq) →	$\text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
Compounds in aqueous solution	The ions formed in aqueous solution
KCl (aq) →	$\text{K}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
$\text{MgCl}_2(\text{aq}) \rightarrow$	$\text{Mg}^{2+}(\text{aq}) + 2\text{Cl}^-(\text{aq})$
$\text{Na}_2\text{SO}_4(\text{aq}) \rightarrow$	$2\text{Na}^+ + \text{SO}_4^{2-}(\text{aq})$

- What is an electrolyte?

An electrolyte is a substance that forms ions in water or in the molten state and therefore an electrolyte can conduct an electric current.

- When is a compound a strong electrolyte and when is a compound a weak electrolyte?

A strong electrolyte forms lots of ions in aqueous solution and a weak electrolyte forms very little ions in aqueous solution

- Will KCl(aq), MgCl₂(aq), and Na₂SO₄(aq) be strong or weak electrolytes? Explain your answer.

All of the compound are very soluble in water and are therefore strong electrolytes. They form lots of ions in solution.

- What do you learn from this experiment?

You have learned that aqueous solutions of ionic compounds like NaCl conduct

electricity while aqueous solutions of covalent compounds like table sugar are non-electrolytes. The reason is that ionic compounds dissolve in water and produce a lot of ions. This enables them to be strong conductors of electricity in their solution form. On the other hand covalent compounds do not dissolve in water to produce ions. Hence they do not conduct electricity.

Clean up time

MYLAB apparatus	Waste disposal
Wash and clean apparatus according to instructions	
Wash test tubes with test tube brush and rinse well. Dry or place upside down in apparatus stand	Dilute the waste with lots of water before disposing of the waste in the outside drain or on the ground
Close lids of chemicals properly and put back in the correct place	
Pack set according to packing instructions	
WASH HANDS on completion of experiments!!!	

Source: MyLab [2012]

Appendix 4: List of main apparatus/equipment and chemicals which are required to perform the mandatory chemistry experiments specified in the Ethiopian secondary chemistry syllabus

Apparatus/equipment				Chemicals					
1	Beakers of various sizes	34	light bulb	1	Acetic acid	34	Gentian violet	67	Sodium chloride
2	bunsen burner	35	litmus papers	2	Alcohol	35	glycerine	68	sodium dichromate
3	Burette	36	Measuring cylinder	3	aluminium metal	36	graphite	69	Sodium hydroxide
4	carbon rod	37	melting point tube	4	aluminium oxide	37	hexamethylenediamine	70	sodium metal
5	Clamp	38	nichrome wire	5	ammonia solution	38	hexane	71	sodium peroxide
6	combustion tube	39	pH meter	6	Ammonium nitrate	39	hydrochloric acid	72	sodium sulphate
7	condenser	40	Pipette	7	ammonium phosphate	40	hydrogen gas	73	sodium carbonate
8	conical flask	41	platinum wire	8	ammonium sulphate	41	hydrogen peroxide solution	74	starch
9	Cork	42	pneumatic trough	9	Ba(ClO ₂) ₂	42	iodine crystals	75	Sulfuric acid (18M)
10	cotton wool	43	porcelain	10	barium chloride	43	iron (II) nitrate	76	Sulphur powder
11	deflagrating spoon	44	power supply (DC)	11	barium nitrate	44	Iron fillings	77	tin metal
12	delivery tube	45	quickfit apparatus	12	barium peroxide	45	iron metal	78	toluene
13	distillation flask	46	reagent bottles	13	benzene	46	lead bromide	79	universal indicator
14	Doppers	47	round bottom flask	14	Bile	47	lead iodide	80	wooden spirit
15	dropping funnel	48	rubber tube	15	boiling chips	48	lead metal	81	yeast
16	dry cells	49	sand paper	16	bromine water	49	lead oxide	82	zinc metal

17	electrodes of different types	50	separatory funnel	17	calcium carbide	50	magnesium metal	83	zinc oxide
18	electronic balance	51	spatula	18	calcium carbonate	51	magnesium oxide	84	zinc strip
19	Erlenmeyer flask of different sizes	52	Stand	19	calcium hydroxide	52	magnesium ribbon	85	zinc sulphate
20	Evaporating dish	53	Stirrer	20	calcium metal	53	manganese dioxide		
21	filter funnel	54	stoppers	21	calcium oxide	54	marble chips		
22	filter paper	55	stopwatch	22	carbon tetrachloride	55	mercury		
23	forceps	56	switch	23	cobalt chloride	56	methyl red		
24	funnel	57	test tube holders	24	copper carbonate	57	naphtalene		
25	gas jar	58	test tube stand	25	copper metal	58	nitric acid		
26	gas jar lid	59	Test tubes	26	copper oxide	59	phenolphthalein		
27	gas syringe	60	Thermometer	27	copper powder	60	potasium thiocyanate		
28	Glass rod	61	tongs	28	copper strip	61	potassium chloride		
29	gloves	62	tripod	29	copper sulphate	62	potassium iodide		
30	goggles	63	U-tube	30	copper wire	63	Potassium permanganate		
31	graphite electrodes	64	voltameter	31	copper chloride	64	silver nitrate		
32	insulated electric wires	65	Watch glass	32	Distilled water	65	Sodium acetate		
33	iron rod	66	wire gauze	33	ethanol/alcohol	66	sodium carbonate		

OPPORTUNITIES AND CHALLENGES IN OPEN DISTANCE POST-GRADUATE STUDENT TRAINING IN CHEMISTRY: UNISA'S EXPERIENCE

Fikru Tafesse* and Malose J. Mphahlele

Department of Chemistry, College of Science, Engineering and Technology, University of South Africa, P.O. Box 392, Pretoria 0003, South Africa

*Author for correspondence: tafesf@unisa.ac.za

ABSTRACT

The Department of Chemistry at the University of South Africa (UNISA) has a proven track record and culture of research and postgraduate student training dating back to the correspondence era. The practice of offering postgraduate programs in laboratory-based disciplines within the Open Distance Learning (ODL) context as practiced in UNISA is discussed in detail. The authors use their experience to shed light on the models that work well for laboratory-based postgraduate student training within the ODL framework. [*AJCE 4(3), Special Issue, May 2014*]

INTRODUCTION

Universities are uniquely positioned to critically evaluate knowledge, challenge knowledge and extend intellectual boundaries locally, nationally and internationally through global networks for teaching and research. The capacity for countries to adopt, disseminate, and maximize rapid technological advances is dependent on the strength of adequate systems of tertiary education. Improved and accessible tertiary education systems can help a developing country progress toward sustainable achievements that are critical determinants of a country's economic growth and standard of living [1]. Indicators of scientific activity of a nation include: gross national product and its proportion spent on research and development. The mid 1990's brought a revolution in the history of higher education in SA when the Department of Higher Education (DoHE) changed its focus and funding formula to fund tertiary institutions based on student throughput and research outputs than just student numbers [2]. This paradigm shift compelled UNISA to be transformed from being a dedicated teaching institution to become a research institution with well developed postgraduate programs. Likewise, UNISA evolved from a correspondence institution to modern day Open Distance Learning (ODL) institution with adequate teaching and research laboratories. Open Distance Learning (ODL) is a multidimensional concept aimed at bridging the geographic, economic, social, and communication distance between students and the university, students and academics, students and courseware and students and peers.

Objectives of an ODL institution are:

- To provide education to students deprived of higher education opportunities including those in employment and adults who wish to upgrade their education.

- To provide equality of education through multi-media teaching–learning approach.
- To provide flexibility for enrolment, age of entry, choice of programs, methods of learning, conduct of examinations and operation of the programs
- To promote integration within the educational policies
- To offer degree programs and non-degree certificate programs for the benefit of the working population
- To make provision for research and dissemination of knowledge amongst the populace
- To serve as a source of continuing education

ODL is considered nowadays as the most viable means for broadening educational access while improving the quality of education, advocating peer to-peer collaboration and giving the learners a greater sense of autonomy and responsibility for learning [3]. Although some contact institutions also have distance learning (DL) programs at undergraduate and postgraduate levels, these are restricted to non-laboratory based disciplines. Available information shows that less than ten “ODL institutions” in the whole world offer undergraduate chemistry degrees presumably because of the requirement for routine access to research laboratories and analytical facilities. Generally the training of chemists entails two main categories: professional chemists and chemical technologists. Chemical technologists are trained mainly through the Universities of Technology whereas professional chemists are trained through conventional or comprehensive university programs.

Direct contact with students forms an integral part of any experimental training in disciplines such as chemistry and the training requires routine and sustainable access to adequate laboratory facilities by students. The nature of chemistry experiments and safety aspects, on the other hand, require students to have regular monitoring and support by the supervisors throughout the training. UNISA's Department of Chemistry has a history and culture of research and postgraduate student training dating back to 1960. At the time the modus operandi was mainly correspondence which gradually transformed to the now ODL program. The profile of the students also changed in terms of age and demographics. Nowadays our programs in chemistry in both undergraduate and postgraduate levels have relatively younger candidates with no attachment to industry. The UNISA undergraduate chemistry program is structured as comprising of course work (75%) and laboratory work (25%). The BSc honours programme, on the other hand, is structured as a combination of course work (65%) and limited research work and mini-dissertation/thesis (35%). The course work in both cases may be accomplished in open distance electronic learning (ODEL) mode while the laboratory component demands a face-to-face contact and access to a working chemical laboratory. The MSc and PhD programs, on the other hand, are 100% research based and culminate into dissertations or theses, respectively.

UNISA'S ADMISSION CRITERIA INTO POSTGRADUATE PROGRAM:

The UNISA chemistry postgraduate studies brochure clearly stipulates that for admission into Honours BSc degree in chemistry, students must possess an accredited BSc degree in chemistry or equivalent qualification (within the past five years) and a pass of the four third level chemistry sub-disciplines with a minimum average of 60%. For admission into an MSc program in chemistry a student must possess an honours degree in chemistry with an average of 60% or

above. The department may recommend that some candidates register and pass some modules selected from the honours program. The MSc study is a research program (100%) and culminates into a dissertation or thesis and at least one submitted publication to an accredited chemistry journal. A student may be admitted into a PhD programme if he possesses an MSc degree with an average of 60% and above for his/her MSc thesis. The department may recommend that the student concurrently register and pass some selected honours module. The PhD study is a research program (100%) and culminates with a dissertation and at least one accepted or published paper and one or two papers submitted to accredited chemistry journals. In addition to meeting the minimum requirements for admission into MSc and PhD programs in chemistry, it is clearly stated in the Department of Chemistry Postgraduate Brochures that the student must:

- a) have a suitable research topic selected in consultation with the Department;
- b) agree to utilise the laboratory facilities at UNISA or have access to a laboratory facility suitable for the research work envisaged; and
- c) select or have access to a suitably qualified supervisor or joint supervisor (with at least a PhD degree qualification) under whose direct guidance the research work can be carried out.

Final admission into masters and doctoral programs depends on passing research proposal module. The research proposal module requires a student to have secured a research topic and concept paper, research advisor (and co supervisor), and a laboratory facility either at UNISA or accredited laboratory facility which has to be approved by UNISA. This requirement is easily met by students who are currently employed in chemical industries and higher institutions of learning. For the other group of students who don't have access to laboratory and analytical facilities, the training may be accomplished on full time basis in the facilities of the

Department of Chemistry at UNISA. Two types of programs exist for postgraduate student training in chemistry within the ODL context, namely, the split-site study models and in-house.

Split-site postgraduate training models

The split-site postgraduate student supervision models are applicable to both national and international students attached to either chemical industry or tertiary institution with entry-level infrastructure for research. The arrangement may be between the academic department and industry or between two academic departments from two different institutions. In both cases, the department and student need to be fully aware of available expertise and their track record in student supervision or publication. In principle, this arrangement requires prospective departments from different institutions to first identify their common goals based on their strengths and weaknesses in terms of human resource and infrastructure capacity. Both participating departments are expected to have adequate infrastructure for research and to complement each other in terms of skills and specialized programs. The following issues have to be agreed upon to launch the program:

- The role of the main supervisor and the co supervisor
- Shared outputs in terms of publications
- Consumables and equipment of the total cost
- Accommodation, subsistence and travel costs of researchers visiting a host institution or country as part of their participation in the project
- Number of exchange visits and duration

The arrangement can be reached with or without memorandum of understanding (MOU) between participating partners.

University-industry model

The inception of postgraduate program in chemistry at UNISA was based on this model between the Department of Chemistry and the Council for the Scientific and Industrial Research (CSIR) as well as the Atomic Energy Corporation (AEC, now NECSA). The model is still been continued with SASOL, CSIR, SAPPI, SA Police Forensic Laboratory, iThemba Labs, *etc.*, for BSc honours, MSc and PhD student training. Issues such as intellectual property, ethical clearance or joint papers are addressed before the start of the project. Under this arrangement, the student is required to identify a prospective co-supervisor in industry for technical guidance and support.

The Department of Chemistry at UNISA, on the other hand, appoints a supervisor and the two advisors work with the student on a concept paper to lead to the design of a feasible research proposal based on literature survey. The student then executes the laboratory work either in industry and/ or in the department under full supervision by the co-supervisor or supervisor. The costs for consumables and for analytical facility are incurred by the industrial partner with no additional payment to the co-supervisor if experimental work is carried on the other side. In some cases, the academic department may provide additional support in terms of access to instrumentation or laboratory space and consumables. Under this arrangement, the academic department is responsible for quality assurance and assessment of the project as well as accreditation of the degree. This model has been found to work well for the South African-based students working in chemical or agrochemical industry as well as the Police Forensic laboratories with adequate laboratory infrastructure and analytical facility. The students are required to present seminars (face-to-face or through Skype, *etc.*) and also submit written reports

to the department periodically as part of progress monitoring, quality assurance and scientific information presentation skill development.

Department-Department model

This model involves a mutual cooperation between UNISA chemistry department and another chemistry department locally or abroad. A prospective student is required to identify a co-supervisor on his/her side and the department appoints an internal supervisor. An agreement is reached between the two participating departments in terms of shared costs and outputs. Under this arrangement, the two departments share co-authorship of publications, eventhough the degree is awarded by UNISA. The costs for consumables and for the co-supervisor, on the other hand, are incurred by the Department of Chemistry at UNISA. The student, on the other hand, is expected to spend some time in both laboratories for hands-on experimentation or for access to appropriate analytical techniques.

This model is also appropriate for academic and technical staffs who are permanently appointed at other institutions locally or abroad with routine and sustainable access to chemistry laboratory infrastructure and entry-level analytical facility. The model is also applicable for our own junior academic and laboratory staff pursuing higher studies in the area/s where we lack capacity. The staff member is encouraged to register the degree with UNISA and to identify a suitable expert elsewhere for possible appointment as the main supervisor. A co-supervisor is then appointed within the department to provide guidance and technical support to the candidate throughout the project. The main supervisor is required to visit UNISA chemistry department for discussions with the student and co-supervisor as agreed upon during the initiation phase. This arrangement should not be confused with external supervision, which sheds all the mentoring

responsibilities to an external expert attached to another university or industry. External supervision would probably work well for disciplines that do not require routine supervision of the students. Progress monitoring and quality assurance are achieved through seminars and written reports to the department.

University–university model

This involves a collaborative action between the Department of Chemistry at UNISA and another chemistry department in South Africa or abroad. The arrangement usually involves memorandum of understanding (MOU) between the two participating institutions. To lead to a mutual cooperation (collaboration) and success of this model for masters and doctoral programs, it is imperative for the cooperating departments to engage first to identify suitable expertise and common goals based on their strengths and weaknesses in terms of capacity before the institutions can enter into any agreement. A memorandum of understanding acceptable to the participating institutions and researchers should then be signed and ratified.

UNISA's experience has shown that a number of intra-governmental attempts to launch split-site postgraduate programs in laboratory-based disciplines such as chemistry were not adequately satisfactory. This is because the MOUs are finalized from the top without the involvement of researchers neglecting crucial points such as the admission criteria, capacity on both sides, *etc.*

The MOU's for the UNISA-Ethiopia and the UNISA-University of Lagos (UNILAG) project, for example, were signed before researchers from participating departments could interact (co-option). A perception was created on the other sites that postgraduate chemistry research can be undertaken through ODL as it is applicable to other non-laboratory based

disciplines. The misunderstanding of ODL by the co-signatories as applied to laboratory-based sciences created an impression that UNISA could train several hundred Ethiopian chemistry postgraduate students to completion with minimum expense and short time. The proposed number of students to be trained far exceeded the total number of chemistry postgraduates produced by the 21 South African universities in the same period.

The admission criteria and the length of degree programs of South African institutions differ from those of other countries. Progression into MSc degree in Ethiopia, for example, requires a 3 year bachelor's degree whereas we expect our students to have a BSc (3 years) and BSc honours (1 year) for possible admission into MSc program. The four year degree of most universities in other African countries, for example, either incorporates a foundation level in the 1st year or a professional program (teaching/education) not related to chemistry in the 4th year. In our view, the logical progression to the launch of such split-site program involving programs of different levels should have involved collaborative action in the well established course offerings of UNISA at BSc honours level. UNISA has a well established and working model of course offering and assessment procedures for both senior undergraduate (BSc honours) and postgraduate training, which could have been extended to other participating institutions. Moreover, Unisa has several learning centres abroad, eg., the centre in Akaki (Ethiopia) to facilitate communication (video conferencing, Skype, *etc.*) and learning.

