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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 I 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]
SATLC APPLICATIONS AS EXAMPLES FOR SYSTEMIC CHEMISTRY EDUCATION REFORM IN THE GLOBAL AGE

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ABSTRACT
Systemic Approach to Teaching and Learning [SATL] has evolved in the field of teaching and learning chemistry starting in 1997, as a fruitful cooperation between Fahmy, AFM (Egypt) and Lagowski, JJ (USA). It is focused on the students and their good teaching and learning and encompasses instruction that encourages active learning, reciprocity and cooperation between students, and between students and their local and global contexts. It is also used as a vehicle to engage the students in a deep learning that focuses on relating ideas and making connection between new and prior knowledge. As applications of SATLC I present here systemic chemistry related units experimented in Egyptian secondary schools and universities with examples on systemic assessment. [AJCE 4(2), Special Issue, May 2014]
INTRODUCTION

After the wide spread of systematization in various activities including tourism, commerce, economy, security, education, health etc., and after globalization became a reality that we live and survive with its positive and negative impacts on our life, and after the current educational systems deals quite intensively with the impact of the “globalization’ on educational planning and decision making, SATL became a must for preparation of citizens. SATL is a new way of teaching and learning, based on the global idea that nowadays everything is related to everything [1-5]. It is considered as a way of teaching and learning that intensify deep learning which differs from surface learning that focuses on rote memorization and superficial understanding of concepts. The following table (1) shows the comparison between students achievements and outcomes when they treated by either DLA (deep learning approach) or SATL strategies.

<table>
<thead>
<tr>
<th>Deep Learning Approach [DLA]</th>
<th>Systemic Approach to Teaching and Learning [SATL]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables student to do the following;(6)</td>
<td>Enables student to do the following ;(5)</td>
</tr>
<tr>
<td>1.Retain Knowledge and apply it in new and different contexts.</td>
<td>1. Retain knowledge and apply it in a new global context.</td>
</tr>
<tr>
<td>2.Focus on relating ideas and making connections between new and prior knowledge.</td>
<td>2. Focus on relating concepts and making interconnections between them and between prior knowledge.</td>
</tr>
<tr>
<td>3.Come to see concepts, ideas and/or the world differently.</td>
<td>3. See the relations between concepts beside concepts in a pattern of cognition.</td>
</tr>
<tr>
<td>4.Engage in independent, critical, analytical thinking in a quest of personal meaning.</td>
<td>4. Engage students in analytic- synthetic thinking [systemic thinking] enable them to solve the daily life systemic problems.</td>
</tr>
<tr>
<td>5.Engage in active learning by interacting with others and course material in learning.</td>
<td>5. Engage in active learning by interacting with themselves, and with teachers and course materials.</td>
</tr>
<tr>
<td>6.Rely on intrinsic motivation to learn.</td>
<td>6. Rely on the ease of teaching and learning to increase motivation of students to learn.</td>
</tr>
</tbody>
</table>
From the above mentioned table we can say that SATL strategy coincides with deep learning strategy in most of the above mentioned items. So SATL strategy covers deep learning strategy, i.e., student treated with SATL will go in a deep learning. However, DLA doesn’t cover all aspects of SATL strategy.

WHY SATL IN CHEMICAL EDUCATION REFORM? [2]

SATL:
1. Helps students to understand interrelationships between concepts in a greater context.
2. Engages students in a deep learning.
3. Assures that students attain the major goals of education helping them to acquire the higher order cognitive skills.
4. Provides new forms of educator evaluation that include outputs (student learning results) in addition to inputs.
5. Provides the basis for systemic thinking.

WHAT IS THE MEANING OF SATL?

By "systemic" we mean an arrangement of concepts or issues through interacting systems in which all relationships between concepts and issues are made clear up front to the teachers and learners in contrast to the usual linear method of teaching the same topics. In systemic chemistry education we arrange the course content materials in a systemic way [5]. This means arrangement of concepts or issues through interacted systemic in which all relationships between concepts and issues are clear (Fig.1).
Fig.1: The idea of systemic arrangement of chemistry course materials

However, linear presentation of chemistry course materials means arrangement of chemistry issues and concepts in a sequential presentation as in (Fig.2).

Fig.2: The idea of linear arrangement of chemistry course materials

In practice, the systemic building strategy allows the teacher to build up sequentially a single concept map starting with prerequisite concepts required for the student before he/she starts on a systemic approach to learning. Fig.3 shows this systemic strategy for building the closed cluster of chemistry concept maps (systemic; SD1-SD5) involving the five concepts entitled E, F, X, Y, Z (2).
Figure 3. The evolution of a completed closed chemistry concept cluster from a starting point

The instructor has in mind the concept linear structure shown in Figure 2, which he/she wants to develop into the closed cluster (systemic) shown as Figure 1. The prerequisites are simple bi-directional relationships between the concepts. Thus, initially, there are four unknown (to the student) relationships in the final cluster of concepts (Fig. 3). The full closed cluster concept map [SD5] can be developed in four stages by sequentially introducing the (initially) four unknown concepts. At each step another part of the final closed concept cluster is added and developed. This process clearly illustrates the systemic constructivist nature of systemic arrangement of the course content materials. This building strategy could be used in teaching different branches of chemistry.
SATL EXPERIMENTS IN EGYPT

We have conducted numerous experiments in Egypt which we attempted to establish the effectiveness of SATL methods not only in chemistry, but also in other basic sciences, medicinal sciences, engineering sciences, agriculture, and pharmaceutical sciences. In chemistry we conducted a series of successful SATL-oriented experiments at the pre-university and the university levels of education. We have created SATL units in General, Analytical, Aliphatic, Aromatic, Green, and Heterocyclic Chemistry. These units have been used in Egyptian universities and secondary schools to establish the validity of the SATL on an experimental basis.

I-PRE-COLLEGE EXPERIMENTS

Our experiments probing the usefulness of SATL to learning Chemistry at the pre-college level was conducted in Egypt at Cairo and Giza school districts.

I-1-SATL CARBOXYLIC ACIDS AND THEIR DERIVATIVES

Our initial experiment probing the usefulness of the SATLC to learning chemistry was conducted at the pre-college level in the Cairo and Giza school districts [5]. Nine SATL-based lessons in organic chemistry (Fig. 4) taught over a two-week period were presented to a total of 270 students in the Cairo and Giza school districts. The achievement of these students was then compared with that of 159 students taught the same material using linear methods (Fig. 5).
Fig. 4: Systemic based Teaching and Learning material

The results indicate that a greater fraction of students exposed to the systemic techniques, the experimental group, achieved at a higher level (Fig. 6) than did the control group taught by conventional linear techniques (Fig. 7).
Fig. 6: Percent of students in the experimental classes who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the systemic intervention period.

Fig. 7: Students in the control classes who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the linear intervention.
The experimental group was taught by SATL-trained teachers using SATL techniques with specially created SATL materials, while the control group was taught by traditional teachers using the conventional (linear) approach with the conventional materials.

I-2:- SATL-CLASSIFICATION OF ELEMENTS

Our second experiment about the usefulness of SATL to learning Chemistry at the pre-college level was conducted in the Cairo and Giza school districts. Fifteen SATL-based lessons in inorganic chemistry taught over a three-week period were presented to a total 130 students. The achievement of these students was then compared with 79 students taught the same material using standard (linear) method. The periodicity of the properties within the linear horizontal periods and within the vertical groups in the periodic table was illustrated systemically [5, 7].

LINEAR AND SYSTEMIC PERIODS

In the periodic table the graduation in properties are studied in a linear method from left to right increasing or decreasing.

e.g.: In period -2: The linear graduation of the properties in the second period starting from lithium to neon increasing or decreasing as in (Fig.8).

<table>
<thead>
<tr>
<th>Li</th>
<th>Be</th>
<th>B</th>
<th>C</th>
<th>N</th>
<th>O</th>
<th>F</th>
<th>Ne</th>
</tr>
</thead>
</table>

Fig.8: Linear Period .2 [LP-2]

But in systemic period-2: The graduation in the properties is studied systemically starting from any element in the period to any other element as shown in the (Fig.9).
It shows increasing or decreasing in the given property (?) on moving from one element to another through the systemic period. The systemic period [SP] is characterized from the linear period [LP] in the following:

1- Find a relation between any element of the period and all the other elements.

2- Solve the abnormality in the periodicity of some properties because it finds the relation between each element and the next element in a certain property till the end of the period.

**e.g.: Periodicity of electron affinity**

The electron affinity increases by increasing atomic number with the exception of Beryllium, Nitrogen and Neon. (table.2)

**Table.2**: Periodicity of electron affinity in linear period-2 [LP-2];

<table>
<thead>
<tr>
<th>Li</th>
<th>Be</th>
<th>B</th>
<th>C</th>
<th>N</th>
<th>O</th>
<th>F</th>
<th>Ne</th>
</tr>
</thead>
<tbody>
<tr>
<td>-58.5</td>
<td>+66</td>
<td>-29</td>
<td>-121</td>
<td>+31</td>
<td>-142</td>
<td>-332</td>
<td>+99</td>
</tr>
<tr>
<td>↓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(abnormal)</td>
<td>(abnormal)</td>
<td>(abnormal)</td>
<td>(abnormal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
However, the periodicity of electron affinity in the systemic period -2 [SP-2] shows that the relation takes place between any two elements from the point of electron affinity as in Fig.10.

Fig. 10: Periodicity of electron affinity in systemic period -2 [SP-2]

As the (-ve) value increases the amount of energy released increases so the electron affinity increases.

GENERAL SHAPE OF THE SYSTEMIC PERIODS [GSP]

Generally the systemic period (SD-P) can be drawn as follow.

Fig. 11: Periodicity of properties in general systemic period (GSP)
LINEAR AND SYSTEMIC GROUPS

The graduation in the properties through groups in the periodic table are studied in linearity from top to bottom as shown in the general linear group (Fig. 12)

<table>
<thead>
<tr>
<th>EP1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EP2</td>
<td></td>
</tr>
<tr>
<td>EP3</td>
<td></td>
</tr>
<tr>
<td>EP4</td>
<td>Increasing Or decreasing</td>
</tr>
<tr>
<td>EP5</td>
<td>E = element</td>
</tr>
<tr>
<td>EP6</td>
<td>P = period</td>
</tr>
<tr>
<td>EP7</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 12: Periodicity of properties in general linear group (GLG)

But in case of systemic group the graduations in the properties are to be studied systematically starting from any element to another. It can be represented by the following systemic diagram of GSG as shown in Figure (13).

Fig. 13: General Systemic Group (GSG)

The characteristics of the systemic groups are the same as in the systemic periods.
Example

Periodicity of properties of (atomic radius - Ionization potential - electro negativity) through systemic group (SG-1)

![Periodicity of some properties in SG-1](image)

The results of experimentation indicated that a greater fraction of students exposed to systemic techniques in the experimental group achieved at a higher level than did the control group taught by linear techniques. The overall results are summarized in Figs. 15 and 16.

![Percent of students in the experimental groups who succeeded](image)

Fig.15: Percent of students in the experimental groups who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the systemic intervention period.
Conclusions: Our results from the Secondary Level experiment point to a number of conclusions that stem from the qualitative data, from surveys of teachers and students, and from anecdotal evidence.

1. Implementing the systemic approach using one unit of general chemistry within the course has no negative effects on the ability of the students to continue their linear study of the remainder of the course using the linear approach.

2. Teachers from different experiences, professional levels, and ages can be trained to teach by the systemic approach after a short period of training.

3. After the experiment both teachers and learners retain their understanding of SATL techniques and continue to use them.

II-UNIVERSITY EXPERIMENTS

II-1:-SATL-ALIPHATIC CHEMISTRY

A study of the efficacy of systemic methods applied to the first semester of the second year organic chemistry course (16 lectures, 32 hours) at Zagazeg University was conducted. The
experiment was conducted within the Banha branch, Faculty of Science, Department of Chemistry with second year students. The experiment involved 41 students in the control group, which was taught using the classical (linear) approach; 122 students formed the experimental group, which was taught using SATL methods. The details of the transformation of the usual linear approach used to teach this subject to the corresponding systemic closed concept cluster that represents the systemic approach were presented.

**Stage-1: Linear arrangements of the chemical properties of Alkanes**

The usual linear approach used to teach alkanes involves separate chemical relationships between alkanes and other related compounds as shown in (Fig.17).

![Diagram of linear arrangement of alkanes and related compounds](image)

**Stage-2: Systemic arrangements of the chemical properties of Alkanes:**

The synthesis and chemical properties of Alkanes can be arranged systemically by changing the linear arrangement in the linear diagram (Fig.17) to systemic arrangement as illustrated in the systemic diagram (SD0) (Fig.18).
In the systemic diagram SD0 some chemical relationships are defined whereas others are undefined. These undefined relationships are developed sequentially.

**Stage-3: Systemic arrangement of the chemical properties of Alkenes**

After using the diagram shown in Fig. 18 as the basis for the study of the synthesis and reactions of alkenes, and alkynes, we can modify this systemic diagram (SD0 in Fig. 18) to accommodate chemistries of Alkenes as shown in (SD1) (Fig. 19).
Fig. 19: Systemic diagram (SD1) that represents some of the major chemistries of alkenes

**Stage-4: Systemic arrangement of the chemical properties of Akynes:**

After the study of the chemistry of Acetylene we can modify the systemic diagram SD-1(Fig.19) to SD-2 (Fig.20) by accommodating chemistry of Acetylene (Alkynes).

Fig.20: The Systemic relationship between the aliphatic hydrocarbons and their derived compounds.
Systemic diagram (SD2) shown in Figure 20 can accommodate to the chemistries of ethyl bromide and ethanol yielding a new systemic diagram.

**The results of experimentation**

Figures 21 and 22 show the final data in terms of student achievement in experimental and control groups, respectively.