Individual scientists are the real actors in research alliances, while institutions play a secondary role. In institution-initiated alliances too, individual scientists are the key actors while the institution provides the support required to realise an alliance. Often individual scientists are the initiators of any successful collaborative action, banking on informal contacts and acquaintances. However, when alliances stem from informal contacts, responsibilities are often

unclear; and when commitment is uncertain, collaboration can become stressful. The department-industry model involving postgraduate students employed in chemical industry is the only example of split-site model that has proven to work within the ODL context. This is because the chemical industry is committed towards the costs for the project, laboratory space and analytical facility as well as the provision of the co-supervisor for technical support. Bureaucracy, issues related to ownership of intellectual property and organizational culture on postgraduate student training, on the other hand, have been found to hamper mutual co-operation involving academic department–department or university–university postgraduate student training models. This is also compounded by the lack of commitment by the counter-partners on funds for running costs and provision of adequate infrastructure for research and postgraduate student training.

In-house postgraduate training model

Until recently (2012), only the Departments of Chemistry and Physics had adequate laboratory infrastructure for research and well developed postgraduate programs involving students with access to industrial laboratories. The Department of Higher Education (DoHE) enacted an act in the late 1990s to allow UNISA to offer postgraduate degrees through the contact mode, a monopoly previously enjoyed by the residential or contact institutions. Permission for UNISA to offer in-house postgraduate programs, on the other hand, led to increased influx of young students into the sciences. The merger of former UNISA Faculty of Science and Technikon South Africa to comprise the new comprehensive university offering degree and diploma programs further placed enormous strain on the laboratory infrastructure.

With the goal to become the leading African University in the service of humanity through quality research, UNISA recently erected a completely new Science and Technology campus for research and postgraduate student training at the Florida campus. Moreover, the University Senate approved the request by the Department of Chemistry and related disciplines to focus largely on the training of postgraduate students through the in-house model. The requirement for the in-house model is that the prospective student must be willing to travel to our facility and secure accommodation closest to the university to facilitate routine and sustainable access to the laboratory and library facility. Unlike contact institutions, UNISA has no accommodation facility for students. With adequate infrastructure in place, the question is' *how does UNISA manage to run the in-house postgraduate student training model with success without accommodation facility?*

UNISA has established a strategic project 'Grow Your Own Timber (GYOT) Project' to support the in-house graduate students by offering them temporary employment on fixed-term contract as postgraduate assistants to alleviate the economic burden of the student. The appointed candidates, in turn, are required to render service to the department as tutors, markers or demonstrators for undergraduate practicals as part of skill development. With the generous financial support mechanism in the form of GYOT project in place, the responsibility lies with departments to recruit and admit students into the postgraduate program. It is to be noted that this provision does not cater for all of the graduate students and some students have to source support elsewhere.

The prospective student is assigned a supervisor with proven track record to supervise postgraduate students to completion. Joint- or co-supervision of the student's project is also encouraged as part of skill development and succession plan. Moreover, joint supervision has

also been found to circumvent dropout rates due to supervisor-student relationship or lack of proper support. Depending on the availability of expertise, in some cases the department may appoint an expert from outside the institution to serve as the main or co-supervisor. Technical support to the student will be provided by the host institution. Students are required to present seminars and submit written reports to the department as part of progress monitoring, quality assurance and scientific information presentation skill development. The model has been found to increase the success rate and student throughput. Majority of the in-house trained students are able to complete their studies within the minimum prescribed period of 2 or 3 years for MSc and PhD degrees, respectively.

CONCLUSIONS

Direct contact with students forms an integral part of any experimental training in disciplines such as chemistry. The training, on the other hand, requires routine and sustainable access to adequate laboratory facilities by students. The advent of virtual laboratory programs has created a perception that laboratory-based disciplines such as chemistry could offer postgraduate programs through ODL mode with limited or no access to laboratory or analytical facility.

This view led to the creation of generic admission policy for postgraduate studies with the intent of increasing postgraduate enrolment figures and presumably at a cheaper cost. Adequate research infrastructure (laboratory space and analytical equipment), costs for consumables and analysis (service rendering) and availability of expertise constitute the main factors that determine the admission of students into postgraduate program in chemistry and thus their success.

These requirements for postgraduate student training in chemistry within ODL context are easily fulfilled through the in-house postgraduate student training model or the department-industry collaborative action. The models described herein all emphasize mutual cooperation between the stake holders. Mutual co-operation in research is a working relationship which involves equipment and laboratories as well as human beings. This is because science is no longer a centralised activity located in a single place, but is dispersed far and wide. Moreover, scientific activity is an interaction between scientists and their socio-technological environment.

Processes such as collaboration are part of this interaction, having consequences for the production of knowledge and the scientific wealth of nations. Collaboration, domestic or international, accelerates scientific growth and advancement. Some of the split site models tend to fail to achieve the set goals because of several factors as alluded above and the interpretation of collaboration by various stakeholders. To benefit fully from collaboration, the parties (individuals, institutions or countries) need to reach a certain level of scientific absorptive capacity, including the infrastructure of support, communication and research [4]. They need to have a fair idea about the costs and benefits. Meticulous cost-benefit analysis works in multiple ways; it lends the partners the opportunity to assess the worth of their involvement [5]. Bureaucracy, issues of ownership of intellectual property and different organizational culture on research tend to impede on mutual co-operation involving academic department-department or university-university postgraduate student training model. Collaboration, in essence, is between individuals and not institutions [6].

Understanding the personal components in collaboration is not always easy, however, prior knowledge about the cultural and attitudinal dimensions of academic activity can shed light on the human side of collaboration [7-8]. Despite provision of adequate laboratory infrastructure

and analytical facility, venturing into postgraduate program in experimental disciplines such as chemistry through ODL mode is costly in terms of running costs and funds for human resource component. In our view, the models discussed above may be adapted to fit the needs of the other laboratory-based science disciplines that plan to venture into the business of postgraduate student training within the ODL context.

REFERENCES

1. Trevors, J.T. (2011). Evaluating Science, *Water Air and Soil Pollut.* 219, 1–2.
2. Steyn, A.G.W.; de Villiers, A.P.(2007). Public Funding of Higher Education in South Africa by Means of Formulae. Review of Higher Education in South Africa, http://www.che.ac.za/documents/d000146/5-Review_HE_SA_2007.pdf.
3. Calvert, J. (2006). Achieving Development Goals- Foundations: Open and Distance Learning, Lessons and Issues. <http://pcf4.dec.uwi.edu/overview.php>. (Accessed on 3 May 2010).
4. Olson GM, David PA, Eksteen J, Sonnenwald DH, Uhler PF, Tseng S-F, (2001) International collaborations through the Internet. In: Shrum W, Benson K, Bijker W, Brunnstein K, editors. Past, present and future of research in the information society. New York: Springer; 2007. p. 97–114. http://dx.doi.org/10.1007/978-0-387-47650-6_7.
5. Sonnenwald DH. Scientific collaboration: A synthesis of challenges and strategies. In: Blaise C, editor. Annual review of information science and technology. NJ: Medford; 2007. p. 643–683.
6. Katz JS, Martin BR. What is research collaboration? *Res Pol.* 1997;26(1):1-18. [http://dx.doi.org/10.1016/S0048-7333\(96\)00917-1](http://dx.doi.org/10.1016/S0048-7333(96)00917-1).
7. Fox MF, Faver CA. Independence and cooperation in research: The motivations and costs of collaboration. *J High Educ.* 1984;55(3):347–359. <http://dx.doi.org/10.2307/1981888>.
8. Lee YS. Technology transfer and the research university: A search for boundaries of university-industry collaboration. *Res Pol.* 1996;25(6):843-863. [http://dx.doi.org/10.1016/0048-7333\(95\)00857-8](http://dx.doi.org/10.1016/0048-7333(95)00857-8)

ACKNOWLEDGEMENTS

The authors are grateful to the National research foundation (NRF) and the University of South Africa (UNISA) for financial support.

TO PROFESSIONALS: CHEMICAL SAFETY AND CHEMICAL SECURITY OVERVIEW

Wafaa M. Abdou
Chemical Industries Division, National Research Centre,
Elbohouth St., Dokki, Cairo, Egypt
Email: wabdou@link.net

ABSTRACT

The importance of laboratory safety has been recognized for many years in industry. However, educational and research institutions have been slower to adopt such safety practices and programs. A science program has certain potential dangers. Yet, with careful planning, most dangers can be avoided in an activity-oriented science program. It is essential for all involved in the science instruction program to develop a positive approach to a safe and healthful environment in the laboratory. Safety and the enforcement of safety regulations and laws in the laboratory is the responsibility of both the staff and the employees—each assuming his/her share. Safety and health should be an integral part of the planning, preparation, and implementation of any science program. Security, on the other hand, is a top priority for leading chemical producers' and the governmental authorized people. Responsible care companies should be expert in chemical security and work hard to safeguard the communities. Items discussed in this paper are thus: Why do we worry about chemical safety? fundamentals: personnel protection ; chemical storage: general handling and storage; emergency management; waste management: what are some strategies to reduce the amount and/or toxicity of chemical waste generated in the laboratory; risk government strategy; conclusion. [AJCE 4(3), Special Issue, May 2014]

INTRODUCTION

The importance of laboratory safety has been recognized for many years in industry. However, educational and research institutions have been slower to adopt such safety practices and programs.

Security, on the other hand, is a top priority for leading chemical producers. Responsible care companies should be expert in chemical security and work hard to safeguard the communities. Chemical professionals should collaborate with governments, national and international chemical organizations to raise awareness about chemical security and safety, and to reduce the risk of chemical threats.

The relationship between chemical safety and security

Safety is: The control of exposure to potentially hazardous substances to attain an acceptably low risk of exposure.

Security is: The preventive measures designed to reduce the risk of **intentional** removal (theft) and misuse of a chemical hazard – **intent** to cause harm.

Risk assessment is: The identification of **preventive** measures.

Chemical Safety is the protection against accidents while **Chemical Security** is the protection against deliberate harm.

Many practices are the same for chemical safety and security, but there are a few areas of conflict. The following table (Table 1) shows some conflicts between chemical safety and chemical security:

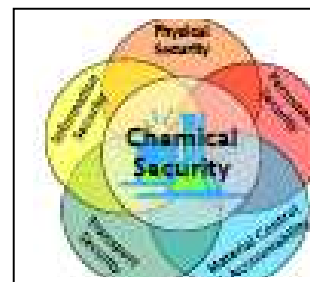


Table 1: Some Types of Conflicts between Chemical Safety and Chemical Security:

Safety	Security
Label everything so people can recognize hazardous chemicals.	Labeling help identified targets for theft or attack.
Let community and especially emergency responders know what chemical dangers are.	Sharing locations of chemicals can publicize targets for theft or attack.
Share knowledge about chemical hazards so people know to be alert.	Sharing knowledge of chemical hazards could inspire harmful behavior.
People need to be able to leave quickly via many routes.	Exits & entrances should be controlled, so, chemicals (or equipments) are not be taken.

Why do we worry about chemical safety?

Chemicals that are used every day in labs and factories can be hazardous. Chemicals can be harmful to the health of the workers. They can be also a threat to the safety of the workers, the community and to the environment. In sequel, safety is the most right thing to do! Anticipation and considering the safety rules in the beginning, is easier, cheaper, safer, and it saves you time.

In the following table (Table 2) some common possible chemical health problem:



Table 2: Some Possible Chemical Health Problem

Chemical	Diseases	Chemicals	Diseases
Vinyl chloride	Liver cancer	Lead	Reprotoxin, birth defects
Asbestos	Mesothelioma	Thalidomide $C_{13}H_{10}N_2O_4$	Reprotoxin, Developmental



			Defects
Carbon tetrachloride	Hepatotoxin	Methanol	Blindness
Mercury	Neurotoxin, CNS, narcosis	CO, CS ₂	Hematopoietic hemoglobin, cyanosis



But disease depends on many factors:

- ❖ Genetics
- ❖ Specific chemical
- ❖ Protection controls
- ❖ Dose & Duration
- ❖ Concentration
- ❖ Life style
- ❖ & Environment



FIRST: LABORATORY CHEMICAL SAFETY

The purpose of achieving the laboratory chemistry program is to establish uniform, safe and efficient practices in the laboratories and to assist in the safety instruction of new laboratory employees. There are general in nature and specific problems should be referred to the Chemical Abuse. It is the policy of the Lab safety is to do all that is reasonable to prevent injury to persons and the damage to property and to protect the employees, facility, patients, the environment, and the public from injury, fire or other damage.

In order to achieve these goals, the administration urges the active cooperation and commitment of all departments and employees. Ongoing dialogue and feedback are encouraged by labs' management, and they should support safety program in its promotion of employee. However, the attitude of the employee is the key to employees and environmental safety. If

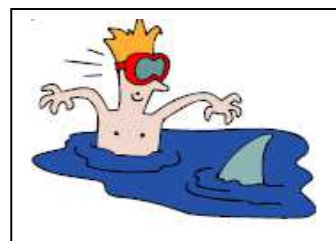
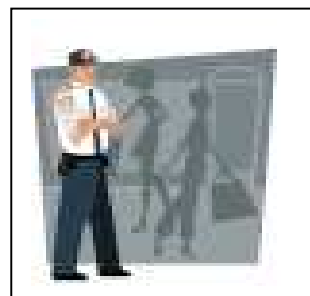
he/she is interested and willing to follow the simple safety rules outlined in this manual, there will be little chance of injury or damage from material being handled in the laboratory.

I. Fundamentals:

Personnel Responsibilities Rules For Safe Practice

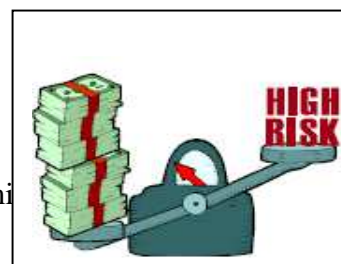
A. Laboratory Staff

- Lab staff is expected to obey safety rules.
- To report all unsafe conditions.
- Each person working with or around chemicals, having been properly trained and is responsible for remaining aware of the hazards associated with these chemicals and handling them in a safe manner.
- If there is any doubt as to the specific hazards/ material to the proper method of handling, the employee is expected to ask his supervisor for the appropriate information.
- Assess the risk by determining the likelihood and consequences to allow for strategic decisions on control measures.
- Ideally we consider elimination or substitution **first**, to remove the hazard.
- A combination of measures might be used based on their effectiveness and our ability to use them and maintain them.
- Cost versus performance (risk reduction) is important.
- E.g. a) Describe the work activities: Snorkeling; b) Identify



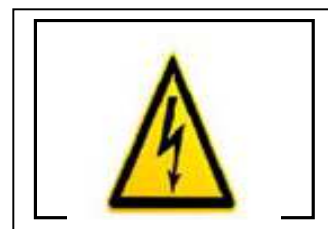
the hazards: shark; c) Determine Risks: shark bites and/or drowning.

- The same for chemicals: a) Describe Work Activities: mixing reactive chemicals; b) Identify Hazards: reactive/ incompatible chemicals; c) Determine Risks: explosions and/or fire.



B. For All:

- ❖ Do not eat, drink, or smoke or in the lab.
- ❖ Do not bring food into the laboratory.
- ❖ Mouth pipetting is forbidden.
- ❖ Wear a full-length, long-sleeved laboratory coat or chemical-resistant apron.
- ❖ Wear shoes that adequately cover the whole foot; low-heeled shoes with non-slip soles are preferable. Do not wear sandals, open-toed shoes, open-backed shoes, or high-heeled shoes in the laboratory.
- ❖ Appropriate gloves are recommended when handling any chemicals. Be sure that gloves are resistant to the particular material being handled.
- ❖ When it is not practical to wear gloves, extra care should be taken to avoid exposure.
- ❖ On leaving the lab remove your coat and wash your hands.
- ❖ Cover all cuts, abrasions, open sores and bruises with waterproof tape.
- ❖ Read all labels and warning signs.
- ❖ Be acquainted with local procedures in case of fire, or accidents;
- ❖ Clean up all spills and leakages immediately.
- ❖ Eye protection must be worn when handling materials that may splash.



Employees who wear contact lenses should be aware that fumes from concentrated acids and solvents can cause eye irritation and damage to lenses. Should eye irritation occur, remove lenses immediately and rinse eyes with clean water.



- ❖ Make Hair tied back, if shoulder length or longer.
- ❖ Keep the work area tidy and free of unnecessary equipment and materials.
- ❖ Shoes with open toe or open heel are prohibited in all areas.
- ❖ Low heeled, rubber soled shoes constructed of solid material are required.
- ❖ Do only the authorized work; no horseplay should take place in the laboratory.



C. General Safety Rules:

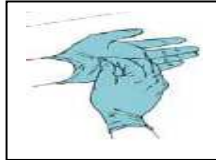
- **Fire Regulations & Extinguishers should be trained and practiced & rechecked regularly.**
- Specify required training.
- Laboratory hoods/its ventilation are the basis of engineering controls.
- Label all chemical containers.
- Never someone work alone, especially after hours.
- Specify when eye protection & PPE is required.
- Specify operations that require hood use.
- Alarm system is well recognized and followed.
- Report all injuries, spills, and other releases of hazardous materials to the Safety Team.



D. Personal Protective Equipments (PPE):

PPE includes:

- Eye protection (Goggles),
- Gloves,
- Laboratory coats... etc.,
- Respirators,
- Appropriate foot protection

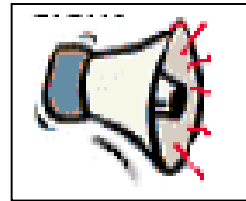


E. Lighting & Noise Levels

Sufficient Lighting: is essential for each working area.

Elevated noise levels: can be a problem:

- ❖ Potential Hazards,
- ❖ Examples: bone-cutting saws,
- ❖ Mechanical water aspirators, pumps.
- ❖ Control Measures.
- ❖ Inspections, PPE, warning.
- ❖ Labels, training.




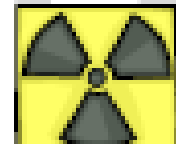






II. STORAGE

A) RECOGNITION

i. Chemicals/Lables



	<i>Flammable</i>		<i>Corrosive</i>
	<i>Poison</i>		<i>Radioactive</i>
	<i>Explosive</i>		<i>Compressed Gas</i>
	<i>Special Substances</i>		<i>Biohazards</i>



ii. Chemical Storage: Cryogenics

- ❖ Store cryogenics (liquid nitrogen & dry ice) separately from other chemicals & in well ventilated areas.
- ❖ Use proper PPE (including eye protection) when handling & moving cryogenics.
- ❖ Do not use cryogenics in closed areas.



Exploding liquid nitrogen cylinder ruins lab.

III. EMERGENCY MANAGEMENT

The staff, employee, and workers should consider the informal and formal guidelines, and the requirements. Terrorism and vandalism represent a significant risk to all facilities that use or store hazardous chemicals. It is important to recognize vulnerabilities of your facility and do

Common Safety Symbols and warnings whatever is necessary to reduce or eliminate risk.



A. GENERAL ASPECTS

Emergency Planning and Response is Based on Four Principles:



1. Anticipation: **It means the emergency planning and the response.**
2. Recognition
3. Evaluation
4. Control



Examples for applying these principles:

- ❖ If people are expected to use extinguishers, they must be trained.
- ❖ Clearly post each room with emergency phone numbers.
- ❖ And after hours phone numbers/ person(s) to be contacted.
- ❖ Centrally locate safety showers and eyewashes. And teach employees to properly use the Safety Shower.
- ❖ Centrally locate spill clean-up kits.
- ❖ Clean up spill: only if you know the chemical hazards have appropriate equipment and are trained to do so!



Location	
Hazardous Material	
Primary Contact	
Second Contact	
Emergency Material Safety	
Department Head	
Fire/Police/ Ambulance	911
Center Health & Safety	
Location & Inventory	



IV. WASTE MANAGEMENT

Wastes must be regulated & heavily minimized:
(Incineration: “is a waste treatment process”)



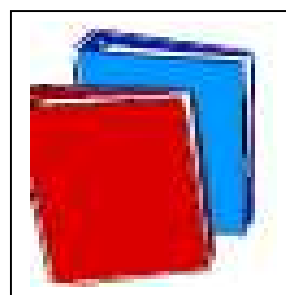
General guidelines: a) Nonhazardous waste:

- ❖ Lab wastes are packaged in small containers.
- ❖ Used oil (uncontaminated) is not considered hazardous waste Label Containers "USED OIL (not hazardous waste).
- ❖ Uncontaminated PPE (gloves, wipes).
- ❖ Triply rinsed glassware (bottles, droppers, pipettes).
- ❖ Secure and lock waste storage area.



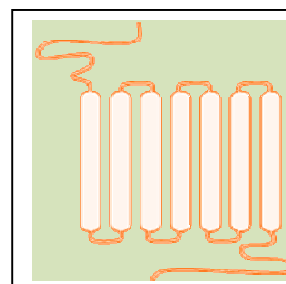
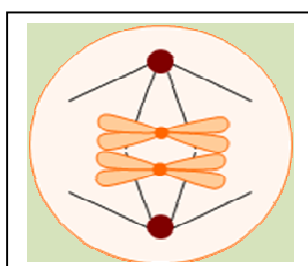
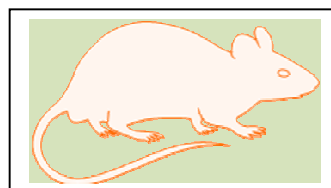
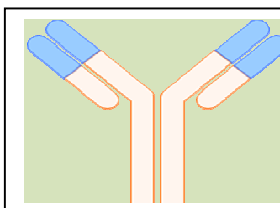
b) For Metal's Waste

- Certain metals cause disposal problems
- When mixed with flammable liquids or other organic liquids.
- Pressure can build up in a waste vessel.
- Corrosion can occur in storage vessel.
- *Secondary containment is necessary*
- *Glass waste containers can break*



c) Medical wastes & Biological Wastes:

- Blood and tissue.
- Sharps –needles, scalpels.
- Contaminated glassware, PPE.
- Autoclave or sterilize wastes.
- Each employee should attempt to minimize wastes generated.
- Do not spill liquids.



➤ **Waste Mercury (Hg) Needs Special Treatment:**

- Collect pure liquid mercury in a sealable container
- Label as "MERCURY for Reclamation".
- Place broken thermometers and mercury debris in a sturdy sealable plastic bag, plastic or glass jar.



- Label the container "Hazardous Waste - Hg SPILL“.
- Never use a regular vacuum to clean up.
- Mercury spill -contaminates vacuum, heat evaporates Hg.
- Never use a broom to clean up mercury –
- Spreads smaller beads-contaminates the broom.

DARMOOUTH COLLEGE: Dimethyl-Mercury Poisoning

One of the most tragedy accidents:

Karen Wetterhahn, professor and founding director of Dartmouth's Toxic Metals Research Program & expert in the mechanisms of metal toxicity. In 1996, she spilled a few drops of dimethylmercury on her gloved hand. She cleaned up spill Hg immediately, believing that the Latex glove is protective.

Six months later, she became ill, and died of acute Hg poisoning at age 48 years. The investigation by **Occupational Safety and Health Administration (OSHA)** revealed that there was another case from Dartmouth/a researcher died from dimethylmercury poisoning in this century. **OSHA** has proposed fining Dartmouth \$13,500 for: allegedly not providing enough training to employees, limitations of protective gloves were not considered, and there was inappropriate and for having deficiencies in the laboratory's chemical hygiene plan.



Environmental Hazards:

California State University, Northridge: Earthquake:

On January 17, 1994 – 4:31 am, an earthquake of Magnitude 6.7 surprised Epicenter, located a few km from California State University, Northridge campus. 57 death, and 11000 injuries were the victims of the earthquake. Several fires in science buildings allowed to burn because firemen worried about chemical hazards. It was a big problem as **Professors and students lost equipment, notes, materials, samples.**





Another Big World Chemical Disaster was Bhopal: Pesticide Plant

Chemical Release



On 1984, Union Carbide plant making Sevin released ~ 40 tonnes of methyl isocyanate in the middle of the night. Low local demand for pesticides meant the plant was only partially running. Some hardware was broken or turned off, including 12 safety equipment – Safety measures and equipment were far below normal standards.



The problem was being the **Plant** was in heavily populated area. For more information about The Bhopal disaster and its consequences: a review, Environ. Health: A Global Access.



DELIBRATE HARM

Tokyo, Japan: Hydrogen cyanide attack

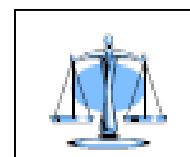
On purpose, a Sarin attack on Judges in Matsumoto, June 1994 was operated. The Sarin sprayed Hydrogen Cyanide from a truck at night: 7 deaths, 144 injuries.



SECOND: SECURITY

Security is a top priority for leading chemical producers. Responsible care companies should be expert in chemical security and work hard to safeguard the communities. Chemical professionals should collaborate with governments, national and international chemical organizations to raise awareness about chemical.

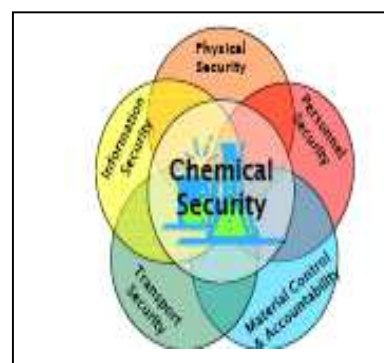
Government Regulations: Rules and Laws are different from country to country. E.g. a) the legislation needed to fulfill requirements under the chemical; b) Weapons Convention–Each country passes appropriate laws; c) Each country must declare and track certain chemicals.



Chemical Security Assessment

Characterize chemicals and threats:

- Evaluate chemical compounds at a facility (Asset Assessment);
- Evaluate adversaries who attempt to steal those chemicals or equipment (Threat Assessment).



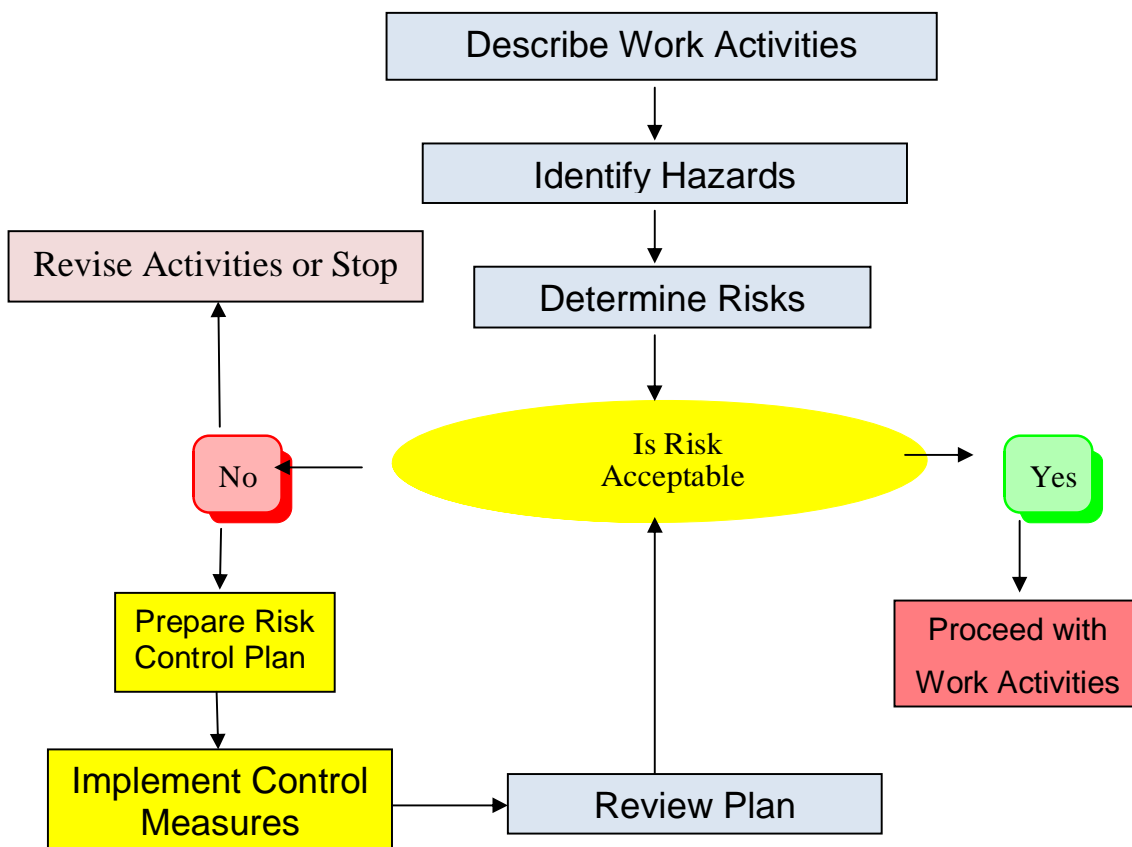
2. Characterize the facility

- a) Evaluate the likelihood the facility will be targeted;
- b) Evaluate the likelihood of a “Risk” or an **Event** that has consequences.

3. Characterize the risk:

On facing an accident or a disaster, we should determine what is acceptable and what is unacceptable risks; develop risk statement; assess the risk by determining likelihood and consequence to allow for strategic decisions on control measures; ideally we consider elimination or substitution first, to remove the hazard. A combination of measures might be used based on their effectiveness and our ability to use them and maintain them. *Cost versus performance (risk reduction).*

RISK GOVERNMENT STRATEGY



CONCLUSIONS

Generally, it is a chain of commands to handle specific safety/secure responsibilities within the facility. Chem. Security, in conjunction with Labs Safety Team individual science teachers, holds responsibility for developing and maintaining a safe working environment for lab workers. Finally, security, the staff & employees are one team, responsible for Secure/Safe Lab.

And finally, together we can design, build, and operate safe/secure laboratories!

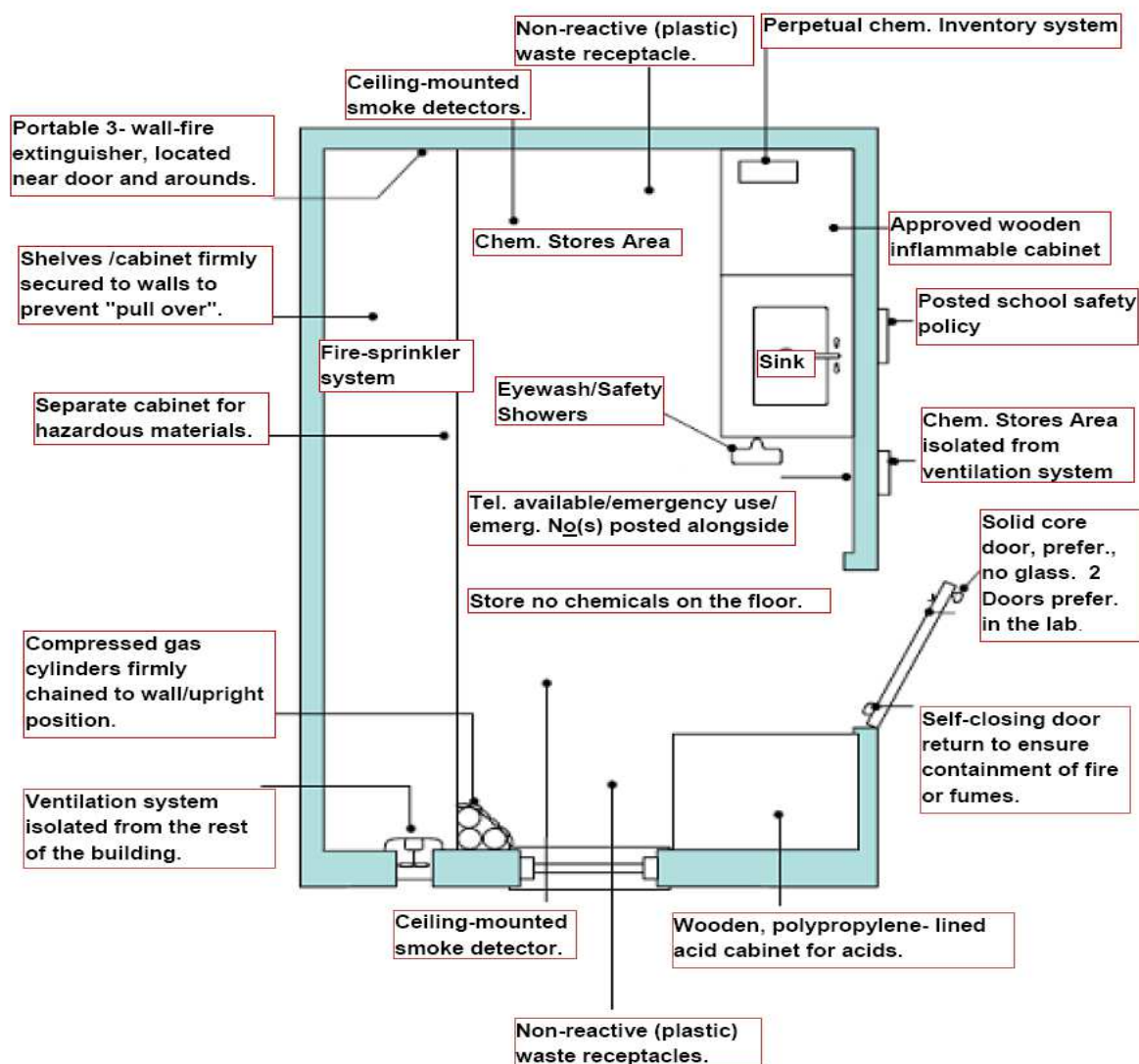


Appendices

1. Figure is a model for the Lab.
2. Questionnaire to help in the Inventory, Chemical Safety, Chemical Security Issues and the Assessment Questionnaire Laboratory Safety and Security.

1. Is your laboratory a safe/secure place to work?

The following Figure is a model for the Lab:



The following form has been devised as a Questionnaire to help in the Inventory, Chemical Safety, Chemical Security Issues and the Assessment Questionnaire Laboratory Safety and Security. This questionnaire is intended to orient the assessor to the nature of hazardous chemical use and control in laboratories at the facility.

1. Who at the facility is responsible for development, implementation, and administration of programs for compliance with applicable governmental and company requirements for each of the following lab chemical safety and security issues:
 - 1.1. Setting criteria to determine and implement control measures for exposure reduction in laboratories?

1.2. Developing experimental protocols and proposing control measures to reduce potential employee exposures?

1.3 Employee exposure determination/monitoring?

1.3. Identification of select carcinogens, reproductive toxins, and acutely toxic chemicals, and maintenance of a chemical inventory?

1.5 Limited access policy, including procedures, training and awareness?

1.6. Ventilation system maintenance?

1.7. Laboratory containment and safety equipment?

1.8. Personal protective equipment?

1.9. Training?

1.10. Hazardous waste?

1.11. Medical surveillance?

1.12. Emergency response?

2. List the names of laboratory heads/managers and principal investigators, and the names of lab technicians who have safety and security responsibilities. Also indicate who at the facility is designated the Chemical Safety & Security Officer.