Fig. 21: Average scores for experimental group before and after intervention

<table>
<thead>
<tr>
<th></th>
<th>Linear Questions</th>
<th>Systemic Questions</th>
<th>Total Exam Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Intervention</td>
<td>31.30%</td>
<td>31.00%</td>
<td>22.30%</td>
</tr>
<tr>
<td>After Intervention</td>
<td>65.60%</td>
<td>59.10%</td>
<td>62.10%</td>
</tr>
</tbody>
</table>

Fig. 22: Average scores for control group before and after intervention

<table>
<thead>
<tr>
<th></th>
<th>Linear Questions</th>
<th>Systemic Questions</th>
<th>Total Exam Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Intervention</td>
<td>33.33%</td>
<td>21.54%</td>
<td>24.38%</td>
</tr>
<tr>
<td>After Intervention</td>
<td>32.00%</td>
<td>22.73%</td>
<td>27.00%</td>
</tr>
</tbody>
</table>

The data indicate a marked difference between the control and experimental groups.
II-2: SYSTEMICS TO LABORATORY INSTRUCTION [BENIGN ANALYSIS]

We have created qualitative benign analytical chemistry course for the first-year students of Faculty of Science, Benha, Zigzag University, and Faculty of Education, Helwan University, Cairo, Egypt [8]. The Systemic based course materials were presented in 24hrs (2hrs period/ per week) From September-December 2001.

In contrast to the linear approach of learning chemistry of cations from a laboratory experience, a systemic approach has been developed that focuses attention on individual species (Fig.23).

![Fig. 23: Systemic Investigation of species A⁺(SI-Plane)](image)

The diagram shows the plane for qualitative investigation of the species (A⁺), the preparation of (A⁺) compounds, and the interconversion of the species. This laboratory instruction allows students to experience the colors of chemical species, their solubility characteristics, and their redox behavior.

Examples:

Systemic Investigation of [Bi⁺³] (SI): Bismuth Cycle

The students follow the (SI-Plane) to investigate (Bi⁺³) in a series of experiments (1-3), then recycle the product of (Exp.3) to Bi (NO₃)₃(Cf. SI-Final).
Systemic Investigation of [Cd²⁺] (SI): Cadmium Cycle

The students follow the (SI-Plane) to investigate (Cd²⁺) in a series of experiments (1-4), then recycle the product of (Exp.4) to Cd (NO₃)₂ (Cf. SI-Final).

Results of Experimentation

Applying the Systemic Approach to laboratory instruction reveals the following advantages, which constitute to the principles of benign analysis [8]:

- Smaller amounts of Chemicals are used.
- Recycling of Chemicals.
- Experiments are done with fewer hazards, and more safety.
- Experiments are done more rapidly.
- Students easily acquire a working sense of the principles of green chemistry.

Statistical data showed that the students of the experimental group are significantly improved towards the principles of qualitative Benign Analysis and achieved higher cognitive levels (Analysis, synthesis, evaluation) (Table 3).

**Table 3**: Means, Standard Deviations, (t) value and Effect Size of the results of students in the final practical observation scale for the experimental and control groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>No. of students</th>
<th>Means</th>
<th>SD</th>
<th>t  value</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>60</td>
<td>23.81</td>
<td>1.95</td>
<td>10.77</td>
<td>2.26 large</td>
</tr>
<tr>
<td>group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>effect</td>
</tr>
<tr>
<td>Control group</td>
<td>35</td>
<td>20.30</td>
<td>1.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at < 0.01

The experimentation results showed that the benign scheme reduces the consumption chemicals in comparison with the classical scheme as shown in table (4). This means low cost, and less pollution.
**Table 4**: Amount of salts needed for Experimental group (Benign scheme), and Reference group (Classic scheme)

<table>
<thead>
<tr>
<th>Salts</th>
<th>Amount required (gm / 50 Students)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Classic Scheme Solid (g)</td>
</tr>
<tr>
<td>Pb(NO₃)₂</td>
<td>100</td>
</tr>
<tr>
<td>Al(NO₃)₃</td>
<td>200</td>
</tr>
<tr>
<td>CrCl₂.6H₂O</td>
<td>200</td>
</tr>
<tr>
<td>NiCl₂.6H₂O</td>
<td>200</td>
</tr>
<tr>
<td>Co(NO₃)₂.4H₂O</td>
<td>200</td>
</tr>
<tr>
<td>CaCl₂.5H₂O</td>
<td>150</td>
</tr>
<tr>
<td>BaCl₂.2H₂O</td>
<td>200</td>
</tr>
<tr>
<td>MgSO₄.7H₂O</td>
<td>200</td>
</tr>
</tbody>
</table>

**CONCLUSION**

- SATLC improved the student’s ability to view the chemistry from a more global perspective.
- SATLC helps the students to develop their own mental framework at higher-level cognitive processes such as application, analysis, and synthesis.
- SATLC increases student’s ability to learn subject matter in a greater context.
- SATLC increases the ability of students to think systemically.
- SATLC in Egypt could be used as a successful model for teaching and learning Chemistry in other African countries.

**IV-SYSTEMIC ASSESSMENT [9]**

Systemic Assessment is a new tool to assess student achievement.

- It measures the cognitive structure from the cumulative (quantitative) to the interactive and tuned (qualitative).
- Assess students higher-order thinking skills in which students are required to analyze, synthesize, and evaluate.
- Measures the students’ ability to correlate between concepts.
- Develop the ability to think systemically, critically and creatively, to solve problems.

**IV-1-Types Systemic Assessment Questions: [SAQ, s]**

1- Systemic Multiple Choice Questions [SMCQ, s].

2-Systemic True, False Questions [STFQ, s].

3-Systemic Matching Questions [SMQ, s].

4-Systemic Sequencing Questions [SSQ, s].

5-Systemic Synthesis Questions [SSynQ, s].

6- Systemic Analysis Questions [SAnQ,s].

We will illustrate examples on the first three types.

**IV-1-1: Type-1: Systemic Multiple Choice Questions [SMCQ, s]**

Form (I): Choose From Triangular Systemic:

Put (√) in front of the correct systemic diagram:

**Examples**

Q1. The systemic diagram represents the correct chemical relations between (Na) and its related compounds are one of the following:
Answer: (a) √

Form (II): Choose From Quadrilateral Systemic:

Put (√) in front of the correct systemic diagram

Q2. The systemic diagram represents the following reactions sequence.

[Substitution –Substitution- Elimination –Addition-] is one of the following:

Answer: (a) √
IV-1-2: Type-2: Systemic True False Questions [STFQ, s]

STFQ, s are well suited for testing student comprehension, synthesis and analysis, and require a student to assess whether the systemic is true or false.

Form-I: Choose From Triangular Systemics

Examples

Answer: True systemics (b, d) (√); False Systemics (a, c) (X).
Form-II: Choose from Quadrilateral Systemics

Q-2 : Which of the following systemics are true and which are false?

Answer: True systemics (a, c) (✓); False Systemics (b, d) (X)

IV-1-3: Type.3: SYSTEMIC MATCHING QUESTIONS: [SMQ, s]

Form I: Matching on Trigonal Systemics

Q1: Choose aliphatic compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C).
### Form II: Matching on Quadrilateral Systemics

Q2) Choose elements and compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C):

<table>
<thead>
<tr>
<th>(A)</th>
<th>(C)</th>
<th>(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td></td>
<td>H₂O</td>
</tr>
<tr>
<td>KOH</td>
<td></td>
<td>O₂/heat</td>
</tr>
<tr>
<td>NaCl</td>
<td></td>
<td>CO₂</td>
</tr>
<tr>
<td>Na₂CO₃</td>
<td></td>
<td>HCl</td>
</tr>
<tr>
<td>NaNO₃</td>
<td></td>
<td>Electrolysis</td>
</tr>
<tr>
<td>Na₂O</td>
<td></td>
<td>HNO₃</td>
</tr>
<tr>
<td>NaOH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Form (II): Choose From Quadrilateral Systemic:

Put (√) in front of the correct systemic diagram

Q2. The systemic diagram represents the following reactions sequence.

[Substitution –Substitution- Elimination –Addition-] is one of the following:

**Answer:** (a) √
REFERENCES

6. Final report (2011). The task force on innovative teaching practices to promote deep learning at the University of Waterloo.
WHAT MAKES CHEMISTRY DIFFICULT?

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ABSTRACT
According to many students, introductory chemistry is difficult. We are investigating what makes students believe Chemistry is difficult and what can be done to overcome these difficulties. Our investigation includes an initial Free-response survey given to approximately 100 students in an introductory chemistry course and a second survey, which was given to approximately 93 students in another semester, distilled from the responses to the first survey. Also Department members and technical assistants (TAs) for chemistry courses were asked to complete the second survey. Our findings show that the perceptions of the students and department members are different in terms of difficulties which students have in a chemistry course. The perceptions of teachers and TAs are mostly the same. Both students and department members agree that student-related factors, such as scientific language literacy have the most influence on students’ successes in chemistry. [AJCE 4(2), Special Issue, May 2014]
INTRODUCTION

Many students from secondary schools to universities in many countries struggle to learn chemistry and many do not succeed [1]. Research has shown that many students do not correctly understand fundamental chemistry concepts [2]. And also many of the scientifically incorrect ideas held by the students go unchanged from the early years of the schooling to university and sometimes beyond [3]. By not fully and appropriately understanding fundamental concepts, many students have trouble understanding the more advanced concepts that build upon these fundamental concepts [4].

Many high school and university students experience difficulties with fundamental ideas in chemistry [5]. Despite the importance of the foundation of chemistry, most students emerge from introductory courses with very limited understanding of the subject [6]. Chemistry had been regarded as a difficult subject for students by many researchers, teachers and science educators [7-8] because of the abstract nature of many chemical concepts, teaching styles applied in class, lack of teaching aids and the difficulty of the language of chemistry. All these cause students, from primary level to the university, to develop poor understanding and misunderstandings. Misunderstanding of concepts in chemistry has attracted attention over the last three decades [9-13]. A number of studies have been conducted on different topics in chemistry [14-15], and in other areas such as biology, physics, or in general, in science [16-19].

An examination of studies on students’ learning of basic physical and chemical concepts clearly demonstrates that most of the basic concepts were poorly learned [20-21]. More research needs to be done to identify what sort of difficulties students face in the learning of physical and chemical concepts. Learning difficulties are important for both teaching and learning. Both science educators and cognitive researchers agree that efforts to understand and improve science
education should be focused on fundamentally important knowledge domains [22]. Hence, it has been concluded that it is worthwhile to conduct a research study about chemistry undergraduates’ learning difficulties.

PURPOSE OF THE STUDY AND RESEARCH QUESTIONS

The purpose of this study was to identify and classify the chemistry undergraduate learning difficulties and to determine the reason why students find these topics/concepts difficult. More specifically, the following research objectives were sequentially investigated:

a. Identify and classify the learning difficulties experienced by chemistry undergraduate introductory students in Ethiopia.

b. Determine the reasons why students, instructors and laboratory technicians find principles identified in phase I of this investigation difficult to learn.

The specific question that guides this study is “What makes chemistry difficult in selected universities in Ethiopia and what are the factors that make these difficulties?” In addressing this question, the research considered the following sub-questions:

1. What are the learning difficulties in introductory chemistry undergraduate students in Ethiopia?

2. Where do these learning difficulties arise? What are their sources?

METHODOLOGY

Research Context

The introductory chemistry course for chemistry majors is offered in the fall, first semester, and summer semesters of the Dire Dawa and Haromaya universities in Ethiopia. The
number of students varies each semester. The course includes three 50-minute lectures, one two-hour recitation in which students work on conceptual and numerical problems, and one two-hour lab every other week consisting of concept pretests on the web, hand-written homework, reading quizzes on the web, and discussion quizzes in the recitations sessions. Teaching Assistants (TAs) are available in a help center during weekdays and weekends. Old exams and lecture notes can be obtained from the course website.

Data Collection

The Initial Survey

We administered a one-page free-response survey to approximately 100 students in reaction sessions near the end of the fall semester. The students were asked to write five responses to each of the two questions: (i) what makes chemistry difficult? And (ii) what can be done to overcome these difficulties?

After examining all students’ responses, we separated the most common replies into three categories: (i) factors that were environmental related, (ii) factors that were course-related, and (iii) factors inherent to students, and (iv) factors that are staff-related.

The Second Survey

The second survey listed the 10 most popular items in each of the four categories noted above. We asked about 100 students in first semester as well as 12 chemistry staff members with experience teaching the course, and three TAs of the course to choose the five most important items in each of the three categories. In addition we asked which of the categories has or should have the most influence on success in a chemistry course. Of the 100 students surveyed, 93
replied. Six of the 12 staff members replied and 3 teaching assistants replied. Responses of each group are listed expressed in diagrammatic representation as a result of this study.

RESULTS

There were several areas which staff members and students, and TAs and students agreed. Also there were differences in some areas. We categorized the perception of instructors, students and technical Assistance with the following for perceptions and discussed each area separately:

- **Learning environment related**
- **Course related**
- **Student related**
- **Staff related**
Figure 2: Lecturers and TA perception of learning difficulties in chemistry
Figure 3. Students' perception of solutions to learning difficulties in chemistry.
DISCUSSIONS

This study looked at the student and staff perceptions of students’ learning difficulties in Chemistry and their possible solutions. Some of the results from this study confirm the results of a previous study [23] on what makes physical chemistry difficult as related to the perception of Turkish chemistry undergraduate students. The result was similar to another study [24] that explored students’ conceptions of equilibrium and fundamental thermodynamics concepts in college Physical chemistry of the University of North Colorado. The results have some similar contextual function with the major exception such as the fourth factors learning environmental
style was considered explicitly in this research in addition of confusing the technical meaning and ordinary meaning of chemical function, lack of resource, numeracy skills, scientific language, overcrowded class, staff economic condition, teachers ego-stocking, specific feedback questions and scientific reasoning. Whereas these explicit factors were highly reflected on Ethiopian students, they were not considered for the Turkish and North Colorado universities.

Although it is not appropriate to generalize from a single study, the findings suggest that students and staffs sometimes perceive the learning difficulties differently. The results showed that lecturers and students were partly in agreement on the students’ learning difficulties which are related to the course, and there were discrepancies about student and staff related difficulties as well as some course related difficulties. Students were critical of the course content, the resources available, the lecturers and their teaching methods. However, only a few students blamed themselves that they do not do the work on their side.

Lecturers generally focused on the factors that are related to the course, such as overcrowded classes, lack of resources and staff, and indirect factors, such as student background and socio-economic conditions. Lecturers partly blamed themselves as well. The findings suggest that there is a great deal of discrepancy between staff and student perceptions, although some points about the course related difficulties were shared by both sides. These common points and discrepancies may be used to improve the quality of teaching and learning.