3. Are there job descriptions specifying responsibilities, authorities, accountabilities, and measures of performance for each person identified in 1 and 2 above?	Yes	No	N/A
	_____	_____	_____

4. Are the people identified in 1 and/or 2 above responsible for keeping up-to-date with regulations/guidelines in their respective areas?	_____	_____	_____
--	-------	-------	-------

5. Does the facility have a lab safety & security committee?	_____	_____	_____
--	-------	-------	-------

5.1 List the members' names and credentials below:

Member	Credentials
_____	_____

5.2 How often does the committee meet? _____

5.3 What does the committee usually discuss? _____

6. Briefly describe the major function(s) of the laboratories at the facility and characterize operations, protocols, assays, etc. by function. _____

7. List the types of containment and safety equipment used at the facility (e.g., chemical laboratory hoods, biological safety cabinets, safety showers, eye wash stations, etc.).

	Yes	No	N/A
8. Are there any areas designated especially for work with particularly hazardous substances?	_____	_____	_____

Locations and operations: _____

	Yes	No	N/A
9. Does the facility have a lab safety & security manual and/or Chemical Safety & Security plan?	_____	_____	_____

9.1 Who writes and updates this document?

9.2 How often are updates provided?

10. Does the facility have any of its own specific policies, procedures, standards or guidelines pertaining to:

	Yes	No	N/A
10.1 Evaluating chemical hazards?	_____	_____	_____
10.2 Employee exposure duration?	_____	_____	_____
10.3 Labeling hazardous chemicals?	_____	_____	_____
10.4 Receipt, distribution, storage and inventory of hazardous chemicals?	_____	_____	_____
10.5 Maintenance of (M)SDSs?	_____	_____	_____
10.6 General rules for handling hazardous chemicals in the lab?	_____	_____	_____
10.7 Housekeeping?	_____	_____	_____
10.8 Transportation of hazardous chemicals and wastes?	_____	_____	_____
10.9 Limited access policy?	_____	_____	_____
10.10 Installation, certification, testing and maintenance of ventilation systems and laboratory containment and safety equipment?	_____	_____	_____

10.11	Decontamination of equipment, wastes and/or emergency response?	_____	_____	_____
10.12	Personal protective equipment?	_____	_____	_____
10.13	Hazcom training for non-laboratory personnel?	_____	_____	_____
10.14	Lab safety and security training for laboratory personnel?	_____	_____	_____
10.15	Training for hazardous chemical emergencies?	_____	_____	_____
10.16	Emergency response?	_____	_____	_____
10.17	Medical surveillance?	_____	_____	_____
10.18	Injury, illness and accident recordkeeping?	_____	_____	_____
10.19	Internal lab safety and security inspections?	_____	_____	_____

		Yes	No	N/A
10.20	Other?	_____	_____	_____

For each of the topics above, indicate whether SOPs or other written documents have been prepared.

11.	Does the facility have an emergency response plan?	_____	_____	_____
11.1	Does the plan address accidental releases of hazardous chemicals to the environment?	_____	_____	_____
11.2.	Does the plan address community response?	_____	_____	_____
11.3	Does the plan address achieving awareness with local authorities?	_____	_____	_____
11.4	Does the plan address programs for achieving community awareness?	_____	_____	_____

12.	Does the facility conduct routine inspections audits/reviews of its operations to ensure compliance with applicable rules and regulations, and policies and procedures?	Yes	No	N/A
12.1	Who conducts these reviews?	_____	_____	_____

13. Does the facility maintain files for documents relating to:

		Yes	No	N/A
13.1	Activities of the lab safety and security committee?	_____	_____	_____
13.2	Standard operating procedures (indicate topics) and experimental protocols?	_____	_____	_____

13.3	Receipt, distribution, storage and inventory of hazardous chemicals?	_____	_____	_____
13.4	Transportation of hazardous chemicals and wastes?		_____	_____
13.5	Installation, certification, testing and maintenance of ventilation systems and laboratory containment and safety equipment?	_____	_____	_____
		Yes	No	N/A
13.6	Use and maintenance of personal protective equipment?	_____	_____	_____
13.7	Hazcom training for non-laboratory personnel?		_____	_____
13.8	Lab safety and security training for laboratory personnel?	_____	_____	_____
13.9	Emergency plans?	_____	_____	_____
13.10	Pre-employment physicals and screening?	_____	_____	_____
13.11	Employee exposure mentoring?		_____	_____
13.12	Injury, illness, and accident reports?	_____	_____	_____
13.13	Internal safety/security inspections?	_____	_____	_____
13.14	Insurer reviews?	_____	_____	_____
13.15	OSHA inspections?	_____	_____	_____
14.	Is the facility currently under a consent order, compliance schedule, etc., to comply with regulatory program requirements?		_____	_____
14.1	If yes, who is responsible for ensuring compliance with this order or schedule?			_____
15.	Is training provided to facility personnel in the following categories?		_____	_____
		Yes	No	N/A
15.1	Facility lab health and safety rules including methods to detect presence or release of hazardous chemicals?		_____	_____
15.2	Hazard communication content of CSSP, including physical and health hazards of chemicals in the work area?		_____	_____
15.3	Proper use of laboratory containment and safety equipment?	_____	_____	_____
15.4	Proper use of personal protective equipment?	_____	_____	_____
15.5	Emergencies?	_____	_____	_____
16.	Who receives training in these topics?			
	Name(s) of interviewee(s): _____			

Chemical Safety and Security Officer Training

Useful Websites

Chemical Security Engagement Program: <https://chemsecurity.sandia.gov/>

Chemical Safety

“Prudent Practices in the Laboratory: Handling and Disposal of Chemicals,” and “Promoting Chemical Laboratory Safety and Security in Developing Countries,” National Academies Press, 2010: [*English-French-Arabic-Indonesian translations*]:

<http://dels.nas.edu/global/bcst/Chemical-Management>

“Safety in Academic Laboratories, Vol.1 & 2,” and “Less is Better,” American Chemical Society, Washington DC, 2003.

Chemical Security

Organization for the prohibition of chemical weapons (OPCW): <https://www.opcw.org/>

CWC Implementation Assistance Program: <http://iap.cwc.gov/>

Australia Group: <http://www.australiagroup.net/en/index.html>

UN Security Council Resolution 1540: <http://www.un.org/sc/1540/>

“Raising Awareness: Multiple Uses of Chemicals and the Chemical Weapons Convention”, IUPAC Project 2005-029-1-050: <http://multiple.kevs.ca/>

“Terrorism and the Chemical Infrastructure: Protecting People and Reducing Vulnerabilities”, National Academy Press, 2006, available online:

http://www.nap.edu/catalog.php?record_id=11597

“Toxic Chemical Agent Safety Standards”, US Department of the Army Pamphlet 385–61, 2002, available online at:

http://www.army.mil/usapa/epubs/385_Series_Collection_1.html

Pesticides

“Programmes: International Code of Conduct on the Distribution and Use of Pesticides”, Food and Agriculture Organization of the United Nations.

<http://www.fao.org/DOCREP/005/Y4544E/y4544e00.htm>

“The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification, 2004”, updated June 2006:

http://www.who.int/ipcs/publications/pesticides_hazard_rev_3.pdf

“Organochlorine waste management”, Roger Papp, Pure & Appl. Chem., Vol. 68, No. 9, pp. 1801 -1 808, 1996:

<http://old.iupac.org/publications/pac/1996/pdf/6809x1801.pdf>

Chemical Waste

“Training Resource Pack for hazardous waste management in developing economies”, Prepared by David Wilson, Fritz Balkau and Maggie Thurgood for International Solid Waste Association, United Nations Environment Programme, Division of Technology, Industry and Economics. UNITED NATIONS PUBLICATION ,ISBN: 92-807-2235-2, 2002.

<http://www.unep.fr/shared/publications/cdrom/3128/menu.htm>

“Chemical waste management resources for laboratories”, Natural Sciences Research Institute, University of Philippines, Diliman, Quezon City. Includes chemical safety guidelines and on-site treatment.

<http://www.nsri.upd.edu.ph/CWM/>

MEASURING THE EFFECTS OF CLASS SCHEDULING ON STUDENT SUCCESS IN SECODARY SCHOOL CHEMISTRY USING CONTENT-BASED VERSUS LOGICAL THINKING-BASED ONLINE COMMERCIAL PROGRAMS

Robyn Ford^{*}, Anna George^{**}, Cathy Molina^{*}, and Diana Mason^{*}

^{*}Department of Chemistry, University of North Texas, Denton, Texas, USA, 76203

^{**}Department of Chemistry and Biochemistry, University of Wisconsin-La Crosse, La Crosse, Wisconsin, USA 54601

Corresponding author e-mail: drdiana@alumni.utexas.net

ABSTRACT

The guiding question of every educational decision is supposed to be “What is best for the student?” Many secondary schools have experimented with a variety of class scheduling patterns in an effort to maximize teacher expertise as well as student time and access to courses mostly relying on anecdotal data to support decisions. Schools entering the 21st century often turned to the use of technology as a method to ensure student achievement. This study evaluated the effectiveness of two commercially available online programs. An online chemistry content-drill program, Study Island©, and a Web-based program aiming to improve logical-thinking skills, Lumosity™, were considered in this research. These Information and Communication Technology (ICT) programs were evaluated based on pre- and post-test scores of 74 pre-Advance Placement (pre-AP) chemistry students on the American Chemical Society's California Chemistry Diagnostic Exam (CA Dx). Also, reported are the results of the effect of class scheduling versus student achievement on the CA Dx exam after experiencing these brain-training programs. [AJCE 4(3), Special Issue, May 2014]

INTRODUCTION

Learning is a continuous process that is built upon prior knowledge and results in an increased understanding of the subject in question. Instruction in chemistry usually stresses the importance of linking prior knowledge with new information learned in a classroom [1]. According to Edelson [2], knowledge is not transmitted to others equally; results vary depending upon the learner's prior knowledge and experiences, and desired "rich knowledge" is not constructed instantaneously rather it is created in incremental steps where understanding is gained. There are numerous commercial training interventions claiming to improve general mental capacity and there is a "widely held belief that commercially available computerized brain-training programs improve general cognitive function in the wider population" but the lack of empirical support for these claims is sparse [3-4].

The one-on-one direct learning mode of a computer incorporates the three basic learning styles (visual, auditory and tactile) with auditory and visualization outputs and physical manipulations together in a single educational event. According to a study published by Schoenfeld-Tacher, McConnell, and Graham, students tend to be more apt to be on-task and consequently have a greater chance of success when experiencing online instruction as compared to the traditional classroom presentation [5]. Since Web-based instruction has advanced to the point that asynchronous learning (even within the timeframe of a single class period) is easily accessible, it is now time to evaluate the most effective use of typical online lecture material and complementary support material along with how it is delivered to students.

This study was designed to compare the effects of different types of online practice (either logical thinking skills or supplemental content drill and practice) on student achievement completed by pre-Advance Placement (pre-AP) chemistry students whose classes met on similar

and different schedules. Academic gains were measured by evaluating the changes in student scores on the American Chemical Society's California Diagnostic Exam (CA Dx) Form 1997.

Tools for Information and Communication Technologies (ICT)

Cooper presented the following observations about doing homework: positive effects include content retention, better comprehension of concepts, extended problem-solving practice with improved training of habits, bettered attitudes dealing with self-discipline, and improved curiosity and independence; negative effects include perceived fatigue and pressure, identified confusion, increased cheating, and potential loss of interest [6]. Difficulties implementing ICT in the classroom also include mechanical issues [7] as well as lack of congruence with teachers' instructional practices and philosophies [8].

Success may depend on how instructors perceive the use of ICT before they begin implementation, because most teachers require proof of student success before they implement a new pedagogy in their classrooms. Similar observations as noted above about doing homework can also be made of using ICT in the classroom. Online learning in and of itself creates an environment where students are required to be participating in an interactive environment. Being on-task translates to being engaged with the subject matter that encourages increased time-on-task. Instantaneous feedback respects where the student is and where the instructor wishes to take them on an individual basis, but as always, what is learned is up to the one that partakes [9].

Online intervention via some sort of "brain training" is one way to meet the needs of students on an individual basis. Immediate feedback dominates why ICT are so advantageous to students' understanding and have been proven to show great promise. The employment of tools supporting ICT when used appropriately also allow the instructor more time to work on the areas

of critical need during the class. Numerous studies have shown that immediate feedback boosts the confidence of students [9]. Epstein, Epstein and Brosvic [10] demonstrated that immediate feedback on academic testing increased retention and confidence levels of students. Also from other studies, lower-achieving students tended to be more apt to stay in classes, as opposed to dropping or withdrawing, if they have the added support of online homework [11-12].

Brain Training

Providing evidence for the effectiveness of cognitive (often called “brain”) training is a current research area in need of empirical support. Cognitive training can be effective and long lasting. However, there are limiting factors that must be considered when evaluating the effects of this training, including individual differences in training performance and the effect of external variables such as of the frequency and duration of contact [4].

In this study, two commercial online systems were compared to evaluate of what type of brain-training, logical thinking or content skill building, is better for improving student achievement. The online brain-training programs used in this study were Study Island© (studyisland.com) and Lumosity™ (lumosity.com) (Fig. 1). Study Island© was chosen to enhance students' content knowledge and Lumosity™ was chosen to contribute to improving students' logical-thinking ability both attributes considered to be important to student success in the study of chemistry.

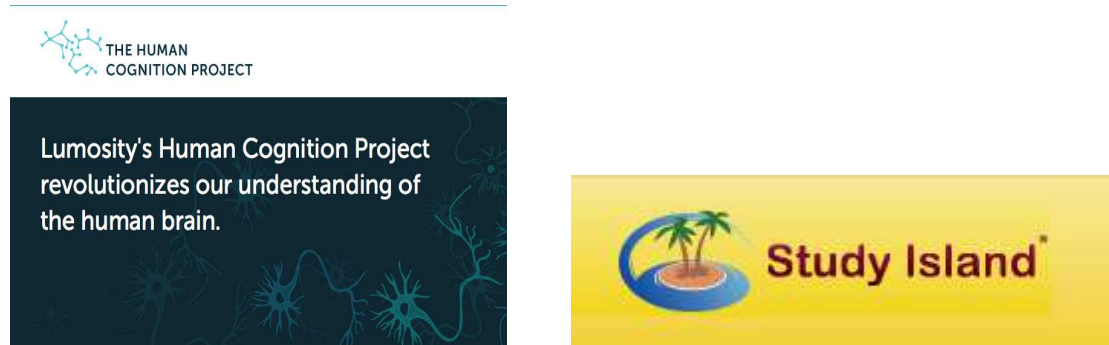


Figure 1. Logos for brain-training programs used in this study Lumosity™ and Study Island©.

Overview of Setting and Sample Population

The societal changes of the 1960s in the United States brought radical changes to the educational system and many felt that emphasizing schoolwork outside of the school day actually neglected other areas of personal fulfillment [6]. By 1980, technology had begun to advance rapidly and the public saw a need for greater educational standards and favored teachers assigning homework [13]. Online homework is known to increase overall student success by at least a letter grade when student master their assignments at the 90% or higher level [14].

In this study, the brain-training programs (logos seen in Fig. 1) were used to enhance student achievement at a high school in north central Texas (Fig. 2). Denton, Texas (population of 1.24 million) is home to two universities (Texas Woman's University and the University of North Texas) and three schools for students attending grades 9-12. The students chosen for this study attended one of the local secondary schools with a population of around 2,000. Forty-two percent of the students were White, non-Hispanic. The largest ethnic group was that of Hispanic students composing approximately 37% of the total population. The remaining ethnic groups were 12% African American, 8% Asian, and 1% classified as other (which includes Native Americans and blended ethnicities). Almost half of the students (42%) received free and/or

reduced cost meals on campus. This percentage is an indicator of the portion of students from low-income families. The participants chosen for this study were enrolled in pre-advanced placement (pre-AP) chemistry classes in grades 9-11 and were of ages 14-16 years. For the treatment intervention, the pre-AP chemistry students completed 45-minutes per week of class time (no time outside of class) of online brain training from the two chosen online programs: Study Island© or Lumosity™.



Figure 2. Location of Denton, Texas, USA.

METHODOLOGY

High school educators have several situations to balance as they plan instruction for their students. Traditionally, high school classes are scheduled to meet five days a week for 55 minutes. Some schools opt to use block scheduling to mimic a more typical class schedule encountered in college, where classes do not typically meet daily. In a block schedule, students meet for specific classes every other day for 90 minutes. Class schedules and assignment of each student are imposed by school administration (see Table 1). Data for this study were gathered over the 2011-2012 academic school year for the 74 students evaluated.

Table 1. Study Group Descriptions (n = 74)

Groups	Class Schedule	Brain-Training Event	Number Students	Gender
D55L	55 Minute Block Meets Every Day	Logical-thinking Skills	27	52% female
A90L	90 Minute Block Meets Every Other Day	Logical-thinking Skills	26	42% female
A90C	90 Minute Block Meets Every Other Day	Content Skill Building	21	67% female

Abbreviations for Groups: D = daily; A = alternating days; L = logical skill; C = content skill

Research Questions

Student achievement in this study was measured by success on the American Chemical Society Division of Chemical Education's California Diagnostic Exam (1997) (CA Dx) that has a national mean (SD) of 20.45 (7.56). Students were given the CA Dx exam as a pre/post assessment at the beginning and end of the study.

1. What are the differences in student achievement on the California Diagnostic Exam when students meet every day and used Lumosity™ or every other day and used Lumosity™?
2. What are the differences in student achievement on the California Diagnostic Exam when students have similar schedules meeting every other day and experience different brain-training programs of Study Island© or Lumosity™?
3. What are the differences in student achievement on the California Diagnostic Exam independent of the class scheduled meeting times when students used either Study Island© or Lumosity™?

Instrumentation: Study Island©, Lumosity™ and California Diagnostic Exam

While classroom teachers are not able to dictate the schedule chosen for a school, they do have the option of determining the type of instructional tools that can be used in the classroom.

Chemistry is a course that requires students to develop logical-thinking and reasoning skills as they learn about chemical principles. Therefore, it would stand to reason that practice problems designed to help students develop their logical-thinking skills would also help them to be successful in learning chemistry. As previously discussed there are online programs designed with the emphasis on chemistry concepts as well as programs with an emphasis on logical-thinking skills appropriate for students in grades 9-12.

Attending to academic tasks is one of the most important aspects of learning according to the Unified Learning Model (ULM) of Shell et al. [13]. Lumosity™ is part of the Human Cognition Project. Researchers from Lumos Labs published the first-ever study demonstrating that normal, healthy adults could use online cognitive training to enhance memory and attention [15]. According to data published in the *Mensa Research Journal*, participants who trained 20 minutes a day for 5 weeks saw an approximate 10% improvement in working memory and approximately 20% improvement in visual attention. The control participants who did not train did not improve [15].

Study Island© is an online program intended for use in USA secondary classrooms. "Study Island is a leading academic software provider of standards-based assessment, instruction, and test preparation e-learning programs." [16]. Study Island© presents interactive lessons that are personalized for each student guiding them through the intended curriculum (in this case for first-year chemistry at the secondary school level) at their own pace. The training content is intended to prepare students for the end-of-course exam in chemistry.

The California Diagnostic Exam (CA Dx) is a 44-question multiple-choice exam designed to evaluate chemistry content knowledge. The CA Dx was administered to each of the participating sections on two separate occasions. The test was administered prior to completion

of any online practice to evaluate the amount of prior content knowledge of the students. The second administration of the test was given at the end of the term to evaluate any changed in student content knowledge.

RESULTS AND DISCUSSION

Data Analysis

The scores for the CA Dx were recorded as the number of correct responses out of 44 questions for each student on both the pretest and the repeated posttest. The mean pre- and post-test scores for each group are compiled onto Table 2. The following groups were evaluated to determine if statistically significant differences were present at the .05 level: same program with different schedules, same schedules with different programs, and comparison of the two programs overall. Levene's test for homogeneity of variance was used to evaluate the difference in variances of scores between groups and the independent samples student *t*-test used to compare the mean score of each group. The Levene's test and independent samples student *t*-test should not produce statistically significant results on the pretest because all students participating in the study are from the same population. The posttest values for these tests should be statistically different for comparisons in which the treatment has had an impact on student performance.

Table 2. Raw Score Data for Pre/Post California Diagnostic Exam Results (n =74)

Brain-Training Treatment Groups*	Pre-Test Mean (SD)	Post-Test Mean (SD)	Change in Raw Score
D55L: Logical Thinking Meets Every Day	15.19 (5.70)	23.52 (7.11)	8.33
A90L: Logical Thinking Meets Every Other Day	14.08 (4.19)	17.15 (7.21)	3.07
A90C: Content Drill Meets Every Other Day	12.90 (5.38)	18.42 (5.09)	5.52

*Abbreviations for Groups: D = daily; A = alternating days; L = logical skill; C = content skill

Same Program and Different Schedules

Student performance on the pre- and post-tests was compared for students who completed the brain-training program highlighting skills emphasizing logical thinking (Lumosity™) on different schedules. For this intervention students enrolled in sections that met for different lengths of time and frequencies were evaluated. Data from Table 2 indicate that the students who were in the class that met every day and received the logical-thinking treatment outperformed the other student group that attended class every other day and used the same program. This may indicate that students who received frequent, smaller increments of instruction have an advantage over instruction that is less frequent. On the average both groups improved on the posttest with the daily group exhibiting a larger increase: student improvement by approximately 8 questions for group D55L and by approximately 3 questions for group A90L. The difference in student performance for these groups was evaluated with Levene's test of homogeneity of variance and independent samples student *t*-test at the .05 level. These results are reported in Table 3.

Table 3. Independent Samples *t*-Tests Comparing Groups who used the Same Program under Different Schedules (n = 74)

D55L vs. A90L*	Levene's Test of Homogeneity		<i>t</i> -Test for Equality of Means
	F	Sig.	Sig. (Two-tailed)
Pretest	1.596	0.212	0.425
Posttest	0.087	0.770	0.002

*D55L = Meets daily for 55 min. and used Lumosity;
A90L = Alternating days for 90 min. and used Lumosity

The difference in student performance on the pretest was not statistically significant that indicates that the two samples were equivalent at the beginning of the study (see Table 3). The

Levene's test of homogeneity was not statistically significant for the posttest scores but the independent samples *t*-test for equality of means was statistically significant. The difference in the distribution of the scores was not statistically significant, but the difference in average student performance across both groups was statistically significant. On average the section that met daily for a shorter period of time performed better on the posttest than the section that met less frequently for a longer interval by approximately 5 questions.

Different Program with Same Type Schedule

Student performance on the pre- and post-tests was compared for students who completed different brain-training programs and met for the same length of time and frequency. The overall performance of these groups is reported in Table 4. The difference in student performance for these groups was evaluated with Levene's test of homogeneity of variance and independent samples student *t*-test at the .05 level. These results are reported in Table 5. Neither the pretest or posttest scores showed statistically significant differences between the groups of students with similar meeting schedules.

Table 4. Raw Score Data for Students Meeting Every Other Day and Using Different Brain-training Programs (n = 74)

Brain-Training Treatment Groups*	Pretest Mean (SD)	Posttest Mean (SD)	Change in Raw Score
A90L: Logical Thinking Meets Every Other Day	14.08 (4.19)	17.15 (7.21)	3.07
A90C: Content Drill Meets Every Other Day	12.90 (5.38)	18.42 (5.09)	5.52

*A90L = Alternating days for 90 min., used Lumosity™;
A90C = Alternating days for 90 min., used Study Island©

Logical-thinking brain-training group (A90L) had approximately a 3-question improvement on the posttest score compared to the pretest score. The content-drill brain-training

group (A90C) had approximately a 6-question improvement on the posttest score compared to the pretest score. The difference in mean student performance was not statistically significant for the pre- and post-tests. Additionally, the Levene's test of homogeneity was not statistically significant for the distribution of either set of scores (see Table 5). Overall, the average scores and distribution of scores for the groups with the same meeting schedule (A90L and A90C) were not statistically different from each other despite receiving different brain-training events.

Table 5. Independent Samples *t*-Tests Comparing Groups who Used Different Brain-training Programs Under Similar Schedules (n = 74)

A90L vs. A90C	Levene's Test of Homogeneity F	Sig.	<i>t</i> -Test for Equality of Means Sig. (Two-tailed)
Pretest	0.054	0.817	0.405
Posttest	1.914	0.173	0.564

*A90L = Alternate days for 90 min., used Lumosity™;
A90C = Alternate days for 90 min., used Study Island©

Different Programs and Different-type Schedule

The two groups that participated in the brain-training program designed to improve logical-thinking abilities (D55L and A90L) did not exhibit a statistically significant difference on the pretest (see Table 3). These two groups were combined to evaluate the difference in student performance based on participation in the different brain-training programs (logical-thinking vs. content drill and practice) independent of the frequency and duration of class meetings. The overall performance of these groups is reported in Table 6.

Table 6. Raw Score Data for Students in Different Brain-Training Groups (n = 74)

Brain-Training Treatment Groups*	Pre-Test Mean (SD)	Post-Test Mean (SD)	Change in Raw Score
D55L & A90L: Logical Thinking	14.65 (5.00)	20.40 (7.78)	5.75
A90C: Content Drill	12.90 (5.38)	18.42 (5.09)	5.34

*D55L and A90L = had different scheduled times and frequency and both used Lumosity™;
A90C = Alternating days for 90 min., used Study Island©

Brain-training groups (D55L and A90L) that experienced logical-thinking skill practice had approximately a 6-question improvement from the pretest score to the posttest. The brain-training group that practiced content (A90C) had a 5-question improvement from the pre- to post-test score. The difference in student performance for these groups on the pre- and post-tests was evaluated with Levene's test of homogeneity of variance and independent samples student *t*-test at the .05 level. These results are reported in Table 7.

Table 7. Independent Samples *t*-Tests Comparing Different Treatments Independent of Schedule (n = 74)

D55L & A90L vs. A90C	Levene's Test of Homogeneity		<i>t</i>-Test for Equality of Means
	F	Sig.	Sig. (Two-tailed)
Pretest	0.151	0.699	0.192
Posttest	3.602	0.062	0.245

When the students are grouped based on the brain-training program used in class, there was not a statistically significant difference in the means or the variance of the scores on the pre- and post-tests at the .05 level. This supports the results in Table 5, which also shows that there is

not a statistically significant difference in student performance based on the program used for instruction.

Limitations

The scheduling and class assignments for this study were determined by the school's administrators, not the researchers. It would have been ideal to have a group of students in the content-training group that had met every day but the nature of the school class assignment system did not allow for this addition to the study. Future trials for this study will not be available using the same content drill brain-training program. Sapling Learning© (saplinglearning.com) will replace Study Island© as the content drill brain training program in future trials.

CONCLUSIONS

Impact of Scheduling on Student Success (Research Question 1)

The impact of scheduling on student performance when the same brain-training program was assigned was determined by evaluating the difference in student performance on the pre- and post-test for the two groups who participated in the logical-thinking brain-training program, D55L and A90L. The change in the mean raw score was approximately 8 questions for group D55L and approximately 3 questions for group A90L. The variance and mean of the scores between these two groups were not statistically significant on the pretest. The difference in the variance of the scores on the posttest was not statistically significant. However, the difference in the mean scores between these two groups on the posttest was statistically significant even though the overall distribution of scores across the two groups remained homogeneous.

Additionally, the statistically significant difference in the mean scores on the posttest indicates that the section that met more frequently for a shorter duration, D55L, was more beneficial for student learning.

Impact of Brain-Training Programs on Student Success

Same Meeting Schedule (Research Question 2)

The impact of the brain-training programs on student performance, when students were assigned to sections that met for the same duration and frequency, was determined by evaluating the difference in student performance on the pretest and posttest for the two groups that met for 90 minutes every other day, A90L and A90C. The differences in the mean and variance of the scores between these two groups were not statistically significant for either the pretest or the posttest. The overall distribution of scores across the two groups remained homogeneous and the different brain-training programs did not produce a statistically significant difference in student performance.

Independent of Meeting Schedule (Research Question 3)

The performance of the two groups that participated in the logical-thinking brain-training program, D55L and A90L, were combined and compared with the performance of the group that participated in the content drill brain-training program, A90C. This analysis was completed to further investigate the finding that the brain-training programs did not produce a statistically significant difference in student performance. The differences in the mean and variance of the scores between these two groups were not statistically significant for either the pretest or the posttest, confirming the results found in the previous analysis [17].

The duration and frequency of instruction influenced the progress of students' performance on the content assessment. Based on current data, there is not a statistically significant difference in the two types of interventions. Therefore, duration and frequency of instruction were influential on student performance and the type of brain-training program used during instructional time did not show a significant impact.

Future Recommendations

The ULM promotes three components that underlie student learning and e-instruction: (1) **prior knowledge** is the most predictive element that determines students' success in their current courses; (2) **engagement** with the course's subject matter is also very important to success because if students do not attend to the material that is required to succeed, they will miss important information that will limit their success; and (3) **motivation** that is the driving force behind how students attend to the subject matter [13]. Mastery of online content has previously been defined as correctly completing 90% or more of the expected content [14, 18].

We propose that future research should not only investigate whether cognitive-training works, but also should determine what training regimens and what training conditions result in the best transfer effects, investigate the underlying neural and cognitive mechanisms, and finally, investigate for whom cognitive training is most useful.

REFERENCES

1. Bodner, G. M. (1986). Constructivism: A theory of knowledge. *J Chem Educ*, 63, 873-878.
2. Edelson, D. C. (2001). Learning-for-use: A framework for the design of technology-supported inquiry activities. *J Res in Sci Teach*, 38, 355-385.
3. Owen, A. M.; Hampshire, A.; Grahn, J. A.; Stenton, R.; Dajani, S.; Burns, A. S.; Howard, R. J.; Ballard, C. G. (2010). Putting brain training to the test. *Nature*, 465, 775-778. doi: 10.1038/nature09042 Received 25 January 2010 Accepted 29 March 2010 Published online 20 April 2010.

4. Jaeggi, S. M.; Buschkuehl, M.; Jonides, J.; Shah, P. (2011). PNAS: Proceedings of the National Science Academy of the USA. <http://www.pnas.org/search?author1=Susanne+M.+Jaeggi&sortspec=date&submit=Submit>
5. Schoenfeld-Tacher, R.; McConnell, S.; Graham, M. (2001). Do no harm—A comparison of the effects of on-line vs. traditional delivery media. *J Sci Educ & Tech*, 10, 257-265.
6. Cooper, H. (1989). Synthesis of research on homework. *Educ Res*, November, 85-91. Retrieved April 28, 2010, from www.addison.pausd.org/files/addison/homework/Synthesis%20of%20Research%0on%20Homework.pdf
7. Kay, R.; Knaack, L. (2009). Exploring the use of audience response systems in secondary school science classrooms. *J Sci Edu. & Tec.*, 18, 283-392.
8. Lee, H.; Feldman, A.; Beatty, I. D. (2012). Factors that affect science and mathematics teachers' initial implementation of technology-enhanced formative assessment using a classroom response system. *J Sci Educ & Tech*, 21, 523-539.
9. Dutton, A.; Prnka, M.R.; Belland, J.; Mason, D. (2012). Influence of e-homework use on student success in general chemistry. Published Conference Proceedings: *La Chimica nella Scuola XXXIV – 3* (pp 225-231) of ICCE-ECRICE.
10. Epstein, M. L.; Epstein, B. B.; Brosvic, G. M. (2001). Immediate feedback during academic testing. *Psych. Reports*, 88, 889-894.
11. Richards-Babb, M.; Jackson, J. (2011). Gendered responses to online homework use in general chemistry. *Chem Educ Res & Prac*, 12(4), 409-419. DOI: 10.1039/C0RP90014A
12. Cole, R. S.; Todd, J. B. (2003). Effects of Web-based multimedia homework with immediate rich feedback on student learning in general chemistry. *J. Chem Educ*, 80(11), 1338-1343. DOI: 10.1021/ed080p1338
13. Shell, D. F.; Brooks, D. W.; Trainin, G.; Wilson, K. M.; Kauffman, D. F.; Herr, L. M. (2010). *The Unified Learning Model: How motivational cognitive and neurobiological sciences inform the best teaching practices* (Vol. 1). New York, NY: Springer Science+Business Media.
14. Mason, D. (2013). Keynote address at the First African Conference on Chemical Education, Addis Ababa, Ethiopia.
15. Lumosity™. <http://blog.lumosity.com/new-research-finds-cognitive-training-can-make-you-smarter/#sthash.lLnDXGqh.dpuf> (last accessed January 2014).
16. Study Island©. <http://www.studyisland.com> (last accessed January 2014).
17. Wiliam, D.; Lee, C.; Harrison, C.; Black, P. (2004). Teachers developing assessment for learning: Impact on student achievement. *Assess in Educ: Principles, Policy & Practice*, 11(1), 49-65.
18. Powell, C. B.; Pamplin, K. L.; Blake, R. E.; Mason, D. S. (2009). Summer professional development in chemistry for inservice teachers using OWL Quick Prep. *J Sci Educ & Tech* (paginated issue April 2010, 19: 126-132). (DOI: 10.1007/s10956-009-9186-y)

ACKNOWLEDGEMENTS

The authors would like to thank the students who participated in this study and express appreciation to Lumosity™ that allowed the use of their product gratis.

CHALLENGES LEFT-HANDED STUDENTS FACE IN KENYAN GIRLS' SECONDARY SCHOOL SCIENCE LABORATORIES

Benerdeta Mwikali Malusi
Mount Kenya University, Kenya
Email: faithemm@gmail.com

ABSTRACT

Previous research on left-handedness has mainly taken place in developed countries. This study aimed at investigating the challenges left-handed students faced in secondary school laboratories and how well they coped with the challenges in Kenya. It also sought to find out whether teachers were aware of the challenges and what help if any they gave the students. The participants were five left-handed science students and their respective subject teachers from a girls' school in Kenya. The students were enrolled in practical subjects: Chemistry, Biology, Physics, Computer studies and Home science. Qualitative data was collected through classroom observations, individual and group discussions. Data revealed that left-handed students experienced challenges generally in school and specifically during practical work. These challenges resulted mainly from having to write left-to right (handwriting), unfavorable sitting positions in uncomfortable desks, handling and manipulating of some apparatus during practical work among others. These challenges posed many disadvantages to the students as they reported inability to finish timed tasks. Majority of the teachers were aware of the students' challenges but gave insufficient help. The school had nothing in place for the left-handed students, a confirmation that like in many parts of the world, left-handedness has never been considered a special learning need in our context. The conclusion of this study provides evidence that there is need for Kenya government to rethink her initial and in-service special education needs' teacher training to include a module in left-handedness in order to equip all teachers to be able to identify and assist left-handed students to learn with least difficulty. The researcher suggested that left-handed learners like other mild special needs learners be added more time during timed tasks especially the practical papers in KCSE examinations. [AJCE 4(3), Special Issue, May 2014]

INTRODUCTION

In the Kenyan context like in many parts of the world, the secondary school science curriculum involves an inclusion of hands-on activities that authenticate and endorse scientific claims through the collection of scientific data, analysis and make inferences. Students need to verify that $E=mc^2$ or determine whether photosynthesis actually takes place in the dark thereby living through science at first hand and build stock of personal experiences [1].