Among the students’ difficulties, the abstract nature of the chemical concepts was a common theme. This is also recognized by the lecturers. The other difficulty which is related to the nature of the subject, or general chemistry, was the mathematical content of the course. One in three students perceived Chemistry as too mathematical.
The remainder of the difficulties relating to the course focused either on teaching methods or the physical conditions of the teaching environment. The lecturers generally emphasized the difficulties relating to the poor teaching environment which prevents better teaching. However the interview data suggests that the lecturers have not given sufficient thought to how students learn, despite the large amount of literature on that issue, for example [23-24]. This might be due to staff’s lack of pedagogical content knowledge (PCK). It seems from the students’ concerns and proposed solutions that there is a demand for the pedagogical aspects of teaching and learning to be considered. For example, propositions such as promoting group work and discussions, motivating students, using educational technology in teaching, focusing on conceptual understanding, establishing consistency between the exams, the lectures and the laboratory, as well as promoting student-centered teaching, may help to achieve better understanding.

The findings for this study suggest that of the four potential issues indentified in Ethiopian student situation (namely, Numeracy, Scientific Reasoning, the use of Scientific Language, Teacher’s ego-stroking and Classroom Climate), Numeracy is the major issue for students studying Chemistry. Low performance in Scientific Reasoning tasks also is an issue, but this probably influenced at least in part by the numeracy issues that underpin some of the reasoning skills problem items used in the instrument. In addition both students and lectures view scientific language literacy can change classroom climate.

The research presented here allows for some solution for the particular educational context in which this study was completed Dire Dawa and Haromaya universities). In light of the interpretive nature of this inquiry, it is also possible that these findings may serve to inform other practice in different, but related educational contexts [25-26]. As is the case in any interpretive-
based work, it is up to the reader to best judge the veracity of any transferability of research findings into his or her own educational context. These recommended solutions for what makes chemistry difficult are provided in the light of the above comments.

RECOMMENDATIONS

- Students who just meet the university entry requirement could be subject to a departmental diagnostic test (the design of which is informed by the above study) to be conducted in the first week. The purpose of this test is not to exclude students, but to identify the specific areas in which they need help.

- At risk students should be required to attend additional tutorials (on say a fortnightly basis) which target basic skills identified.

- If students were identified as being weak in a specific area, say numeracy, they could attend remedial tutorials in numeracy rather than academic content (which have in the past proven unsuccessful). But students for whom numeracy was not a problem, but who struggled with scientific language literacy might benefit from tutorials that were targeted to such learning difficulties.

- A student’s learning style has to do with the way he or she processes information in order to learn it and then apply it.

- Providing a variety of approaches to the material can keep most of the students engaged in the class throughout the semester.

- A dominant “academic culture” exists in college classrooms which encourages sequential, verbal and reflective learners to progress quickly to advanced positions in a
field. It is thus important to “fit” once teaching techniques to both your course objectives and to students’ varied learning styles.

- Teacher’s behavior is an important determinant in the establishment of a safe or comfortable climate. Be aware of the fact that comments that are not fully explained invoke stereotypes or promote inaccurate conclusions. Beware that rapid acceptance of a correct answer favors the faster thinker/speaker.

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1. Reid.L.(2008).Identifying threshold concepts in geosciences; Taking inventory with students and faculty alike .threshold concepts .from theory to practice conference Queen’s University,Kingston.ON.1
THE DEVELOPMENT OF A NEW CHEMISTRY CURRICULUM IN THE NETHERLANDS: INTRODUCING CONCEPT-CONTEXT BASED EDUCATION

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ABSTRACT
This paper describes the recent changes in chemistry education in secondary school in the Netherlands. The way these changes came about is described as well as the development of the current curriculum. An example of a module, demonstrating the current features of chemistry teaching in the upper level of secondary school is given. [AJCE 4(2), Special Issue, May 2014]
INTRODUCTION

The educational system in the Netherlands underwent a major change in 1998. Up to then students in secondary education took a final exam in 7 subjects. The subjects Dutch, English, and Mathematics were compulsory. These subjects are considered to be basic knowledge that each student should have after finishing secondary education. The other 4 subjects were almost completely free of choice. If students choose the subject Chemistry, students followed on the average 3.5 50 minute lessons of chemistry per week during their last three years. The chemistry curriculum was set up broadly focusing mainly on inorganic chemistry, with a short introduction into first and second law of thermodynamics and some organic chemistry.

MAJOR CHANGES IN SECONDARY EDUCATION

In 1998 four majors were introduced, of which two were society-oriented and two were science-oriented. At the same time the number of subjects to be studied was increased to 14 in the last 3 years. For all subjects this lead to major changes in the curriculum. Most specifically in the amount of time available for each subject. Chemistry went back from 3 or 450-minute lessons per week to about 250-minute lessons per week in the final three years. Because of this time limit a number of subjects were deleted from the curriculum. Examples of scratched subjects are reaction mechanisms in organic chemistry, but also the concept of free Energy was no longer part of the curriculum.

The change led to major problems for teachers [1]. Teachers had difficulty adapting to the new chemistry curriculum, which was determined top down. They felt the curriculum was not set up logically. They disagreed with the deletions and were basically disappointed with the
reduction in time for their subject. They then ran into time problems because they tried to teach all the concepts of the old curriculum in about half the time.

**Identification of the problems**

Based on these first developments the ‘first van Koten committee’ was asked to identify the current problems with chemistry education in pre-university education [2]. One of the most important conclusions was that the chemistry curriculum in secondary schools was outdated. It was still based on the original curriculum of 1848, when chemistry was first introduced in secondary education in The Netherlands. Furthermore, there was virtually no link with the role of chemistry in society today and the curriculum did not give an overall picture of the type of research being done in universities. On the other hand, less and less students chose a science-oriented major in secondary education.

In a next report the ‘second van Koten committee’ proposed a set of recommendations for a new chemistry curriculum [3]. Van Koten was then asked to prepare a new chemistry curriculum. This new curriculum was published in 2010 [4] and in 2011 accepted by the Ministry of Education. Since September 2013 this chemistry curriculum is implemented in the upper level of secondary schools.

**THE NEW FORMULATED CHEMISTRY CURRICULUM**

The new chemistry curriculum is implemented in the last three years of the upper-level of pre-university secondary school. The curriculum consists of several modules. The new curriculum has a number of basic principles. It:

- is context oriented
• connects macroscopic phenomena to the molecular and atomic level
• demonstrates the role of chemistry in society
• introduces contemporary research in the classroom
• focuses on ‘scientific literacy’, thereby focusing not only on content but also on attitudes and skills

In table 1 the major topics of the new chemistry curriculum are indicated, in table 2 an indication of the competencies is presented. Apart from these competences students should learn aspects of the Nature of Science, including doing research, designing and the use of models.

Table 1. Major topics of the new chemistry curriculum for pre-university chemistry education (unpublished material SLO)

<table>
<thead>
<tr>
<th>Core concepts</th>
<th>concepts</th>
<th>Short description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matter</td>
<td>Models</td>
<td>A model that explains the structure of matter</td>
</tr>
<tr>
<td></td>
<td>Chemical bonds</td>
<td>All electromagnetic interaction between particles</td>
</tr>
<tr>
<td></td>
<td>Intrinsic properties</td>
<td>Properties that can be used to recognize matter (includes things like hydrophilic/ hydrophobic, acid/base properties etc.)</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>Defines the amount of matter</td>
</tr>
<tr>
<td>Scale/ proportion/ amounts</td>
<td>Chemical calculations</td>
<td>Stoichiometry, pH, ppm, excess</td>
</tr>
<tr>
<td></td>
<td>Energy calculations</td>
<td>Enthalpy of formation</td>
</tr>
<tr>
<td></td>
<td>Chemical analysis</td>
<td>Techniques used to acquire qualitative and quantitative data</td>
</tr>
<tr>
<td>Reactivity</td>
<td>Chemical processes</td>
<td>All types of reactions but also cycles, like carbon cycle</td>
</tr>
<tr>
<td></td>
<td>Design principles</td>
<td>Life cycle analysis, cradle to cradle</td>
</tr>
<tr>
<td>Production processes</td>
<td>Chemical technology</td>
<td></td>
</tr>
<tr>
<td>Chemical equilibrium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinetics</td>
<td>Reaction mechanisms</td>
<td>Includes simple organic chemistry</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td>Safety regulations when working in the lab</td>
</tr>
<tr>
<td>Energy</td>
<td>Energy change</td>
<td>Converting energy from one form into the other</td>
</tr>
<tr>
<td></td>
<td>First law of thermodynamics</td>
<td></td>
</tr>
<tr>
<td>Systems</td>
<td>Sustainability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structure/ property relationships</td>
<td>Different structures in matter, proteins/ different grids/ polymers</td>
</tr>
</tbody>
</table>
Table 2. Core competencies in the new curriculum

<table>
<thead>
<tr>
<th>Acquiring chemical knowledge</th>
<th>Using experiments and other research techniques and models to acquire new knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communicating about chemistry</td>
<td>Acquire information from different sources and exchange information at different levels, using and understanding chemical terminology</td>
</tr>
<tr>
<td>Developing chemical knowledge</td>
<td>Using and relating chemical phenomena, concepts, patterns, laws to problems</td>
</tr>
<tr>
<td>Using and valuing chemical knowledge</td>
<td>Recognizing and using chemical knowledge in opinions about societal issues</td>
</tr>
</tbody>
</table>

The Development of the Chemistry Curriculum

In 1998 teachers did not really participate in the development of the curriculum. One of the conclusions of the van Koten committee was that it was essential to have the curriculum developed bottom-up. Teachers would identify themselves that way more with the new curriculum. Enough time was taken in order to involve the teachers in the development processes. The new chemistry curriculum was developed over a period of 10 years. As no educational material was available, this material was developed by groups of teachers, working in close cooperation with educational experts connected to teacher training at a university (‘community of learners’). The results of these experiments were discussed regularly in regional conferences where a majority of the teachers were present.

Few principles were decided beforehand as starting points for the work with the new curriculum. Apart from the principles mentioned above (context oriented, micro-macro etc.) a certain pedagogy was decided upon.

Chemistry in Context

In pedagogy Kansanen [5] introduced the didactic triangle (figure 1). The didactic triangle discusses the need for novice teachers to learn not only scientific content, but also the way they can guide the learning process of the student. In the triangle this relationship is
depicted. At the center of the triangle is pedagogical content knowledge, which is basically the knowledge needed to teach a certain content. Mahaffy [6] coined the term ‘tetrahedral’ chemistry education, by introducing a third dimension to the triangle. He called the third dimension the human element. We called that third dimension the context. Here context “is essentially conceived in terms of a socio-cultural setting, calling for tool-mediated actions, operations, and goals that are to be valued in the framework of that activity’[7, p.481].

We have defined a context to be an authentic situation in daily life involving chemistry. Context can also be placed in an industrial setting or a research setting, as long as the situation is authentic.

![Diagram of the didactical triangle and the tetrahedral chemistry education](image)

**Figure 1.** The schematic representation of the didactical triangle (A) and the Tetrahedral chemistry education (B)

**Pedagogy in ‘Chemie im Kontext’ (CHIK)**

In order to formulate a curriculum educational material was developed by the Community of Learners. This material was organized in modules that took in time about 12 lessons each. In table 3 the modules used in one group of teachers are given, identified by the context they started out with.
Table 3. Titles of modules used in a pre-university school.

<table>
<thead>
<tr>
<th>Period</th>
<th>10th grade</th>
<th>11th grade</th>
<th>12th grade (final year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Perfume (esters, alkenes and alcohols)</td>
<td>Sweetener (stereochemistry, biotechnology, peptides)</td>
<td>Chemistry in the mouth (pH, receptors, crystal structure of enamel, filling materials)</td>
</tr>
<tr>
<td>2</td>
<td>Growing (salts and pesticides)</td>
<td>Green Chemistry</td>
<td>Gasification (technology, fuels, storage of CO₂)</td>
</tr>
<tr>
<td>3</td>
<td>Eco travel (chemical calculations)</td>
<td>Energy to go (redox)</td>
<td>Extra module</td>
</tr>
<tr>
<td>4</td>
<td>Medicine (influence of pH on properties of organic compounds)</td>
<td>Smart materials, new materials, playing a role in solar cells</td>
<td>Training for final exam</td>
</tr>
<tr>
<td>5</td>
<td>Nobel prize (atomic models and Periodic Table.)</td>
<td>Sport en chemistry, (polymers and biological energy)</td>
<td>Antibiotics</td>
</tr>
</tbody>
</table>

The modules produced were at first based on the pedagogical model introduced by ‘Chemie im Kontext’ developed at the University of Oldenburg and IPN in Kiel [8]. In this context-oriented program four phases can be determined, in which different sides of the tetrahedron are facing forward. In the preliminary phase, in which the module is designed, the side with teacher, context and chemistry content is facing forward. (See figure 2.)
In the first phase of teaching, the Introduction phase the side with the teacher, context, and student is facing forward. In this phase the context is introduced. In the second phase, called the curiosity or planning phase, the student is studying the chemistry within the context (Figure 2C). In the third phase the elaboration phase, the teacher and student are working on the chemistry determined in the second phase to answer the questions posed in phase 2 (Figure 2D). In the last phase the contemplation phase the chemistry learned in phase 3 is scaffolded and linked to existing knowledge (figure 2D).

The teachers were completely free in choosing the context and the chemistry involved. One of the changes that occurred was that subjects in chemistry were included in one module, that were previously presented in different chapters in a regular chemistry textbook. For example in the module ‘chemistry of the mouth’ subjects are biochemical in nature, dealing with taste.
receptors in the tongue, it dealt with acid/base theory, discussing the buffer system in saliva as well as the polymers used by a dentist while filling cavities. This was a completely new aspect for both teachers and students.