According to Tan [2] the benefits of the science laboratory have earned it a central and well defined position in science education. However, unless the learners are able to interact with the apparatus fluidly, what goes on in the laboratory may either contribute little to their learning science or does not engage them in doing any meaningful science [3]. Consequently, laboratory experiences can be very annoying if students for whatever reason are unable to interact with the available apparatus successfully as it can lead to tensions in the laboratory [2]. On the other hand, when students struggle with apparatus and fail to observe, measure and record accurately, this experience of 'failure' can lower their self-esteem and self confidence.

In Kenya, the teaching of science requires that learners choose all or two of the sciences offered and examined by the Kenya National Examinations Council (KNEC) at the end of form two. At the end of form four, all students are assessed in individual undertakings in the laboratory in the enrolled science subject. In order to tally 9 points on a 12 point scale and meet the requirements of the Kenyan universities Joint Admissions Board (JAB), a student must have scored at least 30% in the practical component of the subject. Failure to meet the minimum requirement means that a student may not join certain jobs and talent is lost.

Some of the reasons that may make a student not meet the requirements may be the presence of a learning disability which may also present a barrier to learning at the same speed as

his/her peers or worse still the inability to complete timed tasks. Failure to complete timed tasks may not necessarily mean deficient in content knowledge but may include factors intrinsic to the individual [4]. This may be the case of the left-handed learners.

Left-handed learners due to their affiliations have poor motor skills and are clumsy [5]. This has been explained in part to be due to their use of right handed instructional resources. In effect, this use leads to reduced learner outputs which also lead to a negative attitude towards the subject and an eventual withdrawal from active participation in the learning.

Statement of the problem

In situations where the majority of the students and probably the teacher are right handed, the presence of a left-handed student may go unappreciated. They are subjected to the use of instructional resources that are not suited to their grasp. It is the use of these right handed instructional materials that cause challenges to left-handed learners as it makes it difficult for them to cope with these challenges especially when carrying out hands-on activities.

Left-handedness has never been recognized as a special learning need the world over. Therefore, initial teacher training colleges do not prepare teachers to adequately deal with left-handedness. Most teachers are not aware of these challenges and therefore do not offer any help to assist the learners cope yet this affects the learners' gains and attitudes against the subject.

LITERATURE REVIEW

Background to left-handedness: Studies show that left-handers are approximately between 10% and 13% of the world population. Men are more likely to be left-handed (12.6%)

compared to women (9.9%). Young people are more likely to be left handed (14% for men and 12% for women) than the elderly (nearly 6% for both sexes) [6].

Despite their presence in our midst and a large percentage of them in our classrooms, the left-handed are discriminated against in nearly all aspects of their lives; from religion to languages and the everyday tools. The Christian Bible, the Islamic Koran, the Jewish mystical books (Zohar and Talmud) are all in favor of the right hand. All blessings and just decisions are made with the right hand while damnations and deceit arise from the left hand. In Christianity, everyday preferences fortify the positive facet of the right and the right hand. The bible, in particular indicates that Jesus sits at the right hand of God and is in fact God's right hand. Christianity has had wide spread effect on millions of the world population through history and therefore potentially strengthens the spread of the right hand preference.

The long history of language has not spared the left handed either. The major languages of the world have ego deflating figures of speech [7] for left-handedness. For example, in French: '*gauche*' awkward, clumsy; Danish: '*keijthandet*' cat handed; Italians: '*mancini*' crooked, maimed; Germans: '*linkisch*' awkward; Russians: '*na levo*' sneaky; Portuguese: '*canhoto*' weak, mischievous; Spanish: '*zurdo*' malicious and Romanians: '*bongo*' crooked, evil [8]. The Swahili refer to the left-handed as '*mashoto*', to mean abnormal.

Left-handed people therefore grow up in a world that has been taught from near infancy that being left handed is bad and this may be passed on till formal school starts. Left handedness is part of a person's make up and not an inclination than can easily be wished away or down played. Handedness is determined by the brain and not the hand that and the most flexible hand is the one that helps the brain and the hand to work together for language and writing. Therefore, forcing a left-handed child to perform a task with the right-hand means they are using the weaker

and less coordinated hand which eventually makes them clumsy, ineffective and easily wearing out [9]. This practice has also been known to induce dyslexia, stuttering and other forms of motor difficulties in children not to mention terrible frustrations and hatred for school and school work [10] and eventually become introverted [9] and fail to make healthy relationships with their peers as would be expected of a developmental stage in child growth. The experience of speech difficulties may also hinder children from articulating their responses in class yet a lot of learning takes place when children are able to express their thinking not only through paper and pencil but also through speech [11].

Challenges faced by the left-handed

Handwriting: Writing left-to right is a complex activity for the left handed children. They write slowly due to poor pen and paper control which causes them to tire easily [5, 9]. Sometimes they may need to lift up their arm more often to see their work and therefore they may need a longer time to complete timed work.

Technology: this is another area of development that has inaudibly disregarded the left-handed. The majority of tools in any technological society are designed for the right-handed and therefore have inbuilt pro for the right-handed over the left-handed [12]. When the left handed are presented with such intrinsically prejudiced tools, they normally have two options; either learn to use the tool right handed (awkward and inefficient at best) or learn to somehow hold the tool backwards so that it can be manipulated with the left hand (often clumsy).

Home science: the apparatus in the home science laboratory require the students to perform tasks using right handed apparatus which require a left-to-right wrist turning movements. For example, a right handed pair of scissors as used in home management practical

lessons has its cutting blades arranged such that the line being cut along can be seen by the right handed users. When used by the left handed users who rely on the left hand for cutting, the aspect of hand-eye coordination impairment interrupts since they cannot see the cutting line. Extensive use of this apparatus by the left handed leads to varying levels of discomfort.

Handling of apparatus during practical work: multi-tasking is a common practice in science laboratories and requires the students to use apparatus with the right hand supported by the left hand. Faced with these apparatus the left handed try to get a comfortable working position which usually entails moving the apparatus. The shifting so involved may alter the order of arrangement and probably cause a mix up. Using the less coordinated hand to perform the activities involves flexing the muscles of the weaker hand and this adaptation takes considerable time for the students which may obstruct precision expected of the task [5]. Rulers which many mathematics and science teachers do not realize are right hand biased are also other apparatus that front challenges to the left-handed users [12]. The numbers on a ruler (as left-handers see it) are on top and read from left to right. Many a times they may use the wrong scale when taking readings and measurements and this can be a source of inaccuracy and disappointments.

Shared work stations in schools: sharing work stations and notably so during computer lessons, a computer mouse on the right hand side of the computer is quite difficult to use and may at best reduce them to spectators. Even when they get to use the mouse, the keys are made for the comfortable use by right handers. Logitech has in recent times developed a computer mouse convenient for the left handed user [13].

Evidently, left-handers' lives are full of challenges and they are obliged to face more than their share of difficulties [14]. More often than not, right handers do not comprehend the accommodations the left handers have to make in order to fit in a world made from up down by

right handers for the right handers [8]. These accommodations include everything from tying shoes, opening doors, using can openers, calculators, using clocks and watches that wind and move in the wrong direction as well as striking a match to more complex processes like writing left to right alphabets [14]. They often face subtle humiliation, prejudice and discrimination from the predominantly right-handed society. It is this discrimination that can sometimes make students lose buoyancy in themselves and their studies.

Left handedness and the left-handed seem to have drawn very little attention in the African context. This has been explained as due to the in-built level of tolerance of their condition and the assimilation with the society that it draws such little consideration today [10]. Schools appear to have failed to understand and support left-handers educational needs [15]. In so doing, they have deprived them a chance to be what they can be. This anomaly can be traced to the failure of initial teacher training colleges to train teachers on how to handle left-handed learners.

It is rather obvious that there is much diversity in the classroom. However, the focus of this research was to investigate the challenges the left-handed children faced while engaging in practical work in school science laboratories and the home science room whose settings are right hand biased and how well they coped with those challenges. It also sought to find out whether teachers were aware of the challenges and what help they gave the students. The main task was to unearth the emotional content and meaning expressed in the everyday occurrences of this special group of learners. This is a research that was inspired by the need to tell the story of learners whose voices have for a long time been ignored and/or silenced in our schools.

METHODOLOGY

In order to understand the challenges and the underpinnings of left-handedness in secondary school science laboratories, a descriptive and exploratory survey research design was adopted for this study. Data was collected through unstructured classroom observations, one-on-one teachers and students' interviews followed by focus group discussions with the left-handed students.

Three lessons for the study were conducted each for biology, chemistry and physics in the respective laboratories and one in the home science room. All the lessons were planned experiments based on previous term's examination. The materials for common sharing were made available from the teacher's bench.

An observation schedule was used to collect the data in the students natural setting [16] in order to take detailed summaries of events and incidents as they occurred in the laboratory [17]. After the left-handed students were identified by the subject teachers, the researcher carried out a non-participant whole class observation but the focus was the left handed students. Aspects like sitting positions, the students level of participation and interaction with the availed apparatus compared to the right handed and any outstanding issues requiring teacher intervention were observed.

Face-to-face interview was also carried out with the left handed students to ascertain and validate the observed data. The discussions involved probing for elaboration and clarification of observations [18] and therefore access more information. The discussions were audio recorded, helping the researcher to develop a free and easy conversational relationship with the interviewees while the open-ended semi-structured questions helped in keeping the interview in track [17]. Items on cultural attitudes, handwriting, and effectiveness of schools meeting the

students' needs, laboratory and practical experiences and questions that sought to find out the overall quality of life in the school were included. The teachers' interview guides sought to establish teachers' awareness of the challenges the students faced in the science classrooms and the help they offered while the principal's informal interview sought to find out what the school had in place for the left-handed learners.

The focus group discussions were done last and they helped the students to stimulate each others' thinking [19] and bringing to the fore issues they may have overlooked during the face to face interviews, or did not feel comfortable talking about them during the face-to-face interview. The researcher was keen on looking out for dominance and conflicts within the group.

Question	Data Collection Method	Data Collection Tool
What challenges do left-handed students experience as they carry out practical work in the laboratories?	Observations (observation schedule, field notes) Interviews (audio records, field notes)	Observation schedule Semi-structured interview guides
Are teachers aware of the problems faced by left-handed students in carrying out practical work and how do they help them cope?	Observations (observation schedule, field notes) Interviews (audio records, field notes)	Observation schedule Semi-structured interview guides
What does the school have in place to help meet the unique needs of left-handed students?	Observations (filed notes) Informal teacher interview (field notes)	Unstructured observation Unstructured interview

Sample and sampling procedures

The school was convenience sampled due to its large population, accessibility and endowment in terms of infrastructure and students and teachers drawn from across the country.

A large student body meant a relatively large number of left-handed students from several ethnic communities. The students were all left-handed girls in their last year of high school and enrolled in Chemistry, Physics, Biology, Home Science or Computer Studies. The students and their teachers were purposively sampled.

Approaches to data analysis

Data transcription and analysis commenced right at the start of the study. Emerging themes from the data were coded to avoid being swamped [20] by the data. All the data was separated into files; student interviews, teacher interviews and classroom observations to provide building blocks for further reflection [19]. The researcher initial thoughts were inserted against each ‘interesting’ aspect in different fonts. Teacher awareness and how they helped left-handed students cope with the challenges were combined and responded to as “teacher awareness”.

FINDINGS

Under this section, the researcher presented the findings on challenges left-handed student participants (coded S1, S2, S3, S4 and S5) faced as gathered from the classroom observations L.Obs (coded L1, L2, L3, L4 and L5) and the face-to-face interviews (S.Int) with the participants. Teacher interviews (T.Int) for participant teachers T1, T2 and T3 and teacher talk (T.talk) for participating teachers T4 and T5 are also discussed.

Classroom observations and student interviews

These views are presented under; cultural attitudes, handwriting, sitting arrangements, shared work stations and multitasking in science laboratories including the home science room.

Cultural attitudes

The following is a response by S5 on whether she had been discouraged from using her left hand:

Yes... I was discouraged from using my left hand. For example when I was a small child, I was beaten up quite many times to ... they [parents] tried to beat me up to stop me from writing using my left hand ... using it for other things and even when writing with it ... my mother, it's my mum eh ... I think according to them they think it's ... the ...what's the norm ... according then, they thought what is normal is to use the right hand. They took me to a doctor, they even thought I had eh ... I had a problem but the doctor told them it was okay for me to keep using my left hand. ... I don't know, I take it they were ignorant then. ... my relatives, they, they find it weird [to be left handed]. I don't know if it is positive or negative. It's like they flinch at the thought of being left-handed themselves. I think ... I think they think being left handed is a bad omen. I don't know why. (S.Int)

Form this response, the parents and relatives of S5 did not hide the fact that they thought their daughter was not normal. For this reason, they sought the services of a doctor in order to cure their daughter. Forcing her to use the hand she was not comfortable with may have caused her mild stutter as she tended to repeat the first words of her statements. According to T3, S5 was not very enthusiastic about verbalizing her responses in class.

S2 also gave her opinion on the ability of left handed students to perform physical duties. She said,

... especially cutting something even at home you are trying to cook something [pause] when am at home they [parents] will think you will pour it, [pause] cutting something They tell me to be more careful or they come and do it for me. I feel kinda [kind of] low coz [because] may be they will say that if you go and do this [pause] may be you will be told you can't do it so you are never sure whether you are supposed to do or you just leave it. Sometimes I do it, yeah, to see if it will work out, yeah, I do it to prove to them that I can do it... (S.Int)

The two opinions highlight parental and community negative cultural attitudes towards left handedness.

Handwriting

All five participants wrote with their left hand. S1, S3 and S4 wrote quite fast, had large handwriting that was both legible and neat. S2 and S5 wrote slowly, S2 in order to make the handwriting legible even to herself and S5 because fast writing made her smudge her work. S1 and S2 smudged their work too. S5 tended to rub and cancel her work a lot because she felt her letters were not curved the right way. This made her work both untidy and messy. S2 said that “when teacher is dictating notes sometimes my desk mate can help me with her book and write down or read out ... where have not heard” (S.Int). This depicts relying on peers for help when trying to cope with the teachers speed and more so during note taking in class.

Sitting arrangements/positions

All five students said they preferred sitting on the left hand side of the classroom, next to the wall or the left hand side hedge of the laboratory. This was to avoid the ‘irritating habit’ (S1) of knocking elbows with those seated on the participants’ left hand side. In instances when the preferred sitting position was not available, the participants had to move so as to create ample space for themselves and others otherwise they bore the discomfort thereof. According to S5,

... in class I make sure I'd sit next to the wall where my left hand will be away from my desk mate... [on] the left side. ... In class, eh ... my desk mate we exchange sides with her. She, she allowed me to go to the other side to sit in a place where I will be comfortable ... but in the dining hall I do not like sitting with my friends in the table because eh, ... eating with my left and they are using their right so I tend to be uncomfortable so I stand most of the time, most of the times I move away ... I feel like am compelled to be the one to move ... [and] that way I do not get to be on the wrong side with anyone. (S.int)

While S1 said that she felt ‘irritated’ that she could not do what others were doing so effortlessly, S2 said “ sometimes it is like you cannot sit where everybody is, yeah, ... and it

makes one uncomfortable and you cannot stay ... normal like the rest ...” (S.Int). This statement from S2 came as a result of having been made to move from her desk by her primary school teacher with no reasons given for the action.

Shared work stations

Seemingly, the participants were comfortable sharing work stations as long as there was enough space for everybody. It however emerged that they had to squeeze, turn and position themselves in order to fit in the provided space so as to participate in class activities comfortably. Since individual laboratory practical arrangements are done facing the front of the room and are mainly placed on the right hand side of the individual, participants said they preferred working across facing the back of the room. That consequently meant shifting the apparatus to that location, or moving the apparatus from the right hand side to the left hand side when the most preferred option was unattainable. According to S4, “...going to the other side would be easier but ... I prefer staying where I am so that they [teachers and other students] don't say that I cheat [in examinations]. That makes me feel like it is unfair” (S.Int).

Handling of apparatus during practical work

Participants claimed that the arrangement of apparatus posed challenges because they had to shift the provided apparatus or adjust them to suit their sitting and manipulation preferences. The challenges faced in the individual subjects are discussed in the following sub-section.

Home science

S1, the only participant enrolled in home science said she found using of a pair of scissors, the tracing wheel, kitchen knives, can openers and a match box particularly challenging for her. Activities such as ironing, cutting, hand sewing and machine stitching were equally challenging to her. This was because she was unable to stitch a long straight lines however much she tried.

I have this problem of straight lines, I really can't ... I always draw crooked so also when I trace down with the tracing wheel it always comes out crooked. I don't know why. But it just happens. ... and the issue of always turning ... the whole body, ... uh, it's tiring! If am stitching I feel that it will not be straight. It just does not come out straight even when am using the machine sometimes I have to redo and redo I actually manage to finish my work but the teacher is always complaining, straight lines, straight lines! (S.Int)

Ironing also took a lot of the participant's time. This was because she had to first put the iron down to straighten the garment with the left hand as well as position herself in a way as to comfortably iron the garment. She tended to also hold the garment very close to her face during stitching. She reported that this was to allow her to see the stitching line clearly.

Chemistry

All five participants were enrolled in Chemistry. However, only S1 and S2 were observed. During lesson observation L2 taught by T3, S1 took the reagents provided for her group (the students were put into groups of four) to transfer to another container, she poured out some of it. After collecting more reagents from the distribution table she failed to stop the watch on time. Left with no more reagents for the group to carry out further investigations the group members redistributed themselves among other groups because the teacher had made it clear that

all groups had only one chance to change reagents (L.Obs) during the interview, S1 had this to say;

... titration could be a challenge for me because my right hand is weak and not able to control the tap [on the right hand side of the burette] with my left hand and stop a watch with my right hand at the same time ... I pressed my finger [to stop the stop-watch] and it slipped so I did it again and time had elapsed since the end of the reaction. I don't know whether they [group members] were annoyed but [sighs] what could I have done, I did not do it on purpose! (S.Int)

S4 said that during titration “I swirl the flask with my right hand and stop the watch with my left hand. The burette tap is usually on the right hand side so I have to position myself to work on it” (S.Int).

Although S2 was able to coordinate her hands, she reported that;

In titration I have to use this hand [shows the right hand] to shake the ... may be contents and you feel as if you are not doing it right and you keep on shaking I feel like one hand is heavier than the other and sometimes swirl too hard and end up pouring the flask contents (S.Int)

In the overall, it appeared that the failure to meet requirements of the task made the students frustrated and the lose confidence in themselves.

Biology

All students were enrolled in Biology but only S5 was observed in this study. During the lesson [L5] the students were required to draw a rib as drawn by the teacher [T3] on the chalkboard. In the case of the curve of the rib was facing the student's right hand side. S5 was observed doing two diagrams, one facing the right and the other facing the left. The one facing left was later rubbed. For the other facing the right, the direction of the motion of strokes was opposite that of the teacher and the rest of the class (L.Obs). During the interview, S5 said, “I

tend to change the directions in my drawings ... yeah; you can say that I rub a lot too". S2 rubbed a lot too as she said during the interview.

The two participants said they rubbed because when they compared their work with that of their peers, it appeared different and therefore they wanted to change it. S1 said that "sometimes it is difficult to do things the way they are supposed to be done and you wonder why" (S.Int).

Physics

When required to swing a pendulum and a stop watch at the same time, S5 said,

Am not in control because I have to swing it [pendulum] with my right hand and stop the watch with my left hand and am not able to move [flex] finger in time so I usually stop the watch much later (S.Int).

S4 said that she experienced problems doing hands-on tasks involving the stopwatch because when she pressed it with her right hand index finger, the finger slipped, thus compromising the accuracy of her findings and ultimately her final results. S1 on the other hand said she did not have much of a choice when required to do hands-on activities because, "... if I don't do it, who will do it for me?" she wondered. S5 said she tended to confuse the scale when using rulers especially in physics laboratory and often used the wrong scale.

In the Fleming's left-hand (motor)⁴ and right hand (dynamo)⁵ rules, "I have problems coz [because] I have to first think, this is my left hand and this is my right hand" (S.Int) S4 said while S5 on whether being left-handed contributed to problems in physics said, "it ... it ... it does

⁴ If the first finger, the central finger and the thumb of the right hand are stretched in mutually perpendicular directions such that the first finger points along the direction of the field and the thumb is along the direction of the motion of the conductor, then the central finger would give the direction of the induced current (Abbott, 1984, p.429)

⁵ If the thumb, the first finger and the second finger of the left hand are held pointing at right angles at each other and the first finger is pointing along a magnetic field and the second finger points in the direction of current flow, then the thumb points in the direction which the conductor will tend to move (Abbott, 1984, 449)

contribute sometimes in my exam coz [because] ... for example when you are told to indicate the direction of a magnetic field I make the mistake of confusing my hands” (S.Int)

In summary, handling apparatus and performing hands-on activities in science laboratories was challenging to left-handed students. This was despite having been introduced to practical work and handling of apparatus early in high school. The freedom to consult with the laboratory technician any time they needed help did not help either.

Teacher interviews

In this subsection, teacher interviews are presented under T1, T2, T3, T4 and T5. The focus was to detect the teacher’s awareness of left-handed student’s challenges during practical work and what they were doing to help the students around the challenges.

T1: taught both physics and chemistry and was aware that left-handed students faced challenges. In physics, the challenges were more in the manipulation of some apparatus during hands-on activities and concepts that required the use of a specific hand, for example the Fleming’s right hand rules. In a bid to make themselves comfortable during practicals, T1 said,

... left-handed students stand in a particular way and sometimes they disarrange apparatus. They also do things in the opposite direction from the rest of us, for example, in instances like drawings which causes problems to them ... if the direction of a current in my diagram is from the left, the student’s would flow from the right and this would affect hare results (T. Int).

He further said that “lefties are good in the topic on lateral inversion and they have an advantage over the others” (T.Int). he went on to say that he had realized that left-handed students experienced difficulties associating the Fleming’s rules with the ‘right’ hand as the students tended to confuse the hands, “... for the concepts requiring the use of the right hand,

they] left-handers] cram because they cannot use their right hand well yet they have to pass [their examination] anyway (T. Int).

Writing some of the Greek symbols as is common in physics was also a challenge to the left-handed students, for example the symbol lambda (λ) which T1 said the students were unable to write it the right way. He further said that left-handed students also had problems coping with instructions during examinations because they unfortunately confused their right hand side with the left hand side.

T1 who also taught chemistry said, though in apparent reference L2,

In chemistry when they [left-handed students] are doing a practical where they have to add a substance, stir and time, and they have to use two hands, they find it difficult because they add the substance with the left hand also want to use their left hand for stopping and starting the stopwatch. This takes their time ... in an examination when we realize that they have problems, as teachers, we just leave them alone because there is nothing we can do (T. Int).

T1 did not think that left-handed students needed to be treated as special students because they adjusted on their own and “were doing quite well” (T. Int).

T2: taught home science and although she was aware that S1 the only participant enrolled in the subject faced challenges with some apparatus in the home science room, she had not offered any help. T2 did not think S1 needed extra attention in class because the student never asked for help and she eventually finished her tasks. This was despite the possibility that the students often received help from peers (S. Int). In response to whether T2 thought being left-handed hindered S1’s learning in any way she said,

May be when it comes to practical work coz [because] sometimes even our setting of exam we only think of the right-handed people so even the stitching when we are saying they do [work] to the left, you know for her, [pause] her left is the right so I think it may give her some trouble before she orientates on that. I think that might take time, [pause] can consume time before she puts things together (T. Int)

Despite this awareness, there was still nothing she as a teacher did because she awaited the student to come forward and ‘ask’ for help.

T3: taught both biology and chemistry and became aware that left-handed students faced challenges in the laboratory from their drawings which either faced the opposite direction or did not conform to the norm⁶. In response to what may have triggered the realization that S5 was left-handed, T3 said,

... am interested in the way they [my students] hold the pencil and how sharp and the style of starting the diagram. I expect them to start from left to right even if it's a circle but for them [lefties] they start theirs from the right towards the left and that affects the final diagram In chemistry, I expect the tap to be opened by the right hand [pause] and when you find a student doing vice versa then you want to find out why [long pause] may be its an assumption we make that things should be done in a certain way (T. Int)

T3, a perfectionist of some sort said he had offered to help by training the student on how to draw from left to right⁷ since he had realized that left-handed students diagrams were not conforming to the norm and this was perhaps “beyond their [students] capabilities” (T. Int).

On whether he thought being left-handed hindered S5’s learning in any way, he said,

I would not say directly but indirectly [pause] particularly when it comes to drawing, it does affect their final product ... she may have the concept excellently mastered but presentation on the paper [pause], particularly there's a level of tolerance I have to give for their [lefties] diagrams ... I mark as per the set standard marking scheme ... tolerance in terms of the level of perfection I expect. This is so as not to stretch her [S1] to a level she cannot attain, I expect her diagram to this level [shows]. ... I appreciate there is a level of perfection they [lefties] cannot reach (T.Int).

⁶ The researcher observed this in the biology laboratory during L5 when S5 drew multiple diagrams facing opposite directions. The one different from the teacher’s was later rubbed (L.Obs).

⁷ This was however not observed during the classroom observation as the participant drew both diagrams from right to left with the drawings facing opposite directions (L.Obs)

In chemistry, T3 said that the manipulation of apparatus during hands-on activities was a major challenge because left-handed students sometimes had to first rearrange the apparatus for comfort. They also preferred working with some apparatus over others.

While handling apparatus, T3 said he had taken to 'dictating' to left-handed students on how to arrange and organize apparatus. This, he said had helped a lot in the left-handed student's practical work outcomes. The help offered by T3 was out of his own initiative; he took a keen interest in each individual student in his classes.

T4: the boarding mistress was in charge of structures in the school said there was no provision for left-handed students' needs because "there's nothing wrong with them. They have learned to cope with what there is" (T.talk). This opinion was shared by the deputy principal, T5.

T5: the school deputy said that she was aware there were left-handed students in the school but she did not know how many they were. She learned about their presence through observation as they carried out their duties. She confirmed that there were no structures especially meant for left-handed students because they appeared normal to her. In her opinion, there was nothing special about left handedness because "none of the students had expressed the need to be treated as such and they were able to cope with their condition in the given circumstances" (T.talk)

Notably, the nature of challenges left-handed students face in the learning institutions could determine their future career choices. In this study, S2 opted to do physics instead of home science because the challenges she experienced in home science frustrated her efforts while S1, despite the challenges, still went ahead with the subject but felt that she did not perform her best due to the difficulties with the apparatus provided. S1 also blamed her low performance on the lack of help from her teacher.

DISCUSSION AND SUMMARY OF FINDINGS

The study purpose was to investigate the challenges left-handed students face generally in school and specifically in the school science laboratories. It also sought to find out whether teachers were aware of these challenges and the help they lend to the students. The findings have been synthesized from both teacher and student interviews and classroom observations in relation to the research questions. The syntheses is done under the subheadings; cultural attitudes, handwriting, sitting preferences, manipulation and handling of apparatus and lastly teacher awareness and preparedness.

Cultural attitudes

Despite a commonly accepted view that prejudice against the left-handed is a thing of the past [9], left-handers still face a lot of humiliation from the modern society. In this study, S5's parents had to take her to a doctor hoping to get a 'cure' for her good hand. In the process of trying to convert her handedness, S1 may have developed stuttering, a condition resulting from being forced to perform tasks with the less coordinated hand [9]. As a result, S1's academic performance may have suffered because as explained by her teacher T3, she was not enthusiastic about verbal responses in class, yet children learn better when they are able to verbalize their thinking [11]. S2 implied that her father thought she was inefficient in carrying out some activities in the home as he often offered to assist her (see exact words in the findings section). The constant reminder by her parents that she ought to be careful when carrying out activities may have eroded S2's self esteem to a point she did not want to take initiatives for fear of failure.

Handwriting

Writing left-to-right is a challenge the left-handed encounter in school. This is because most of their teachers are right-handed and they may not have any idea on how to train a left-hander to hold the pencil and tilt the paper/book when writing. The aches reported by the participant students may have been due to twisting their bodies because of sitting on the ‘wrong desks’ [12], unfavorable sitting positions [5] and also having the wrong writing habits. However, all participants but S2 had very clear handwriting. S1 and S5 pressed the pen very hard causing cramps to their arms and fingers and ultimately tiring easily during note taking [9]. This eventually made them to sometimes fall behind the teacher and the rest of the class a reason that may explain their failure to finish timed tasks

Being left behind and having to copy notes from others may lead to labeling by the same peers and accusations of being a burden, leading to eventual withdrawal from active class participation and therefore limited associations. It is this fear of stigmatization that probably made the participants to say that they had to work extra hard to catch up with their peers and they felt obliged to prove their worth. Falling behind the teacher in note taking could also have affected their class performance since students spend most of their free time catching up instead of preparing for their examinations and routine class assignments and class work. For this reason, left-handed students may need extra support due to the difficulties encountered during writing or undertaking other tasks within the school.

Sitting preferences

Participants in the study preferred sitting on the left hand side of the room or at the edge to avoid knocking elbows with their right-handed mates. Often, they felt obliged to create a

conducive working environment for themselves and others by readily moving more so when the preferred sitting positions were unavailable or when their peers failed to understand their concerns which resulted in frustrations.

The readiness of left-handed students to create comfort for everybody else as depicted by the participants in the study could have been as a result of pressure and stress of being left handed. It can have its toll on their self esteem particularly if not recognized, understood and supported [5]. The provision of a relaxed learning environment could be a boost to better results as opposed to situations where students have to ‘fight’ for space and comfort.

All the participants were interested in class activities particularly teacher demonstrations, both group and individual work. However, individual differences and preferences came in the way for them. S1, S2 and S5 preferred positioning themselves on the same side of the demonstration table as the teacher. S5 said that she was able to ‘see things better’ from the teacher’s side (S.Int).

Left-handedness and left-handed students therefore need not be seen as a single entity. From the discussion, there were those students who preferred seeing things the way they were (S1, S2, S5) and those who preferred the mirror image (S3, S4). Standing on the same side as the demonstrator helped them visualize things as though they were seeing the mirror image [12].

In the laboratory, the participants preferred working facing the rest of the class because “there is more space” (S3). But since they are known to prefer mirror imaging and as T3 said they are good in the topic on “lateral inversion” it was possible to be accused of cheating in examinations. Rather than this accusation or be seen as “boasting” (S2), left-handers in this study said it was better to work uncomfortably than have their grades cancelled by the teacher.

Manipulation and handling of apparatus

Apparatus in use in the laboratories either require a left-to-right wrist turning or have a right hand in-built advantage [12] and therefore a left-handed student will experience difficulties working with them. Activities that require the use of two hands concurrently for example starting and stopping a stopwatch with one hand while swinging a pendulum with the other, using a pipette for measuring exact volumes which require flexing the right hand index finger in controlling fluid flow, mixing/stirring, swirling and shaking with the right hand were reported to be challenging. Since the right hand ‘feels weak and somehow ineffective’ (S2), this results in clumsiness; a confirmation that left-handed students are both clumsy and have poor motor abilities [5].

Clumsiness and poor motor abilities as observed during lesson observation L2 in the chemistry laboratory is a ‘costly affair’ for the left-handed. As evidenced during the lesson, the group members were forced to redistribute themselves into other groups after their contents were messed up and stopped the stopwatch at the wrong time.

Apparatus such as sewing machines made specifically for manipulation by the right hand supported by the left hand posed challenges to S1. For this participant, she also had problems using the tracing wheel and making straight lines and her stitching and stitching lines came out crooked “no matter how much I try” (S.Int). The stitches have to be done in a uni-directional way, for example, if it is required that stitching is done from left-to-right, a student who does it in the opposite direction is penalized by the examiner. Sadly, left-handed learners will probably and effortlessly take this direction when doing their stitching. Further, there is a certain tension that is expected for the stitches. Since the learners will be using the less coordinated hand, the stitches are likely to come out loose leading to lose of more marks.

What S1 and her teacher T2 did not realize was that her stitches and stitching lines came out crooked because of impaired hand-eye coordination. The stitching line was obscured by her left hand since the apparatus was meant for the right handed user.

Left-handed students will do things in the way that feels most natural for them until they ‘remember’ to change as was observed with S5 during L5. She first drew the rib facing the left hand side until she remembered the requirements of the task. These accommodations are time consuming and especially so in examination situations when they fail to follow instructions.

The tendency to compare their work with the right handed peers is a signal that they probably feel inadequate and may use the right-handers work as ‘yard sticks’ for excellence and when they fail to measure up, they may lack self-esteem and self-confidence.

Teacher awareness

While the teachers were aware of the challenges faced by the left-handed students in the classes, majority of the teachers left the students to deal with the challenges on their own. The students on the other hand preferred talking to their peers about their challenges in the hope of solving their problems “without much fuss” (S.Int). This consciousness saturation and the intrinsic acceptance of their condition (left-handedness), the students may have failed to see the need to ask for help from their teachers, for the same reason the teachers did not offer the help.

T1 was aware that left-handed students faced challenges. But although he understood that in the laboratory the left-handed students had to “stand in a particular way” (T.Int), he did not offer any help and left the student to deal with the challenge on their own. In Physics too, he also knew that they had problems associating the Fleming’s rules with the ‘right’ hand as well as

following directions and instructions. His assertions therefore depicted an awareness that did not match the help offered.

T2 was equally aware that S1 had problems in the science room and especially while using a pair of scissors and stitching along straight lines. Since the student did not ask for help and that “she eventually finishes her work” (T.Int), the teacher, T2 did not think S1 needed extra help. For that reason, she left the student to deal with the challenge the best way she knew how.

T3 had taken an initiative to train his left-handed Biology students on how to draw (refer to previous section). While this evidenced his awareness of the challenges encountered by S5 while drawing, he had no record of previous training in special education. Evidently therefore, teachers’ intuitive practices and training (or lack of it) could shape their classroom practices a great deal. T3 was guided by his interaction with his students and his interest in their work. Though the relationship between training and practices may be distorted, there is a high chance of inclusion if teachers enlarged their perspectives and gave each student a chance to be.