The 5 E Model

In later modules, the teachers wanted to have slightly different steps in the module. They were not completely satisfied with the phases in CHIK. With the 5 E Model they had more time for instruction in the Explain phase. In CHIK there was little room for using the newly learned knowledge in a different context. In the 5 E Model this is made more explicit. Teachers found this to be an essential step in the learning process of the students. Because of that a change was made towards the 5 E model proposed by Bybee, Powell, & Towbridge [9] in which the steps are called slightly different (see table 4)

Table 4. Steps in the 5 E model

<table>
<thead>
<tr>
<th>Engage</th>
<th>Introducing the context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explore</td>
<td>Deriving the chemical content and formulating questions to be answered</td>
</tr>
<tr>
<td>Explain</td>
<td>Finding the chemical knowledge needed to answer the questions</td>
</tr>
<tr>
<td>Elaborate</td>
<td>Scaffolding the knowledge and determining where it might also be used</td>
</tr>
<tr>
<td>Evaluate</td>
<td>Evaluate what was learned (taking tests) evaluating the process, determining next subject / context to be studied</td>
</tr>
</tbody>
</table>

Community of Learners

This bottom-up process of developing a curriculum was deemed very important both by teachers as well as the steering committee, which led the curriculum change [10]. In order to develop modules for the whole three-year curriculum, so-called ‘Communities of Learners’ were formed, in which 5 to 10 teachers worked together with an educational expert, usually from the
teacher training department of the university, a research expert and someone from industry. These ‘Community of Learners’ were extremely successful. At the University of Groningen (the Netherlands) the author worked with a group of teachers that developed more than 10 modules that were used and tried out within the schools. [11].

**Steps in development**

We organized the meetings of the Community of Learners (CoL) on Fridays afternoon. They were held about once a month and took about three hours. Schools were asked to give the teachers 54 hours off in order to participate in these CoL’s. In a later stage sometimes schools were paid compensation to give their teachers time to participate. In principle it was voluntary both on the side of the teachers as well as the schools. Main argument for both teachers and schools to participate in a school was the professionalization of the teacher that took place by participating in the CoL. The modules also had a positive effect on the students.

The development of a module, including the try-out in the own school took about a year and an half. When starting to develop a module the Community of Learners takes a number of steps. It starts out with a number of brainstorm sessions about the chosen context, in which all participants, including researchers and people from industry work together. Part of the brainstorm session may include a visit to research labs or an industrial site. The chemical content is then decided upon. Then, the teachers and educational expert decide on the pedagogical format. Normally the 5 E model would be chosen. Teachers then develop and collect material that can be used in the different phases of the teaching module. In these phases of the 5 E model principles of inquiry based learning and cooperative learning are used. Students are stimulated to become active during the process.
When the material is more or less complete the researchers and industrial specialist give feedback, after which the material may be redesigned before it is carried out by the teachers in their own classes. Based on these experiences, the module is evaluated and improved. The second version is made available to other schools (see www.nieuwescheikunde.nl).

**Continuous Development**

The experience with working with groups of teachers working together this way was recognized was taken further in recent years. At a number of universities these groups were already active in chemistry, physics and biology. At this stage at 10 universities in the Netherlands so called ‘broad support groups’ were founded, in which these three subjects worked together. The groups were expanded with groups teaching mathematics, computer science and a subject called ‘general science’. A grant from the government made sure these groups will stay at least until 2016 (see www.bredesteunpunten.nl). These groups now play a major role in supporting the introduction of the new science curriculum. Not only chemistry has undergone this major revision, biology and physics went through the same processes.

**An example of a module of the new chemistry curriculum: ‘Perfume’**

The module ‘perfume’ is a nice example to demonstrate the context-concept and the different steps of the way the 5 E model works. The chemical content of the module ‘perfume’ is the introduction of simple organic chemistry. It also introduces lab work in organic chemistry using micro scale chemistry kits (Figure 3).
In the ‘Engage’ step we have used the application for android and iphone ‘Molecular City’ which was developed for a science festival organized in the city of Groningen (the Netherlands) where markers were placed in shop windows (figure 4).

When the app was loaded and the camera of the smart phone recognized the marker, a 3D image of a molecule was displayed over the camera view (figure 4). At the same time an audio message was played. For example, for the molecule caffeine the text would be: ‘you keep me awake. In the app, information was given about the molecule (figure 5).
In table 4 the chosen molecules are indicated. There are English, German and Dutch versions of the app. A booklet with a description, including all markers is available on www.molecularcity.nl. Figure 6 depicts the marker for caffeine.

Table 4. Molecules used in the app ‘molecular city’ and the location where the markers were placed in the city

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caffeine</td>
<td>Café</td>
</tr>
<tr>
<td>Aspirin</td>
<td>Apothecary</td>
</tr>
<tr>
<td>Ethanol</td>
<td>One of the bars in the vicinity</td>
</tr>
<tr>
<td>Bombykol (pheromone)</td>
<td>Perfumery</td>
</tr>
<tr>
<td>Bucky ball</td>
<td>Sporting goods shop</td>
</tr>
<tr>
<td>Testosterone</td>
<td>Erotic goods shop</td>
</tr>
<tr>
<td>Iron</td>
<td>Train station</td>
</tr>
<tr>
<td>Water</td>
<td>Water bottle</td>
</tr>
<tr>
<td>Sugar</td>
<td>Ice cream parlor</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Parking garage</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Vegetable store/ fruit market</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Tree</td>
</tr>
<tr>
<td>Urea</td>
<td>Public toilets</td>
</tr>
<tr>
<td>Lead chromate</td>
<td>Museum</td>
</tr>
<tr>
<td>Diamond</td>
<td>Jewelry shop</td>
</tr>
<tr>
<td>Capsaicin</td>
<td>Waga wama (awok restaurant)</td>
</tr>
<tr>
<td>Allyl methyl sulfide (garlic)</td>
<td>Restaurant</td>
</tr>
<tr>
<td>Cellulose nitrate (celluloid)</td>
<td>Movie theater</td>
</tr>
<tr>
<td>Nicotine</td>
<td>Tobacco shop</td>
</tr>
<tr>
<td>Methane</td>
<td>Gas lighter</td>
</tr>
</tbody>
</table>

Caffeine is the stimulating substance in coffee, Red Bull, but also tea. One gram of tea contains even more caffeine than one gram of coffee. However, to make a pot of tea only 4 grams is used and for a pot of coffee more than 80 grams, so a cup of coffee contains a lot more caffeine. Caffeine is addictive. Moreover, you get used to it; you need more to reach the same effect. An overdose of caffeine results in all kinds of side effects, such as sweating, trembling, nervousness, fear, etc.

Caffeine is often added to painkillers like aspirin, not only because it is a stimulant, but also because it increases the effect.

*Figure 5. Text for badgepage caffein*

In table 4 the chosen molecules are indicated. There are English, German and Dutch versions of the app. A booklet with a description, including all markers is available on www.molecularcity.nl. Figure 6 depicts the marker for caffeine.
Students usually work in groups of two or three in the modules. In the module ‘Perfume’ the app is used to introduce the molecules used in organic chemistry (Table 4). The teacher copies the markers and hangs them on appropriate places in the school. Students use their smartphone or pad to find the molecules on the markers.

Afterwards in the **Explore phase** they try to sort the molecules. They recognize similar functional groups. The idea is that students identify several functional groups in the molecules, like alcohols, esters, ketones, double bonds etc. There are also a few polymers.

In the **Explain phase** the teacher then introduces the students to the IUPAC rules for naming organic compounds. They practice and work with these rules so they can recognize simple functional groups within molecules. The students should understand that they now can name simple molecules, but that in nature molecules are a bit more complex. To conclude this phase the group of students received the assignment to design and make a concrete model of one of the molecules (Table 4) and to prepare a short paper listing properties of the molecule.

The concrete models of the molecules needed to be large enough so they could be displayed in an exhibition. The students came up with many interesting ideas to make the
molecules. The molecule ethanol for example was made from (empty) cans that contained light alcoholic beverages that are favorite among these students. In figure 9 you can see the sign that was designed, as an explanation for the model the students made of caffeine. In figure 10 you can see part of the exhibition, showing the molecules bombykol, methane, and caffeine.

Figure 7. sign for molecules

Figure 8. Part of the students exhibition of molecules. Shown are: bombykol (top) bottom left to right: ethanol, vitamin C, Methane and caffeine.
In the Elaborate phase a new context ‘smell’ is introduced with a new set of molecules: Ethyl-2-methyl-butyrate; ethyl butyrate; furaneol; γ-decalacton; cis-3-hexenol. These molecules are presented to the students as about 2% solutions in 50% ethanol. The idea is that they can smell the compounds. Surprisingly, when the five compounds are smelled together you get the smell of strawberries. This leads to a discussion about smell.

Again a different number of examples are given to the students. These five were the first. Then they receive an article about smell [12]. In this article smell is discussed and explained. Properties of molecules that play a role in smell are discussed. A number of examples of these molecules are given in figure 9.

The basic idea that needs to be understood by the students is that although they learn how to name smaller molecules, molecules in the environment are generally more complicated. But they should be able to recognize functional groups within these complicated molecules. That is also the reason these molecules are used in several experiments.

**Practical Skills**

Eugenol and vanillin are used by the students to demonstrate the chemistry of a double bond by adding iodine to the substances. Citronellol and eugenol are used to distinguish between a primary and secondary alcohol.
Normally students will receive detailed instruction about an experiment they need to perform. In this practical, they were asked to perform a steam distillation based on an article about steam distillation and isolation of carvone [13]. Students have to derive and design their own setup, based on the article. In figure 10, an example of a setup made by students is shown.

![Image of steam distillation setup](image)

Figure 10. An example of an experimental setup for steam distillation made by students using the Kontes set.

The students are also asked to synthesize an ester. Students can choose their own acid and their own alcohol. The most favorite was ethyl butyrate, because of the smell difference going from smelly feet to pine apple.

In the **evaluation phase** the teacher helps the students to make an overview about the chemistry concepts they have learned. At the end of the module students take a final (summative and cognitive) test.
COMPLETE CURRICULUM

Using these types of modules a complete three-year curriculum was developed. In Table 6 this curriculum is described as a complete list of the modules used in three years. The different groups of teachers used different modules. Table 6 gives the modules used at the University of Groningen. The complete set of modules was the base for the description of the whole curriculum in a final exam program [14]. In the Netherlands secondary school students take a nationally organized central examination in May each year. The curriculum used for the central examination in chemistry was described using the modules developed in the different CoL.

Table 6. Modules developed at the University of Groningen

<table>
<thead>
<tr>
<th>Module</th>
<th>Context</th>
<th>Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Perfume, grade 10</td>
<td>smell</td>
<td>Introduction organic chemistry</td>
</tr>
<tr>
<td>2. Growth grade 10</td>
<td>What is fertilizer?</td>
<td>Salts, solubility, pesticides</td>
</tr>
<tr>
<td>3. eco travel grade 10</td>
<td>Design your own ecological trip around the world</td>
<td>Chemical calculations, stoichiometry</td>
</tr>
<tr>
<td>4. medicines grade 10</td>
<td>Why are there different ways to administer medicines</td>
<td>Hydrophobic/ hydrophilic molecules, equilibrium, acid/base</td>
</tr>
<tr>
<td>5. Nobel prize grade 10</td>
<td>Who wins the Nobel prize for his contribution to knowledge about the atomic model?</td>
<td>Atomic models of Dalton, Rutherford en Bohr, the periodic table</td>
</tr>
<tr>
<td>6. artificial sweeteners grade 10</td>
<td>Which substances taste sweet</td>
<td>Chirality, carbohydrates, peptide bond, amino acids carbohydrates?</td>
</tr>
<tr>
<td>7. energy to go grade 10</td>
<td>How can produce electrical energy using a chemical reaction</td>
<td>Redox and batteries, corrosion</td>
</tr>
<tr>
<td>8. Smart materials grade 10</td>
<td>Solar cells, special polymers</td>
<td>Polymers used in solar cells, conducting polymers</td>
</tr>
<tr>
<td>9. Sport and chemistry grade 10</td>
<td>Materials used in sport, drinks, biochemistry of training</td>
<td>Krebs cycle, polymers, elasticity</td>
</tr>
<tr>
<td>10. green chemistry grade 10</td>
<td>Production of TiO2 and adipic acid</td>
<td>Industrial processes, energy balance, mass balance</td>
</tr>
<tr>
<td>11. Chemistry in the mouth grade 11</td>
<td>What chemistry takes place in your mouth</td>
<td>Buffers, receptors and polymers used in dentistry, pH-optimum of amylase</td>
</tr>
<tr>
<td>12. gasification grade 11</td>
<td>What is special about a power plant using gasification</td>
<td>Design concepts, processes and temperature, yield, sustainability, role carbondioxide</td>
</tr>
</tbody>
</table>
Overview

I was asked to write this article as a lecture on chemistry education in the `Netherlands, after a presentation I gave at the first African Conference on Chemistry Education (ACRICE-1) held in Addis Ababa/Ethiopia in December 2013. I have tried to sketch the background against which the changes in chemistry education in the upper level of secondary schools during the last 15 years have taken place. These changes have resulted in a new chemistry curriculum consisting of several context-concepts based modules. One publisher was willing to edit the available modules on the web. These modules are freely available for both students and teachers on http://www.vo-content.nl/stercollectie/scheikunde. A limited number of modules has been translated in English and are also available:

- http://www.studioscheikunde.nl/havovwo_bb/Module_Equilibrium/index.html
- http://www.studioscheikunde.nl/havovwo_bb/Module_How can we eat healthily/index.html

In May 2015 the first national examination based on the new curriculum will take place. That will be the time we can see a bit more of the results of the new chemistry curriculum.

ACKNOWLEDGEMENTS

The work described in this paper has been made possible by grants from the Ministry of education, the science departments of the universities, and the faculty of mathematics and natural sciences of the University of Groningen. I have to acknowledge the help of countless teachers that have worked and commented on the development of the new chemistry curriculum. Special thanks to my colleague Dr M. A. Ossevoort for her feedback on this article.
REFERENCES


OTHER RELATED RESOURCES

THE CHEMIST’S TRIANGLE AND A GENERAL SYSTEMIC APPROACH TO TEACHING, LEARNING AND RESEARCH IN CHEMISTRY EDUCATION

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ABSTRACT
The three levels of science thought (macro, micro, symbolic), identified by Johnstone and represented by a triangle, may be viewed as a core closed-cluster concept map of the type advocated in the systemic approach to teaching and learning of chemistry. Some of the implications of this view for teaching, learning and research are explored. [AJCE 4(2), Special Issue, May 2014]
CHEMICAL EDUCATION FOR HUMAN DEVELOPMENT IN AFRICA

There are as many approaches to teaching and learning chemistry as there are chemistry teachers. All school teachers nevertheless are required to follow a defined curriculum, which may be nationally defined. This is certainly the case in Africa, where the national curricula show variation from country to country, but have much in common. Especially at the secondary level of schooling, these curricula emphasize preparation for tertiary-level education, even though it may be a small minority of learners who will follow this path in future.

This divergence between minority expectations and majority needs is quite common around the World and it is not just an African issue. Still, with a conference theme “Chemical Education for Human Development in Africa”, we may pause to reflect on this divergence and question whether we support or do not support the aim implicit in this theme.

A recent paper by Reid [1] illuminates the issue and claims school chemistry as part of and integral with General Education. Reid proposes the following aims of school chemistry curricula:

1. understanding something of the way the world works;
2. appreciating the huge contribution of chemistry in human welfare;
3. appreciating how chemistry gains its insights.

The proposals have no overt national affiliation and indeed they are open to Africa as to any continent. Furthermore on the surface they seem more likely to serve majority needs than most national curricula in Africa currently do. Curricula that just assume that learners see purpose in learning how to do stoichiometric calculations or giving the electron configuration of a ground state copper atom usually do not have such aims. Instead, the implicit aim is to prepare
for the matriculation examination at the end of secondary school so that, if successful, one may access tertiary level study [2].

SYSTEMIC APPROACHES TO CHEMICAL EDUCATION

Fahmy and Lagowski [3] have argued for and researched systemic approaches to teaching and learning of chemistry. An emphasis of these approaches is the inter-relatedness of things, especially the cross-links between vertical developments of concepts as are most often presented in concept maps [4]. Indeed, Fahmy and Lagowski have emphasized the importance of “closed-cluster concept maps” in their recent articles. These too are not associated with any particular school curriculum, but seem well suited to chemical education for human development in Africa.

THE CHEMIST’S TRIANGLE (5)

Johnstone [6] drew attention many years ago (1999) to the existence of what he called the three forms (or levels) of chemistry: macroscopic, sub-microscopic and symbolic.
(representational). These three forms or levels are not independent, but in fact closely related. This can be represented by a triangle with the three forms at the corners of the triangle.

![Fig 2 The Chemist’s Triangle](image)

This may be recognized as one of the centrally-important closed-cluster concept maps of chemistry, which can assist teachers, learners and researchers. Being devoid of other indicators it can serve chemistry education at all levels and in all curricular contexts.

But alone it is but an aide-memoire that can be understood after experiencing its use. There is no better way of doing this than by exploring the points of the triangle and their inter-relationships, with CHEMISTRY itself as the focus.
Fig 3 The Chemist’s Triangle – Chemistry

Contemplating this figure, an experienced chemist would be able to exemplify these generalities for hundreds, or even thousands, of different cases. And thus a teacher, in words suited to the level of education, can explain how it all starts with macroscopic observations and descriptions, leading scientists to identify patterns, etc. Symbols may be invented in support of these. And, as scientists must, they look for explanations of the observations and the patterns of these. In the last few centuries these explanations have been consistently in terms of microscopic (or sub-microscopic) particles and their interaction. This also often leads to additional symbols.
Important periods in the history of chemistry are well-represented within this framework, as is exemplified in the Fig 4 following, simply by adding the names of three critically important chemists from the period 1780-1820:

![Chemistry Development 1780-1820](image)

**Fig 4 Chemistry Development 1780-1820**

We may remember that it was Lavoisier who made the observations that led Dalton to re-launch the atomic theory, and he developed symbols for his atoms. Berzelius however introduced the kind of symbols and formulae for pure substances which are closely related to those generally adopted thereafter.

Discussion around this Figure will illustrate very well the typical character of chemical progress, and how the different corners of the triangle interact and evolve with time. It is the
same for teaching and learning: the eternal dynamic interplay as teaching and learning happen and conceptual development occurs, model the historic development of the discipline itself, which continues in present-day research.

THE CHEMIST’S TRIANGLE IN THE CURRICULUM

We can use the triangle to get our thoughts in order on any chemistry topic or theme. For example, Figure 5 shows how the triangle can be used to generate a rich picture of concepts associated with chlorine:

Fig 5 Chlorine
This example allows us to show too how macro/micro and symbolic concepts can be cross-linked to highlight particular relationships. Teachers might wish to do this for specific reasons within their curriculum, or might call upon learners to find cross-links as a summarizing/revision exercise.

Another example is of a typical chemistry topic, rates of reaction:

![Rates of Reaction Diagram](image-url)
POTENTIAL BENEFITS OF USING THE CHEMIST’S TRIANGLE IN TEACHING AND LEARNING

These have yet to be fully explored, but here we mention two to stimulate further thought.

1. Reducing working memory overload

Johnstone and his group have demonstrated the crippling effect of working memory overload on learning achievement [7]. These researchers showed how restructuring the same course or lesson content with this objective in mind led to consistently better achievement by learners. They note that novice learners have great difficulty in working at all three levels at the same time, almost certainly because of information overload. Deliberate use of the chemist’s triangle has clear potential in this regard (chunking of information for a start!), as do closed-cluster concept maps in general. It can serve as an advance organizer and/or as a meaningful summarizing framework.

2. Language and symbols that confuse

Listening to typical chemistry lessons and reading typical textbooks must often be puzzling for learners even when their teachers think the language and symbols are crystal clear. Apart from specific technical word problems [8], there is the confusion of descriptive language for macroscopic and sub-microscopic thought [9]. The triangle is a stimulus to clarify our language in the classroom as well as in the curriculum documents.

An example would be the topic of acids, where in one and the same chapter or lesson, acids may be described as substances that neutralize bases and change the color of indicators and as proton donors. Clearly the first two statements refer to macroscopic observations, whilst the
third is about microscopic interpretation. It is the molecules of acids which we should say are proton donors, and based upon this model we interpret the observations about neutralizing bases and changing the color of indicators. Symbolically we might use formulae such as HA(aq) for our macroscopic references, whilst the microscopic references might use $\text{H}^+$ or $\text{H}_3\text{O}^+$ and $\text{A}^-$. (Parenthetically we may note that the term proton in this connection is unsuitable and the term hydron should be used instead!)

Another example of this macro/micro confusion is provided by this multiple choice question, where there is only one correct statement completion:

Nitrogen
A. is a colorless, odorless gas
B. is diatomic
C. is trivalent
D. has a triple bond.

Presenting this question invariably causes alarm amongst experienced chemistry teachers because they see all the options as correct. However, careful consideration shows that B and D are attributes of the nitrogen molecule, whilst C is an attribute of the nitrogen atom. These are microscopic attributes. The stem of the question refers only to nitrogen and therefore only A correctly completes the statement. To the teacher it is obvious when the micro is meant even though the macro is stated, but to the novice learner this distinction is not clear. Yet it is a crucial one, as the chemist’s triangle forcefully reminds us.

Symbols and formulae also deserve much more careful attention. For example does it matter or make a difference when we write HA, HA(g) and HA(aq)? Are all these representing
acids? And what about NaCl, NaCl(s) and (NaCl)$_n$? What do these refer to and how should we use them for clarity?

**HOW DO TEACHERS IN AN IN-SERVICE COURSE RESPOND TO THE CHEMIST’S TRIANGLE?**

The RADMASTE Centre undertakes a lot of in-service teacher training which caters for teachers who do not have adequate knowledge and skills. Some may be relatively successful teachers, as measured by the pass rates achieved by their classes. However, these pass rates are often achieved by rote learning, and the teachers may be quite confused about many basic concepts. Therefore we discuss topics in the school curriculum that they are required to teach, deliberately avoiding the typical textbook approaches which they are familiar with and have learned.

One aspect of our approach embodies use of the chemist’s triangle and a frequent emphasis on the three different levels it reflects. The triangle is introduced early and explained with an example and then is also used at the end to summarize. Teachers have some awareness of hierarchical concept maps, but have usually never really thought about the three levels.

Teachers are generally intrigued by this novel vision of the subject and at the end of the course can produce quite acceptable chemists’ triangles with little collections of concepts attached to the correct points. Two example diagrams are attached resulting from an assignment they completed at the end of the course. One of these shows the individual concerned chose sides of the triangle rather than corners, but never mind!
Figure 7 Example of in-service teacher’s triangle – chemical change

Figure 8 Example of in-service teacher’s triangle – reactions in aqueous solution
BRINGING THE CHEMIST’S TRIANGLE TO LIFE

Reference has been made to teachers’ surprise at the three levels of thought represented by the chemist’s triangle. This has prompted us to provide experiences for them (and perhaps for their learners) that can enrich their comprehension of its origins. We can exemplify such experiences with the case of the electrolysis of water. As the following Figures indicate we start (of course) with observations, by doing the electrolysis of water on microscale. On completing this, learners write balanced chemical equations as part of their symbolic description on the macroscopic level. Then comes the interpretation of their observations in sub-microscopic terms, and this can be aided by the use of models – both 2-D (drawn with a molecular stencil) and 3-D (models made with beads and prestik (adhesive putty)). A tremendous amount of thought is involved in getting all these parts of the complete (3-level) picture, and a real eye-opener to those who have never before seen it all together. Despite all the mental effort, the hands-on activities (microscale electrolysis, drawing and model building) are quick, so there is time for the effort. Truly a hands-on, minds-on experience.

Figure 9 Electrolysis of water – microscale set-up
ELECTROLYSIS OF WATER

Using the RADMASTE™ Molecular stencil, draw a microscopic representation of liquid water, H₂O below. Draw 8 water molecules.

The electric current which is passed through the water decomposes the water into two gases. Using the RADMASTE™ Molecular stencil draw microscopic representations of the two gases. Assume all 8 molecules drawn above have been fully decomposed. Name the gases.

Figure 10 Electrolysis of water - 2-D modeling
THE CHEMIST’S TRIANGLE FOR NOVICE LEARNERS

We have not had the chance to try out the kind of approach described here with novice learners. We hypothesize that there will be learning benefits from doing so, but research is needed to find out.

Some authors have made cases for the triangle to be expanded to a tetrahedron to take account of the interaction of chemistry with the environment, or indeed other dimensions. This seems to me to confuse rather than improve. The three levels are the core characteristics of the discipline. The environment, industry, ethics, and so on are without a doubt important. But they do not lie at the core of the discipline and would be better taken into account by a circle around the triangle to signify their relevance to the curriculum at hand.
REFERENCES


ACKNOWLEDGEMENTS

I thank Erica Steenberg and Andrew Chikochi for results from their in-service courses and Beverly Bell for assistance in preparing several Figures.
THE CHALLENGES FOR CHEMISTRY EDUCATION IN AFRICA

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ABSTRACT

The continent of Africa is made up by many country borderlines, but as we know, borders are only lines on a map. Nature and the environment don’t recognize these borders, and therefore, issues of climate change, air pollution, water quality and diseases require collaborations among nations for their solutions. A new way of thinking, teaching and learning chemistry is also required. Chemistry will play a major role in solving the challenges that face our planet and the development of the continent of Africa. We must have chemists who will be able to solve these problems. In order to have these types of chemists, we must have, in the pipeline, students who will become the future chemists able to offer solutions to existing and new problems. This means developing a new curriculum and new methods of teaching chemistry so that chemistry can be accessible to all students in Africa. Sadly enough, many students shy away from chemistry. In order to attract students to chemistry, creative methods for teaching and learning were developed for all levels, from primary school to university, and from the formal to the informal settings. These methods utilize the students’ talents, hobbies, interests and cultural backgrounds. Equal access to science education is a human right that belongs to all [1-2]. If we do not guarantee science education to all, we will form a two-class society divided not by royalty and status, but by knowledge of science. The centerpiece for this method is the development of student projects, which help them to remember and understand abstract scientific concepts. An old Chinese proverb says: “I hear and I forget; I see and I remember; I do and I understand.” These students’ projects take advantage of seeing and remembering, doing and understanding. Through this process, students are active learners, instead of being passive observers. To demonstrate their understanding of scientific concepts through their projects, the students use a media of their choice, from drawing, dance and drama (no tech) to computer animation (high tech). Projects can also take the form of paintings, sculptures, songs, films, and scripts for theater. These projects are used as alternative assessment methods where the whole class is involved in the assessment process. In order for this method to be successful, workshops for teachers as well as parents must be conducted. This way, the students will be taught in a creative way in school and through the joint involvement of teachers and parents, students will be encouraged to pursue chemistry. After all, “it takes a village to raise a child,” as the African proverb states. [AJCE 4(2), Special Issue, May 2014]
NARRATIVE

The world population is growing in an exponential rate (Figure 1). There are many problems facing the growing world population. We as scientists have the obligation to help solve these problems.

- We must guarantee science education for all.
- We must avoid creating two separate social classes: one that is science literate, and another that is not.
- No single teaching method fits all.

Figure 1 World Population 1AD-2050AD (Billions)

Equal access to science education is a basic human right that belongs to all. Therefore, we must develop methods for teaching, learning, and accessing science, which will take into account the students’ talents, interests, and cultural backgrounds [3]. If we will not develop this kind of curricula, we will form two class societies, divided not by royalty and wealth. These two societies would include one with people who have knowledge in science and technology, and can function in the new world, and another would be made up of people who do not have knowledge
in science and technology. We must prevent this from happening by working hard on developing the right methods for teaching science.

Figure 2 Passive Learning

With these new methods, students move from a passive mode of learning, which is teacher centered (Figure 2), to an active mode of learning, which is student centered (Figure 3).

Figure 3 Active Learning
In order to make the chemistry class relevant to the students’ lives and environment, every class from grade five to university starts with a report on a scientific issue that they find in the daily newspaper, magazine, or online. Students are asked to summarize the article and present it to the class in a one-minute presentation. In each class the teachers select a group of students to report to the class. This guarantees that the whole class is coming prepared.

Figure 4 Each class begins with a scientific article from the newspaper

We must emphasize to the students:

- That a basic science background is needed to understand the article.
- That science is part of everyday life.
- That it is important to communicate science accurately.

This exercise helps the students to get into the habit of reading articles about science in newspapers, magazines, and online. This also encourages them to listen to science programs on radio and television. Many times students who graduated come back to say that they are still reading scientific articles, but are lacking a platform to report and discuss these articles. Usually the discussion in class is very lively. It is easy to relate the subject of the day to one of the articles represented. For example, an article on nuclear technology can be a start point for
discussing nuclear power plants, nuclear weapons, fission reaction, the nucleus of the atom, and the structure of the atom as a whole. This way students realize that their chemistry class has relevance to their life and is not just a hard class that they have to take.