Contrary to the science subjects’ teachers, the deputy principal and the boarding mistress had similar assertions that revealed their unawareness of the challenges left-handed students faced during learning. The deputy principal, who was herself a teacher of Biology in the school said that “left-handedness is not a special learning need and none of the students has expressed the need to be treated as such, they [left-handers] are able to cope with their condition in the given circumstances” (T.talk). The boarding mistress on the other hand said that “there is nothing wrong with them [left-handers] because they have learned to cope with what there is” (T.talk). Such views by the school administration could therefore explain the absence of structures to support left-handed students. The particular emphasis that there was nothing wrong with being left-handed was a confirmation that left-handedness is not seen as a special learning need.

In summary, the findings in this study seem to evidence that handwriting; school structures, handling and manipulation of laboratory equipment and time taken by students as they struggle with apparatus pose the main challenges left-handed students have to deal with in school. Also, negative cultural attitudes towards left-handedness and the left-handed have their subtle way of affecting learning outcomes.

In this section, I have presented a summary of key findings with particularly mention of the challenges left-handers experience in carrying out practical work and the teacher awareness of the said challenges and what help they give. In the next section, I have concluded the study by giving an overview of what findings signify as far as the way forward on how teachers, schools and educators can be involved in making the left-handed students learn with least discomfort.

CONCLUSIONS

In this section, the researcher looks at what the conclusions imply for policy. It is hoped that the suggested way forward would help shape educators way of handling children with special learning needs generally and specifically the left-handed for a fully inclusive classroom and in tandem with EFA goals.

The findings from this study point to the fact that left-handed students experience numerous challenges in school generally and specifically in the science laboratories. The findings also confirm that teachers are aware of the challenges faced by the left-handed learners in school and in the classrooms. However, they offered insufficient help. Since the participant teachers got their training in Kenya, these findings serve to confirm that initial teacher training colleges do not train teachers on handling left-handedness in the classroom.

The findings in this study, conducted in a developing country, correspond to similar findings in developed countries in previous studies [9, 21-23). It therefore seems that left-handed children experience challenges the world over. The participants in this study were from a national school (high academic achievers). The challenges they experienced like their inability to complete timed tasks and handling and manipulation of laboratory apparatus adequately due to their special learning need can only mean that other left-handed students in less endowed schools and with lower academic ability could be facing serious problems. The findings in the study therefore make it possible to make certain suggestions to ease the challenges the left-handed students face in classrooms and laboratories.

Learning hands-on

Left-handed students need to be given more time in order to compensate for time spent making the necessary adjustments and accommodations. This way they will be able to complete the timed tasks therefore building their self-confidence and self-esteem. This way their gifting in the sciences, arts and mathematics due to their sequential nature of processing information [24] could easily be tapped if placed in non-threatening learning environments.

Handwriting

Training a left-handed learner how to write from left to right by a right-handed teacher who had never been trained on how to do it could be challenging to both the teacher and the learner. The learner ought to be advised to hold the pen slightly higher up the shaft than a right-handed learner as this helps them to see what they are writing and do not have to bend over their work, thereby avoiding a possible back, neck, shoulder and hand aches. The book can also be

tilted approximately 90⁰ to the right so as to allow strokes to be made both on the flat and the sloping desk. Teachers should be made aware of the need to encourage such students to sit with their bodies turned slightly to the right so as to allow greater freedom for movement to avoid the aches and fatigue coursed by using the wrong furniture. Students can also be introduced to word processing which is less demanding on their writing needs. This approach would however work in schools which have computers or parents can afford laptops for their children.

Sitting positions

Left-handed students need to be discouraged from sitting with their bodies twisted or from bending over their work. The lighting in the rooms should also be in such a way that does not cast shadows over their work as they write. If left-handed students were allowed to sit or stand where they preferred to during class or task taking would ease their discomfort a great deal. It would also help to save some time taken during shifting.

The role of teacher education and in-service programs in teacher awareness

Participant teachers, although they were all trained and qualified did not seem to understand the needs of left-handed students. It is therefore imperative that all teachers are made aware of the special needs of the left-handed, an awareness that ought to cut across all teacher training institutions from early childhood to the universities so that as the left-handed children exit from pre-primary to primary and later secondary school, they are psychologically aware of their unique needs and they can learn to adapt even better. There is therefore the need of a paradigm shift in the training of teachers because teachers in this study were not unique to the school. The government through the ministry of education, science and technology could review

the teachers' training curriculum and include a module on recognizing and handling special needs cases in class. This empowers teacher in identifying left-handed children and mediating using effective measures with corrective techniques which may help improve performance.

First and foremost, left-handedness ought to be recognized as a special learning need at least based on this study findings. Although KISE has started school based in-service courses for special needs education trainees, left-handedness was not recognized as a special learning need. The ministry could supplement KISE's efforts by organizing courses at both local and national levels for all teachers with a specific target of handling children with special learning needs and tapping in to the experience of regular teacher through reflective practice.

Awareness programs aimed at changing the attitudes of parents and peers are also very necessary. This would help at educating the community on the unique needs of left-handed children and the challenges they face in school. This can successfully be done through the help of resource persons, symposia, teach yourself leaflets and persuasive appeals involving mass media.

Resources

As evidenced in this study, resources need to cater for the needs of all children through the provision of the minimum requirements

This research was carried out in a girls' only institution with a sample of only five girls and only looked at the challenges they faced. Further research with older participants and across gender would be appropriate to determine whether the same or similar challenges are faced by the students.

REFERENCES

1. Harlen, W. (1999). *Effective teaching science: A Review of Research*. Glasgow: The Scottish Council for Research in Education
2. Tan, A-L. (2000). Tensions in the biology laboratory: What are they? *International journal of science education*.
3. Hodson, D. (1998). Seeking a more authentic science in and around the school laboratory. In W. Jerry (Ed.), *Practical work in school science: Which way now?* (pp. 93-108). London: Routledge.
4. Lerner, J. W., & Kliner, F. (2006). *Learning disabilities and related disorders: Characteristics and teaching strategies*. Boston: Houghton Mifflin Company.
5. Brookman, H. (n.d.). The left-handed dyslexic – disadvantaged twice? A policy for the teaching of left-handed pupils. Retrieved April 2008 from www.anorldschool.com/uploads/nlefthanded_policy_for_bda1.pdf
6. Marlene, H. (2000). *Left-handedness: Does it mean anything?* Retrieved March 2008 from http://www.psychologistworld.com/influence_personality/handedness.php
7. Brody, J. E. (1983, April 19). Some disorders appear to be linked to being left handed. New York Times. Retrieved February 2008 from <http://query.nytimes/gst/fullpage.html>
8. *Rights for the left-handed?* (n.d.). Retrieved April 2008 from <http://www.csun.edu/~djo41504/left.htm>
9. Milson, L. (2006). Left-handed children failed by their teachers. Retrieved September 2007 from http://lefthandedchildren.org/school_survey
10. Cortese, J. (n.d.). *Growing up left handed*. Retrieved March 2008 from <http://www.io.com/~cortese/sinistrality/index.html>
11. Mason, J., Burton, L., & Stacey, K. (1993). *Thinking mathematically*. Avon: The Bath Press
12. Holder, M. K. (2005). *Left-handers in society: Parents and educators*. Retrieved March 2008 from <http://www.indiana.edu/~primate/lspeak2.html>
13. Wambugu, S. (2008, April 6). Being left-handed need not be a pain. *The Sunday Nation*, p.32.
14. Wenzel, G. T., & Wenzel, N. (2004). *Helping left-handed children adapt to school expectations*. *Childhood education*, 81. Journal abstract retrieved March 2008 from <http://www.questia.com/googleScholar.qst?docId=5007580142>
15. Gross, J. (2000). *Special educational needs in the primary school* (2nd ed.) Buckingham: Open University Press
16. Cohen, L., Manion, L. & Morrison, L. (2006). *Research methods in education* (5th ed.). London: RoutledgeFalmer.
17. Robson, C. (2002). *Real world research: A resource for social scientist and practitioner-researchers* (2nd ed.). Malden: Blackwell Publishing.
18. Wiersman, W. & Jurs, S. G. (2005). *Research methods in education: An introduction*. London: Pearson
19. Litchman, M. (2006). *Qualitative research in education: A users guide*. London: SAGE Publications
20. Bryman, A. (2004). *Social research methods* (2nd ed.). New York Times: Oxford University Press
21. Rueckert, L & Brinkman, D. (2001). Bimanual coordination deficits in left-handers. A paper presented at the annual meeting of the Cognitive Neuroscience Society, New York, NY, March 2001. Accessed March 2008

22. Banham, K. M. (1983). Left-handed pre-school children with orthopaedic disabilities. *Rehabilitation literature*, 44, 23-26
23. Coren, S. (1992). *The Left-Hander Syndrome: The Causes and Consequences of Left-Handedness*. The Free Press, New York.
24. Hibbard, G. (n.d.). *Beta, Phi, Mu- Chi chapter: Students award for scholarship 1996/1997 co-winner*. Retrieved June 2008 from <http://bpm.slis.indiana.edu/scholarship/hibbard.shtml>

ICT IN TEACHING AND LEARNING CHEMISTRY ACTIVITIES ON THE IPAD

G. Robert Shelton* and Diana Mason**

*Austin Peay State University, Clarksville, Tennessee, USA 37044

**University of North Texas, Denton, Texas, USA 76210

Corresponding author e-mail: sheltong@apsu.edu

ABSTRACT

The purpose of this workshop is to equip chemistry educators with practical activities and logistical training to incorporate Information and Communication Technologies (ICT) into their chemistry curriculum. During this workshop, participants will gain hands-on experience using technology such as iPads and a variety of interfaces and sensors (probes) bundled with computer-based activities for chemistry and general science. Participants will gain familiarity with the general chemistry modules, learn about logistics related to implementation, and develop new activities for future use. [*AJCE 4(3), Special Issue, May 2014*]

INTRODUCTION

“We need to understand the learning needs and different learning styles of our students to equip them to contribute to using the tools of chemistry to improve the human condition and that of our environment, and to help each one of them understand the crucial role that chemistry plays in our lives” [1]. However, learning will not happen until the learner is engaged with the subject matter that the instructor intends. The important factors that must always be taken into account when teaching all subjects are (a) what the learner already knows, (b) the abilities of the learner, and (c) the motivation of the learner [2]. Providing students with activities that are appropriate for their ability and encourage engagement will motivate them to learn. The old Chinese proverb remains appropriate for today's classroom and students:

Tell me, I'll forget.
Show me, I'll remember.
Involve me, I'll understand.
Chinese Confucian philosopher Xunzi (312-230 BC)

Objectives

This workshop was intended to involve the participants with the iPad, which is one of the latest Informational and Communications Technology (ICT) tools developed to involve students with their lessons. Technology is today's major link between pedagogy and current, ever-evolving content. With the ability to individualize instruction, provide immediate feedback, and incorporate the three basic learning styles (visual, auditory and tactile) with auditory output, visualization, and manipulation together in a single educational event, the iPad serves well to engage learners. According to a study [3], students tend to be more apt to be on-task and

consequently have a greater chance of success when experiencing online instruction as compared to the traditional classroom presentation.

In this workshop iPad activities were demonstrated in a classroom setting. The overall objective was to use ICT procedures, including iPad apps and the use of Pasco® probeware to collect laboratory data to further develop new personalized activities for future use of the iPad.

Global Learning Objectives:

- a) Use ICT to promote and conduct laboratory investigations on a variety of topics appropriate for introductory-level chemistry.
- b) Use ICT to collect and organize qualitative and quantitative data and make measurements with accuracy and precision using tools such as data-collecting sensors (probes).
- c) Use ICT to identify and explain the process of naming and writing ionic compounds containing main group or transition metals, covalent compounds, acids, and bases, using IUPAC nomenclature rules.
- d) Modify classroom modules for demonstration purposes.
- e) Develop classroom ready modules to be shared with workshop participants.

DESCRIPTION

The purpose of this workshop is to equip chemical educators with practical activities and logistical training to include ICT into their chemistry curriculum. During this workshop, participants gained hands-on experience using technology such as iPads and a variety of interfaces and sensors (probes) bundled with computer-based activities for chemistry and general science. Participants will gain familiarity with the general chemistry modules, learn about logistics related to implementation, and develop new activities for future use.

Required Materials: iPads, Apps, and Sensors

The workshop was attended by 25 participants. These learners self-selected into groups of 3-5 educators from five countries (Ethiopia, Kenya, Egypt, Russia, and the United States of America). Six iPads preloaded with the following apps were provided to the workshop participants. (Costs reflect prices for fall 2013.)

Name Seller CostProductivity

Dropbox	Dropbox Inc.	Free	
GoodReader	Good.iWare Ltd	\$4.99	
Noteshelf	Ramki	\$5.99	
Penultimate (Alternate to Noteshelf)	Evernote	\$0.99	
Keynote	Apple	\$9.99	
Pages	Apple	\$9.99	
eTextbooks	CourseSmart, LLC	Free	
Educreations	Educreations, Inc.	Free	
ShowMe	Easel	Free	
Graphical	Vernier	\$2.99	

Chemistry

Chem Lab	Brian West	\$0.99	
The Elements (Gray's Periodic Table)	Element Collection, Inc.	\$6.99	
NOVA Elements	PBS	Free	
Molecules	Sunset Lake Software	Free	
Mobile HyperChem	Hypercube, Inc.	Free	
ChemDoodle Mobile	iChemLabs, LLC	Free	
Lewis Dots	Carlo Yuvienco	Free	
AtomsInMotion	Atoms In Motion	\$2.99	
Salts: atoms, ions, electrons	Atoms In Motion	\$2.99	
GasLawsHDLite	T. J. Fletcher	Free	
Elemental	Dotmatics Limited	Free	
MahjongChem	Stetson University	Free	
ACS Mobile	American Chemical Society	Free	

Participants also had opportunities to experience the following Pasco® sensor: Advanced Chemistry Sensor, which includes a temperature probe, pH probe, conductivity probe, and a built-in pressure probe. Some of the laboratory activities are structured and others unstructured.

Schedule and Activities

Intended participants: Educators interested in teaching laboratories concerned with chemistry concepts. Science teachers at the pre-university and university levels (e.g., secondary teachers, university professors, lecturers, staff members, etc.)

Objectives:

- (1) Use ICT to promote and conduct laboratory investigations on a variety of topics.
- (2) Use ICT to collect and organize qualitative and quantitative data and make measurements with accuracy and precision using tools such as data-collecting probes.
- (3) Use ICT to identify and explain the process of naming ionic compounds containing main group or transition metals, covalent compounds, acids, and bases, using IUPAC nomenclature rules.
- (4) Use ICT to write the chemical formulae of common ionic and covalent compounds, acids, and bases.
- (5) Participants will gain hands-on experience using the iPads, gain familiarity with the general chemistry modules, learn about logistics related to implementation, and develop new activities for future uses of the iPad.
- (6) Instructors will share classroom-ready modules the with workshop participants. We will also discuss how these activities can be modified for demonstration purposes.
- (7) Participants will develop new modules; these new activities can be incorporated into classes after the workshop is complete.

Agenda of Activities

- 0900-0930 Opening remarks Bob Shelton
- Session -1
- 0930-1030 Active Learning with Project iPad Bob Shelton
- 1030-1045 Break Organizers
- Session-2
- 1045-1145 Experience the Modules Bob Shelton
 MODULE 1: Understanding the Scientific Method
 MODULE 2: Flash activities on the iPad
 MODULE 3: Element Scavenger Hunt
 MODULE 4: Writing chemical formulas from names
- 1200-1330 Lunch Break Organizers
- Session-3
- 1330-1430 Explore the available Apps Bob Shelton
- 1430-1445 Break Organizers
- Session -4
- 1445-1545 Digital Laboratory Denis Zhilin
- Session-5
- 1545-1630 Developing implementation plans Bob Shelton
 Question/Answers/Wrap-up
- Session-6
- 1630-1700 Assessment Participants

LIMITATIONS

ICT tools are becoming more assessable and less expensive as supply and demand benefits increased classroom use. As compared to the updating of a static textbook, apps appropriate for teaching concepts and laboratory probeware of sensors for collecting data have several advantages beyond cost. Yes, iPads do become outdated but even older versions can be passed down to either the lower levels or to classrooms that lack in ICT tools. Internet access

with appropriate bandwidth is always problematic, but as long as the faculty is committed and willing to accept change, issues can be overcome and a positive experience provided to your students.

DIGITAL REVOLUTION

Interactions that provide learners with immediate performance feedback will engage and hence motivate students. Visualizations and animations go well beyond what has been possible in the past. As new apps and sensors become available, changes are easy to make. Technology does not make education better but what is provided is the platform for making education more meaningful for the learners involved.

REFERENCES

1. Interview with Prof. Peter Mahaffy, *African J Chem Ed*, 2011, 1(1), p. 6.
2. Shell, D. F.; Brooks, D. W.; Trainin, G.; Wilson, K. M.; Kauffman, D. F.; Herr, L. M. (2010). *The Unified Learning Model: How motivational cognitive and neurobiological sciences inform the best teaching practices* (Vol. 1). New York, NY: Springer Science+Business Media.
3. Schoenfeld-Tacher, R.; McConnell, S.; Graham, M. (2001). Do no harm—A comparison of the effects of on-line vs. traditional delivery media. *J Sci Educ & Tech*, 10, 257-265.

AFRICAN JOURNAL OF CHEMICAL EDUCATION

AJCE

GUIDELINES FOR AUTHORS

SJIF IMPACT FACTOR EVALUATION [SJIF 2012 = 3.963]

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

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

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

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

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

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

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

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

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

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

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