STUDENT PROJECTS

A requirement in the chemistry class is that students show their knowledge and understanding of the concept discussed through any mediums of their choice [4]. For example [7], the concept of the chemical bond is presented through a drama parodying the popular movie, “The Godfather, but called “The Bondfather” and featuring a mother begging the Bondfather, Don Mendeleev, to break up the bond between her daughter, Chlorine, and her boyfriend, Sodium. The mother says she is afraid that their relationship will be broken in water and she would like her daughter to be in a covalent bond, where she can share electrons with her partner and have a strong bond with them. The same concept is presented by another drama called “Love Story Between Sodium and Chlorine,” following Shakespeare’s “Romeo and Juliet.” Dance students choreographed a dance on the bond between Sodium and Chlorine. They performed this dance in many venues as shown in Figure 5.

![Figure 5 A dance between Sodium and Chlorine](image-url)
Students produce all their scientific visualizations as seen in Figure 6. Nothing is commercially produced. Students use their talents, major fields of study and cultural backgrounds as tools to help visualize scientific concepts [5].

![Figure 6 A student producing computer visualizations](image)

Many times the projects are the result of teamwork to resemble the reality of the workplace. It is extremely important that students learn to work in teams and not just as individuals. Once they are in a chemistry corporation, they will have to be part of a team. Figure 7 shows a student’s description on teamwork.

![Figure 7 A student produced a cartoon demonstrating teamwork](image)
Many television studios showed a video where seventh grade students represented through dance, the depletion of the ozone layer. They interviewed the students and were amazed on how well they understood the concept after performing their dance (Figure 8). This appeared in South Africa, China, WGN, ABC, NBC, and CNN television broadcasts.

Figure 8 Depletion of the Ozone Layer

One of the student dancers, when interviewed by CNN, said the following statement (Figure 9): “After I was on stage… My cousin played one of the atoms. And she was splitting them and everything and I was like ‘oh, that’s how that works.’ I never knew nothing about it until I did the dance.”

Figure 9 A student dancer interviewed by CNN
It is the responsibility of the scientific community to (1) promote the development and use of clean energy resources, (2) add the subject of sustainability in the curriculum to prepare future scientists with the background needed to preserve life on Planet Earth, and (3) guarantee cross-border scientific collaboration and cooperation, even between countries whose governments are hostile toward each other.

Students present projects that show the effect of climate change, oil spills, and other environmental issues that affect the well being of our planet. In Figure 10 a student produced a computer animation on global warming [6].

![Figure 10 Global Warming](image)

It is extremely important to involve the parents in understanding the science that their students learn. Therefore, workshops for parents, teachers and students were conducted with funding from the National Science Foundation. In Figure 11 a mother and daughter are working together in their workshop.
RESULTS

For five years teachers and students were evaluated after attending the workshops. In each school there was a class that the teachers and students were participated in the workshop, and a controlled class where the teachers and students did not participate. The following graphs show the results of testing hundreds of teachers and parents, and thousands of students, comparing them to a controlled group.

Figure 12 Teachers who reported feeling successful in providing science education to their students
As seen in Figure 12, the percentage of teachers who felt that they could teach science was 0% before the workshop. After the workshop, 36% felt very capable in teaching science.

![Graph showing differences in gain in student achievement](image)

Figure 13 Differences in gain in student achievement for children of participating teachers and parents over that of non-participating teachers and parents

As seen in Figure 13, there is a huge difference in achievement by students who’s teachers and parents participated in the workshops, and children from the controlled group. The fifth grade and the eighth grade are very important grades in Chicago and other places in the U.S. After fifth grade students move from elementary school to middle school, and after eighth grade students move from middle school to high school.
REFERENCES

Acknowledgement is given to the National Science Foundation (NSF) for financial support of this work.
ADVANCED STRATEGY FOR TEACHING PHARMACEUTICAL CHEMISTRY COURSES BY IMPLEMENTING PHARMACOPHORES STRATEGY INSTEAD OF SAR ONE

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ABSTRACT

After studying pharmaceutical chemistry course, the students should learn exact relation between chemical structures of drugs (medicines) and their biological activity. This means that when students watch the chemical structure of any drug, they should predict their biological activity at a definite target. In this article a new method was implemented, for the first time, to predict the biological activity of any drug based on pharmacophores concept rather than the structure-activity-relationship (SAR) one. The pharmacophores are template that could represent the interactions exerted by the essential function groups that are carried by chemical nucleus of the drug. The nucleus of any drug acts only as a scaffold to carry the essential groups to the nearest point to the complementary function groups at the binding sites of the drug targets. If we change the chemical nucleus by bioisosteric one that have the same interactions pattern, it will exert the same activity. Implementing this technique in teaching pharmaceutical chemistry courses may be more beneficial and accurate for the students to predict the biological activity of any drugs. [AJCE 4(2), Special Issue, May 2014]
INTRODUCTION

It is well known that any drug should combine with its target to elicit its biological activity. For example, combination of lead drugs at beta receptors [1], Angiotensin Converting Enzyme (ACE)[2] or Angiotensin II (Ang II) Receptors [3], will result in decreasing elevated blood pressure. Similarly, combination of lead drugs at PPARγ receptors will decrease blood glucose and treat diabetes mellitus type-II disease [4]. Meanwhile, combination of lead drugs at Mutated Kinase enzyme in cancer cells [5] will defeat cancer. Also, combination of lead drugs at topoisomerase I or II enzymes of the human cancer cells will result in treating some kinds of cancers [6]. Combination of beta-lactame antibiotics at trans-peptidase enzyme of bacterial cells will result in treating bacterial infections [7]. The mode of interactions with the binding sites may be either irreversible (formation of covalent interactions) or reversible (formation of dipolar, H-bonding or Van Dear Wall interactions) [8].

There are four classes of drug targets; the receptors (at the surface of cell wall), the enzymes, proteins (at blood circulation), the DNA, RNA or genomes (at the cell nuclei) [9]. The 3D structures of most of these targets were unknown till the last few decades. Thus, the pharmaceutical chemists could predict the activity of drugs by virtue of their structures themselves and not through the interactions with the targets. This method is termed Structure Activity Relationship (SAR). For example, the topoisomerase-IV enzyme that is responsible for bacterial replications, is existed only in the bacterial cell and not existed in human cells, were found to be inhibited by quinolone molecules having general structures and corresponding structural activity relationship (SAR) represented in Figure 1 [10]:

Figure 1
Indeed, there are tens of quinolone molecules that are marketed as antibacterial agents and comply with the given SAR in Figure 1. Among these marketed molecules were Nalidixic acid (1), Norfloxacin (2), Sparfloxacin (3), Moxifloxacin (4), Gatifloxacin (5), levofloxacin (6), etc. (Figure 2) [10].

![Figure 1: The reported SAR of Quinolone molecules as topoisomerase IV inhibitors](image)

Figure 1: The reported SAR of Quinolone molecules as topoisomerase IV inhibitors

Actually, in this article, the new non-quinolone molecules (structure 7) (Figure 3), was introduced here, and was found to show 1.3 folds higher activity as topoisomerase-IV inhibitor.
more than the reference quinolone drug; norfloxacin (2), inspite of, it is not comply and not match with the reported SARs of quinolones molecules mentioned in Figure 1.

Figure 3: (Structure 7: A non-quinolone molecule that have high topoisomerase inhibitor activity higher than the quinolone molecules)

The reasons of the persistent anti-microbial activity of structure (7) as topoisomerase IV inhibitor is attributed to its ability to interact with the binding site of its target by a similar interactions like the quinolones analogue (2~6), but through another bioisoteric groups. The tetrazole function at molecule 7 is bioisosteric to the COOH group in molecules 2~6. These two bioisosteric functions can make the same dipolar ionic interaction with binding site. Also, the terminal aminopropoxy function at position 8 in structure 7, is bioisosteric to the N$_1$ of the quinolone analogues 2~6. This raised the assumption that the SAR concept of the embedded heterocyclic nucleus may not be the reason for biological activities. Indeed, the biologically activity of any ligand is due to the interaction exerted by the attached function groups at the embedded hetero-cycle. If we change the heterocyclic system and/or the attached function groups by other bioisosteric ones that give the same interactions with the receptors, the biological activity will remain. The function groups which have the same mode of interactions with the binding sites are termed features and the collections of many features at certain binding site are termed pharmacophores [9].
In this subject, a new method was implemented here, at the first time, to predict the biological activity of any drug without referring to the SAR theory, but referring to pharmacophores concept.

DISCUSSIONS

After the great scientific progresses in all aspects, especially in the biological sciences, molecular modeling, and 3D X-ray crystal structures elucidations, the scientists could recognize the 3D structures of most of living cells targets. These targets became available at the websites (www.pdb.com) and could be used as a template to recognize their own ligands. Molecular modeling generation of the pharmacophores of the essential leads’ function groups (or their complementary function groups at the binding site), of any binding site, would facilitate the prediction of the biological activity of any test set molecules by running the compare/fit study between them.

Pharmacophores are a collection of function groups of certain Lead and their interactions with the binding site. The different features in any pharmacophore may be: Hydrogen bond acceptor features (Vector), Hydrogen bond donor features, Hydrophobic features, Hydrophobic – aromatic features (point or plane), Negative Ionizable features (point), Positive Ionizable features (point), Negative Charge features (atom), Positive Charge features (atom) and Ring-aromatic features (vector) [9]. Each target has its own pharmacophores, which are completely different from one target to the others in the kinds of these features, their numbers, the distances and angels between them. So, they are considered as finger-prints for each target [9]. Figures 4, 5 and 6 represent the features of the topoisomerase IV inhibitors pharmacophore, their distances and angles.
Generation of Pharmacophores

The pharmacophores of any binding site could be directly built from the complementary function groups of binding sites, by running special molecular modeling modules during docking protocols of Accelrys/DS modules. Also, the pharmacophores could be indirectly built from a group of biologically active leads (5-15 leads with similar activity), that are reported to combine with the same given binding site, then run Common Feature Pharmacophore Generation using Accelrys/Catalyst/DS module [11].

For example, the above mentioned topoisomerase IV inhibitors pharmacophore (figures 4, 5 and 6) were generated from the binding site of the 3D crystal structure of topoisomerase IV protein complexed with norfloxacin (2) ligand, by determining the protein aminoacids molecules
of the binding site that bind with this ligand, and then build the corresponding spherical meshes of each interaction at each bound aminoacid molecule to directly get the pharmacophores. Also, the same pharmacophore (figures 4, 5 & 6) could be indirectly constructed from the reported lead molecules (5-15); Nalidixic acid (1), Norfloxacin (2), Sparfloxacine (3), Moxifloxacin (4), Gatifloxacin (5) and Levofloxacine (6) (Figure 2), by running Common Feature Pharmacophore generation protocol of Accelrys/Catalyst/DS module [11].

**Uses of Pharmacophores in predicting biological activity of any agents**

The pharmacophores of most of the binding sites are generated and validated by many authors and are now reported in the literature and could be collected as data bases. The data bases of the different pharmacophores could be used as templates to perform fitting studies with all the available ligand molecules. So, we should have data bases of different pharmacophores and data base of different lead molecules. There are millions of reported and synthesized ligands that have unknown biological activity and the compare fitting virtual screening studies between the different pharmacophores and these millions of ligands compounds by applying simulation compare/fit techniques, could predict the active molecules among these ligands. Molecules that give the highest fitting scores than the reference leads are predicted to have higher activity at this target.

In this study, the generated topoisomerase IV inhibitor pharmacophore (Figures 4, 5 and 6) was used as a template to run compare/fit virtual screening protocol with the non-quinolone molecule [structure 7 (figure 3)], where compound 7 gave higher fitting score (equal 4.95/5=99%) than that of the reference drug; Norofloxacine (4.1/5=88%) (Figure 7).
Antimicrobial Evaluation

The antibacterial activity testing for this non-quinolone molecule (7) and the reference drug; norofloxacin, against various microorganisms was actually performed using zone inhibition and serial dilutions techniques. The results showed that molecule (7) gave 1.3 folds higher antimicrobial activity than the reference drug norofloxacin (2).

Conclusion of molecular modeling virtual screening and antimicrobial evaluation:

The high compare fit score between the topoisomerase IV inhibitors` pharmacophore and the non-quinolone structure (7) was found to be matched with its high antimicrobial activity testing in comparison to the reference drug norofloxacin (2). This result and other similar reported results indicated that the use of pharmacophores as a tool to predict the biological activity of any ligand toward any target is a successful and perfect method. Thus, we can use pharmacophores technique to predict the biological activity.

Figure 7: Compare fit virtual screening between non-quinolone molecule (structure 7) and Topoisomerase IV inhibitor pharmacophore gave Fit value = 4.95/5 (~ 99%) higher than fit value with norofloxacin (=4.1/5 ; 88%).
How to apply Pharmacophores in education of pharmaceutical chemistry courses to predict biological activity

The students or the pharmacists should have Lap-Tops, Tablet or, Mobile Telephone Devices in which the Molecular Modeling Modules were installed. Also, the data bases of the pharmacophores of the different targets and data bases of test set ligands molecules were downloaded to these devices.

Then the students could perform the compare/fitting virtual study between pharmacophores and the tested compounds. The compare/fit scores are criteria for biological activity.

Other Benefits of Pharmacophores

We can apply this concept in research, to perform drug design of new molecules. Also, we can apply this technique for predicting the biological activities of isolated molecules from natural products [12].

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DEVELOPMENT AND EVALUATION OF A SYSTEMIC ASSESSMENT FRAMEWORK IN ORGANIC CHEMISTRY

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ABSTRACT

The Systemic Assessment Questions (SAQs) is an assessment scheme proposed in the Systemic Approach to Teaching and Learning (SATL) teaching model, aiming to a more effective evaluation of the systemic oriented objectives articulated by this model. The goal of a research project carried out in our department for the past five years is the development and evaluation of a systemic assessment framework based on SAQs for the high school organic chemistry. We initially focused on the potential of the SAQ scheme as well as its characteristics required to achieve in capturing aspects of students’ meaningful understanding. It was found that SAQs’ task format, diagrams’ complexity, and cognitive demands play a significant role for this scheme in order to efficiently assess meaningful understanding of organic reactions. Based on these results, the SAQ scheme was then further developed and evaluated in various organic chemistry topics. Currently, a systemic assessment orientation was also adopted by focusing on systems thinking assessment. The SAQ scheme was found to be a valuable strategy for assessing meaningful understanding, as well as systems thinking in organic chemistry. A significant association was observed between students’ performance on SAQs and on objective items designed for assessing meaningful understanding of organic chemistry concepts. This association indicates that the students’ systems thinking level developed in organic chemistry is strongly related with a deeper understanding of the relevant science concepts. [AJCE 4(2), Special Issue, May 2014]
INTRODUCTION

The development of valid and reliable assessment tools is of a great concern to science education researchers. Systemic Approach to Teaching and Learning (SATL) is a teaching model that has been developed during the past decade [1-5]. SATL originators recognize as the basic goal of this approach the achievement of meaningful understanding by students and suggest that this goal can be attained through the development of systems thinking, in a context of constructivist and systemic oriented learning tasks (SATL techniques) [1-3, 5]. In this direction, they have proposed new types of assessment questions, the Systemic Assessment Questions (SAQs), aiming to a more effective evaluation of the systemic oriented objectives in the SATL model [6-7]. The SAQs are concept mapping techniques approaching assessment in a systemic manner. Their construction is based on the idea that students could be facilitated to understand meaningfully if science concepts were viewed as closed, cyclic, interacting, and evolving systems, as meaningful dynamic wholes.

Meaningful understanding is a complex phenomenon. It goes beyond simple retention and recall of knowledge, i.e., rote memorization of facts and algorithms. It includes a variety of abilities, from creating links between different pieces of information up to explaining everyday life phenomena based on the current scientific knowledge. Accordingly, meaningful understanding is comprised of different types of knowledge and the ability to link these knowledge types [8]. Meaningful understanding of chemistry concepts includes the ability to link related chemical information resulting in making judgments, creating relationships, drawing conclusions, predicting what should happen. Meaningful understanding also includes the abilities to draw chemical information from a chemical representation and to construct a chemical representation using chemical information.
Systemics is a broad term, which takes into account the fact that there is a range of different systems approaches. Most of them offer a theory, a methodology for dealing with systemic issues or problems, and a way of thinking as well, namely systems thinking [9]. Cabrera et al. [10] identify four rules or patterns of thinking that characterize all systems approaches, each of which is a special kind of relation between two elements: (a) Distinction (identity/other): draw distinctions between what is internal and what is external to the boundaries of the concept or system of concepts, (b) relationship (cause/effect): inter-linking one concept to another by identifying reciprocal causes and effects, (c) system (part/whole): organize parts and wholes into alternative nested systems, and (d) perspective (subject/object): reorienting a system of concepts by determining the focal point from which observation occurs, by attributing to a point in the system a view of the other objects in the system. According to the Distinction-System-Relationship-Perspective (DSRP) model, to become a systems thinker, one needs only to understand these four conceptual patterns and apply them in the context of a formalistic approach for systems thinking [11].

The SAQs is a novel assessment scheme which incorporates a concept map representation which is called a “systemic diagram” and represents a conceptual system having a closed, cyclic form. In systemic diagrams all concepts are interrelated, directly or indirectly, creating a closed conceptual structure which emphasizes the interactions between concepts. In the SAQ scheme, the valid analysis, construction, or completion of a novel systemic diagram with unique characteristics is required from the examinees. For accomplishing these tasks, students should be able to think in a systemic manner having developed important thinking skills, like the abilities of making distinctions, taking multiple perspectives, and creating relationships in order to organize a conceptual system, namely, to analyze the system to its
fundamental components (concepts and links) and to synthesize these components into interconnected subsystems constituting a coherent whole.

The goal of a research project carried out in our department for the past five years was the development and evaluation of a systemic assessment framework based on SAQs for the high school organic chemistry. The project has been carried out in two phases. Initially, the focus was on the potential of the SAQ scheme as well as its characteristics required to achieve in capturing aspects of students’ meaningful understanding [12]. Based on the results of this study, the SAQ scheme was then further developed and evaluated in various organic chemistry topics. A systemic assessment approach was also adopted by focusing on systems thinking assessment [13]. The methods used and the results of the project are outlined herein.

THE RESEARCH PROJECT

The First Research Phase

In this study, we preliminarily investigated if specific SAQs’ forms are potentially valid and reliable tools for assessing 11th grade high school students’ meaningful understanding of organic reactions.

Methodology

We evaluated only the type of SAQs requiring the completion of semi-completed and structured systemic diagrams ("fill-in-the blanks" SAQs) with missing components not provided [12]. This type of SAQs has a constrained task format and we selected it considering that it is more consistent with the conventional objective questions often used for assessment in high school, and thus more familiar to the students. We had to determine the characteristics of SAQs
under study. Firstly, we had to select the number of concepts in SAQs’ systemic diagrams. There is no logical constraint on the number of concepts in these diagrams. Thus, we decided to comparatively evaluate two SAQs including systemic diagrams with quite a different number of concepts: the first SAQ consisting of six concepts, and the second SAQ consisting of eleven concepts. For this purpose, and given that data collection would be subsumed under the formal Greek high school two-semester assessment, we were oriented towards the construction of two tests (A1 and B1) each containing one of the two compared SAQs, along with some conventional items. These items, requiring just recall of knowledge, would allow us to collect evidence for the “meaningful-rote” character of SAQs under study.

Secondly, we had to select the amount of what would be provided to and what would be required from the examinees. Once again, we selected different amounts of provided features and requirements for each of the two SAQs, with the second SAQ being more demanding for the examinees. Moreover, the second SAQ was constructed to be more “less-directed” compared with the first one. Our next concern was to establish a clear scoring method for SAQs’ items. In a SAQ’s systemic diagram, the various components of the diagram are all interrelated, directly or indirectly, constructing a meaningful whole, i.e. an interconnected conceptual system, with a non-hierarchical structure. We consider that each of these components equally contributes to the creation of this conceptual whole. Therefore, we suggested a 1 point score for each valid component filled-in. The SAQ, as well as one of the conventional questions (CQs), from each of the two tests, A1 and B1, are presented in Figures 1 and 2, respectively.
1) In the following diagram:
   a. Fill-in the blank squares with the chemical formulas of the proper compounds.
   b. Fill-in the blanks on the arrows with the names/types of the reactions.
   c. Two more chemical reactions can be filled-in between compounds in the diagram. Draw the arrows corresponding to these two reactions and complete on the arrows the names/types of the reactions.

```
   CCl\(_2\)CH\(_2\)Cl

   CH\(_2\)=CH\(_2\)

   catalytic hydrogenation

   H C≡CH

   bromine addition

   (one stage)

   acrylonitrile
```

2) Fill-in the blanks in the following propositions:
   a. By the addition of water in acetylene in the presence of H\(_2\)SO\(_4\)/HgSO\(_4\), the final stable product is ...
   b. ....... ....... is the product from the trimerism of acetylene.

Figure 1: Two questions (SAQ and CQ) included in the test A1.
1) In the following diagram:

a. Define the direction of the undirected linking lines (4 lines).
b. Fill-in the 5 blank squares with the chemical formulas of the proper compounds.
c. Fill-in the 5 blanks on the arrows with the reagents/conditions of the reactions.
d. Fill-in two more chemical reactions between compounds in the diagram (draw the two arrows corresponding to these reactions and complete on the arrows the names/types of the reactions).

2) Choose the right answer for each of the following propositions:

a. It shows acid character:
   i. ethanal               ii. 1-propanol              iii. butanone                  iv. propanone

b. It can be detected with addition of a carbonate salt:
   i. 2-butanol           ii. butanal                    iii. butanoic acid           iv. ethanol

Figure 2: Two questions (SAQ and CQ) included in the test B1.

Although conventional questions were purposefully constructed to be closer to the “rote” edge of the learning continuum, we were also interested in observing the influence of some other variables on their “meaningful-rote” character. One of these variables was the “sequential” form of organic reactions. Our experience in teaching high school organic chemistry, as well as
literature report [14] suggest that students are often incapable of relating individual reactions in sequential reaction schemes. Therefore, we included in the tests some conventional questions having a “sequential reaction” format. Furthermore, some of the employed conventional questions included organic compounds which were not exactly the same with those presented in the textbook. This variable is related with transfer of knowledge and was expected to enhance, more or less, the questions’ “meaningful” character.

Seventy-two 11th grade students from a public suburban high school in the Athens area participated in this study. The study was conducted over a five months period and in two stages: In the first stage, the chemistry of hydrocarbons was taught. One chemistry teacher carried out the course using the traditional approach (lectures including presentations and discussions) in 10 teaching hours. Students were provided with worksheets including various types of conventional objective questions as well as some linear questions. The latter had a similar format with SAQs, but different diagrams’ forms including concepts in a linear arrangement. These linear questions were used in order the students to become familiar with the symbolic representation of organic reactions used in SAQs. Afterwards, students were provided with worksheets including some authentic SAQs. At the end of this stage the test A1 was administered. In the second stage, the chemistry of alcohols and carboxylic acids were taught. The course was carried out in 12 teaching hours by the same chemistry teacher, using two series of systemic diagrams corresponding to the two topics under study. Based on the preliminary diagram from each series, the students, guided and supported by their teacher, using a step-by-step approach constructed the final full diagram for each topic. In addition, students were provided with worksheets including various SAQs’ formats and some conventional questions. The last step of this stage was the administration of the test B1.
Results from the first research phase and discussion

The evidence of items’ validity was calculated with “item-total score” correlations using the Pearson’s correlation coefficient (r) and the results indicated that all items contribute to the validity of the tests. The reliability for each test was calculated by Cronbach’s alpha, which was found 0.76 for the first test and 0.83 for the second test, showing that the scales have an acceptable reliability.

The hypothesis of the two dimensions (“meaningful” - “rote”) was tested using exploratory factor analysis. For both tests (A1 and B1) the appropriateness of the factor model was indicated by the Bartlett’s test of sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy. Principal component analysis using Kaiser’s criterion [15] and scree-plot resulted in two common factors, which were subjected to a varimax rotation. A minimum factor-loading criterion of 0.40 was adopted for the final interpretation of the results [16]. Taking under consideration the items’ content and requirements, the more reasonable explanation is that the one principal factor is the “rote” factor, while the other is the “meaningful” one. For the test A1, the fact that two of the three items of the SAQ-A1 (1a and 1b, Figure 1) were strongly loaded on the “rote” factor indicates that the characteristics of this SAQ are not suitable for assessing meaningful learning. For the test B1, all the items of the SAQ-B1 (Figure 2) were strongly to moderately loaded on the “meaningful” factor. This result indicates that the characteristics of the SAQ-B1 are more suitable for assessing meaningful learning compared to the SAQ-A1. A logic conclusion is that, the more “less-directed” SAQ including a more complex systemic diagram and with higher demands from the examinees, was found to be more appropriate for capturing students’ meaningful understanding of organic reactions. Regarding CQs in both tests, most of
them were strongly loaded on “rote” factor as was expected. However, the items having a “sequential reaction” format or requiring a degree of knowledge transfer showed a relatively increased “meaningful” character.

This investigation indicated that SAQs under study have acceptable psychometric properties and are suitable to be used as assessment tools in high school. Exploratory factor analysis revealed that the characteristics of SAQs seem to play a significant role as for their effectiveness for assessing meaningful learning. Between the two compared “fill-in-the blanks” SAQs, the more “less-directed” and demanding which incorporates a more complex systemic diagram was found to be more suitable for this purpose. Concerning the conventional questions, constructed to assess simple recall of knowledge, their “sequential reactions” format as well as the incorporation of “not included in the textbook” compounds seem to enhance their “meaningful” character.

**The Second Research Phase**

In this phase, the SAQ scheme was investigated as a strategy for capturing students’ systems thinking skills in organic chemistry. Various types of objective questions were also developed and evaluated for assessing meaningful understanding. Moreover, the relationship between students’ responses on the applied assessment schemes was explored.

**Methodology**

Two achievement tests, the test A2 and the test B2, were designed for the purposes of the current study. The test A2 assessed students’ knowledge about basic organic chemistry topics, such as the classification of organic compounds, the IUPAC nomenclature for aliphatic
compounds, and the constitutional isomerism of organic compounds. The test B2 assessed students’ knowledge about aliphatic hydrocarbons, with an emphasis on their chemistry. Both tests were constituted by two assessment schemes: the objective items and the SAQ items. The tests were subsumed under the formal high school summative assessment.

To develop a coherent systems thinking assessment tool, we used the assessment triangle framework articulated in Pellegrino, et al [17]. According to this framework, there are three key elements underlying any assessment: a model of student cognition and learning, a set of beliefs about the kinds of observations that will provide the evidence of students’ competencies, and an interpretation process for making sense of the evidence. Trying to articulate the systems thinking construct, we focused on Cabrera’s et al [10] approach. Systems-thinking seems to be inherently related with the ability to analyze a system to its fundamental components/subsystems and to synthesize these components into a meaningful whole, namely, to organize a system of interest. According to the DSRP model, these tasks are accomplished by repeatedly making distinctions between systems’ components, taking multiple perspectives within the system, and identifying the relationships between the parts of the system.

On this basis, we conceptualize the systems thinking construct as a three-step cognitive procedure, characterized by the repeated, step-by-step, implementation of the DSRP processing rules [13]. In a first step, some individual and conceptually unrelated concepts and/or links are identified within the defined conceptual system. In a second step, two or more components are recognized which are connected with a particular relationship, formulating a larger conceptual subsystem that is a part of the whole system. In a final step, all the interconnected larger parts/subsystems constituting a meaningful whole are recognized.
Fill-in-the blank SAQ items were designed to tap high school students’ systems thinking and were included in both tests. SAQs’ characteristics were selected based on the results of the first research phase. Both SAQs had a similar format and characteristics. However, the content of the test-B2 SAQ concerns chemical equations, namely, a specific symbolic representation of organic reactions. In contrast, the content of the test-A2 SAQ is more linguistic requiring less representational competence from students. This difference between SAQs could reveal some preliminary evidence regarding the potential of a more general and extensive use of the proposed systems thinking assessment framework, regardless of the topic or the subject matter to be assessed. The two SAQs developed in the second research phase are presented in Figures 3 & 4.

To successfully complete the SAQ diagrams, a three-step identification procedure should be carried out. By implementing analysis and synthesis procedures, students should first identify the engaged concepts and links, i.e., the fundamental components of the conceptual system of interest. If some of these components are connected with a particular relationship (interrelated), then the corresponding conceptual subsystem, which is part of the whole system, will have been identified. The most desirable outcome will be the recognition of all the interconnected subsystems, namely, the identification of the whole system under study. In each of these identification steps, students should repeatedly implement all the DSRP rules. The items were pilot tested with a small group of students for overall clarity, accessibility, and compatibility with the teaching content.
In the following diagram: (a) Fill in the blanks in eight squares, (b) Fill in the six blanks on the arrows with the proper words or phrases, (c) Define the direction of the five undirected linking lines, (d) Fill in two more relationships (draw two arrows corresponding to those relationships and label the arrows with the proper words or phrases).

![Diagram of chemical compounds and relationships]

Figure 3: The SAQ included in the test A2.

Based on the above mentioned conceptualization, we consider the systems thinking construct as a cognitive procedure that progressively distinguishes three identification steps which include five levels of skills in total, from the “no-connection” level (scored as 1) to system level (scored as 5). The levels “partial connection” (scored as 2), “full connection” level (scored as 3), and “complex connection” (scored as 4) depict the identification of unrelated concepts and links, of one subsystem, and of two or more subsystems respectively [12]. A more practical “one point for each correct component filled-in” scoring scheme, which is more accessible to a teacher
in the context of a classroom assessment, was also used for SAQs. The correlation between the two scoring schemes was examined.

Regarding the objective item scheme, the items should provide opportunities for students to link chemistry information and to translate and construct chemical representations. Advantages of different type items (fill-in-the blank, multiple choice, true-false, and matching questions) are utilized. All the fill-in-the blank questions were scored 1 point for each correct component filled-in. The multiple-choice, the true-false, and the matching questions, were also scored 1 point for each correct response. When a justification was required, the response was taken as correct only if the corresponding explanation was also correct. Two simple recall (questions 1 and 2) as well as a tiered objective question (question 3) used in this study, are presented in Figure 5.
In the following diagram: (a) Fill in the six blank squares with the chemical formulas of the proper compounds, (b) Fill in the six blanks on the arrows with the reagents and conditions of the reactions, (c) Define the direction of the six undirected linking lines, (d) Fill in two more chemical reactions (draw the two arrows corresponding to those reactions and label the arrows with the reagents and conditions of the reactions).

Figure 4: The SAQ included in the test B2.

Ninety-one (46 males, 45 females) 11th grade students from a public urban high school in Athens area participated in this study, which was conducted over a 3-month period. In the first stage, some basic organic chemistry topics were taught regarding organic compounds, i.e., the various classification schemes, the IUPAC nomenclature, and the constitutional isomerism. The applied procedure followed the same steps as the one described in the first research phase.
Results from the second research phase and discussion

Five systems thinking levels were revealed from students’ responses on A2 and B2 SAQs. The distribution of students’ responses indicates that most of the students (29 on SAQ-A2 and 35 on SAQ-B2) demonstrated a “complex connection” level, namely they were able to identify two or more, but not all possible, parts/subsystems of a whole/system. A large number of students (26 on SAQ-A2 and 22 on SAQ-B2) possessed a “system” level, which enabled them to recognize all relevant concepts and possible links that constitute a meaningful conceptual whole.

In the SAQ-A2 system, 9 students were classified in the “no connection” level, 14 students were classified in the “partial connection” level, and 13 students were classified in the “full connection” level. In the SAQ-B2 system, 6 students’ responses demonstrated no scientific meaning, 14 students were classified in the “no connection” level, 8 students were classified in the “partial connection” level, and 6 students were classified in the “full connection” level.

1. Fill in the blanks in the following propositions:
   (a) The organic compounds in which carbon atoms are connected only with single bonds are called ……………… Such a compound is one that has the structural formula ………………
   (b) The constitutional isomerism is divided into……………………. isomerism, ………………….. isomerism, and …………………….. isomerism.

2. Choose the right answer for each of the propositions (a) and (b) :
   (a) By hydrogen addition in acetylene is formed :
      i) ethane               ii) ethine               iii) ethanol               iv) ethanal
   (b) Which of the following is a reaction by which alkenes are formed?
      i) polymerization       ii) photochemical halogenation
      iii) alcohol dehydration  iv) hydrogen addition to alkanes

3. For two hydrocarbons, X and Y, the following information is known:
   • They both decolorize a solution of bromine in tetrachloromethane.
   • Hydrocarbon X reacts with sodium.
   • By hydrogen addition to hydrocarbons X and Y the same compound is formed.

   Accordingly, which one of the following propositions is correct?
   Explain why the other three propositions are false.
   (i) Hydrocarbon X is ethene and hydrocarbon Y is ethine.
   (ii) Hydrocarbon X is propine and hydrocarbon Y is ethene.
   (iii) Hydrocarbon X is propone and hydrocarbon Y is propene.
   (iv) Hydrocarbon X is ethine and hydrocarbon Y is ethene.

Figure 5: Three objective questions used in the second research phase.
The Pearson’s correlation coefficient \((r)\) was calculated to determine extent of the association between the two scoring methods used for SAQs. A very strong positive correlation was found between the scales \((r = .93\) for the SAQ-A2 and .94 for the SAQ-B2, respectively). It is obvious that, independently from the SAQ content, both scoring schemes led to almost identical results. Consequently, the more practical numeric scoring scale was used for further statistical analyses. Items’ construct validity was tested using exploratory factor analysis. For both tests (A2 and B2), the values obtained from the Bartlett’s test of sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy indicated the appropriateness of the factor models. Principal component analysis and scree-plot resulted in two common factors which were subjected to a varimax rotation. An item analysis was also conducted for a better interpretation of the results. For the objective items, an analysis of their meaningful understanding components based on their content and task requirements was also conducted. The item analysis showed acceptable difficulty and discrimination index. The “item-total score” correlations were also calculated using the Pearson’s correlation coefficient \((r)\). The results indicated that all items contribute to the validity of the tests. Moreover, the reliability of internal consistency was calculated for each test. The Cronbach \(a\) was found to be 0.87 for the test-A2 and 0.84 for the test-B2.

Taking under consideration the items’ content and requirements, the more reasonable interpretation of the factor analyses results for both tests is that, the first factor is the “meaningful” one while the second is the “rote”. In the test-A2, the objective items requiring just recall of chemical information were strongly loaded on the “rote” factor, as expected. The remaining objective items were strongly loaded on the “meaningful” factor. These items required not just the recall, but also the activation of some cognitive skills that are necessary for
successfully applying knowledge in specific situations, capturing in this way aspects of students’ meaningful understanding. For correctly answering these items students should have develop sufficient representational skills and they should be able to apply their conceptual knowledge on specific examples. Regarding SAQ items, three out of four items of the SAQ-A2 (items a, b, and d, see Figure 3) were strongly loaded on the “meaningful” factor. The item c, which asked from students to define the direction of the undirected linking lines in the diagram, was almost equally loaded on both factors.

In the test-B2, the multiple-choice and the true-false items, which were designed to assess recall of knowledge, were loaded on the “rote” factor, confirming our assumptions. The remaining questions required cognitive skills beyond simple recall, such as to draw chemical information from symbolic chemical representations and to link chemical information in order to make judgments, identify relationships, or draw conclusions. Three of the SAQ items (a, b, and d, see Figure 4), and the two-tiered objective questions (see, for example, question 3 in Figure 5) requiring a brief explanation, were all strongly loaded on the “meaningful” factor. Although the SAQ items were also moderately loaded on the “rote” factor, their loadings on the “meaningful” factor were clearly stronger.

Finally, the Pearson’s correlation coefficients ($r$) were calculated for the two variables, the total SAQ and objective “meaningful” items scores in both achievement tests, and strong positive correlations were observed ($0.68 < r < 0.77$).

Overall, a variety of tests supported the validity and reliability for the two proposed assessment schemes. The difficulty and discrimination indexes, the “item-total score” correlations, and the calculated Cronbach $a$ values, indicated that the two applied assessment schemes have acceptable psychometric properties and are suitable to be used as assessment tools.
in high school. All the factor analyses results related to the objective items under study indicate that properly designed objective questions are valid and reliable tools for assessing students’ meaningful understanding of organic chemistry concepts. The results suggest that the tiered objective questions as well as other types of objective questions requiring from students the application of conceptual knowledge on specific examples for interrelating organic chemistry concepts, explaining an answer, or translating and constructing symbolic chemical representations, were found potentially effective tools for eliciting aspects of students’ meaningful understanding in organic chemistry. This fact shows that a properly design objective assessment scheme can be a valuable tool for both classroom assessment and research purposes as well [18].

Regarding SAQs, it is noticeable that, although the content of the two SAQs was different and more representational competence is required in SAQ-B2 that involves exclusively symbolic representations of organic reactions, similar results were obtained for the two SAQs (A2 and B2) in factor analyses. This is preliminary evidence regarding the potential of the proposed systems thinking assessment framework for a more general and extensive use. A challenge for future research would be the evaluation of SAQ items having an exclusively linguistic format, i.e., not incorporating symbolic representations, and assessing other chemistry topics as well, as for example a general or inorganic chemistry topic.

The results from the factor analysis procedures showed that the SAQ items, designed to assess students’ systems thinking skills, were mostly loaded on the same factor with the objective items that were constructed to capture aspects of students’ meaningful understanding in the organic chemistry domain. Moreover, strong correlations were observed between the total SAQ and objective “meaningful” items scores. This significant association indicates that the
systems thinking level developed within a science domain is strongly related with a deeper understanding of relevant science concepts. This association certainly worth further investigation, as it may indicate new aspects concerning students’ understanding of chemistry in relation to systems thinking.

Finally, although students’ responses on the two assessment schemes were found to be significantly interrelated, each scheme was developed based on a different approach and therefore it can provide different information regarding students’ cognitive structure. A combination of the two assessment schemes gives a potential of a more multifarious evaluation of students’ conceptual understanding and knowledge integration. Such a multidimensional assessment, in combination with the appropriate learning environment, should provide more opportunities for students to develop meaningful understanding in a scientific domain.

CONCLUSIONS

The results of a research project carried out regarding the development and evaluation of a systemic assessment framework based on SAQs, showed that the psychometric properties of this assessment scheme are acceptable. It was found that SAQs’ specific characteristics, i.e., task format, diagrams’ complexity, and cognitive demands, play a significant role for this scheme in order to efficiently assess students’ meaningful understanding in organic chemistry. The SAQ scheme was also found to be a valuable strategy for capturing students’ systems thinking skills in an organic chemistry context. A significant association was observed between students’ performance on SAQs and on objective items designed for assessing meaningful understanding. This association reveals that the students’ systems thinking level developed in organic chemistry is strongly related with a deeper understanding of the relevant science concepts. It is underlined
that students’ understanding of chemistry in relation to systems thinking certainly worth further investigation.

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ACKNOWLEDGMENTS
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Mnemonic as an Innovative Approach to Creative Teaching of Secondary School Chemistry

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Abstract
Chemistry as a secondary school subject despite its importance and central role in science and development is often found difficult to understand by students. Chief among the contributing factors being the approaches used by chemistry teachers which tend to make chemistry concepts to be too abstract and uninteresting to students. Thus, most often, students tend to view concepts in chemistry as being too “volatile” as they often are unable to remember them. Thus, in order to ensure that chemistry teaching and learning become more interesting and for students to be able to remember learnt chemistry concepts, the use of mnemonics was suggested. This suggestion is based on the premise that learning and remembering of information becomes better when presented in forms that are personal, surprising or humorous and when various scientific facts and procedures to be learnt are well connected to more familiar words and phrases. Mnemonic is defined as a memory aid meant to assist in the learning and recall of information that might have been somewhat problematic to recall. Using some chemistry concepts, the paper identified some forms in which mnemonics can be used innovatively in teaching senior school chemistry. The paper then advocated for the creative usage of mnemonics in teaching chemistry to be included as a vital component of initial training and the retraining of secondary school chemistry teachers. [AJCE 4(2), Special Issue, May 2014]
INTRODUCTION

Science teaching in Nigeria dated back to 1867 when Nature Study and Hygiene were introduced as school subjects. These later became Biology, Chemistry and Physics [1-2]. Chemistry was thus among the three basic sciences introduced into Nigerian secondary schools by the colonial government. Central to the teaching of science and technology in schools is chemistry [3-4].

Chemistry as a branch of science deals with the study of the properties, and composition of matter, and how these undergo changes [5-6]. In Nigeria, chemistry as a subject is being taught starting from the post basic level of the educational system. At the basic level, chemistry is taught as an integral part of basic sciences. The importance of chemistry teaching in science and technological development cannot be overemphasized as chemistry is reputed as being central to the understanding of the other physical sciences owing to its confluence with and influences on the other natural sciences such as physics, biology and geology [7-8]. Edeh & Vikoo [9] had equally asserted that practically all forms of human endeavours and everything in science involves the application of chemistry.

The central role that chemistry plays among the sciences and technology can be discerned from the fact that to gain admissions into any programme in the (physical and biological) sciences, technology, engineering, agricultural and medical science programmes in any institution of higher learning in Nigeria requires at least a credit pass in chemistry [10].

Considering the central role that chemistry plays especially as regards the sciences at the senior secondary school level as well as its roles as parts of the core admission requirements to higher institutions across the African educational systems and especially in Nigeria, it would thus be expected that senior secondary school students’ performance in the subject would be high.
Astonishingly, available reports of students’ performance across West Africa reveal that senior secondary school students’ results in public examinations in chemistry in Nigeria, Sierra Leone, Ghana, Liberia and Gambia had consistently been getting worse. Most often, at least 70% of candidates that registered for the examination have not been able to pass [11-15].

Various factors have been attributed to students’ consistent abysmal performance in school science and mathematics subjects especially chemistry at the senior secondary level [16-18]. Chief among the contributing factors being the approaches used by chemistry teachers which tend to make chemistry concepts to be too abstract and uninteresting to students as well as the general perception of chemistry topics by students [19-20]. Another being that chemistry is generally perceived difficult to learn by students. Jimoh [20] as an example reported that senior secondary school chemistry students perceived 65% of the topics in the senior secondary chemistry curriculum difficult to comprehend. Thus most often, students tend to view concepts in chemistry as being too volatile as they often are unable to remember them [20-21].

**BEST PRACTICES IN TEACHING AND LEARNING**

To remedy this situation science educators have advocated for a wide array of options to enhance the meaningful teaching and learning of chemistry [2, 4, 7 and 9]. As an example, the US National Research Council *of the National Academies* [22] had advocated for the following four pedagogical practices as best practices of science teaching:

1. Engaging resilient preconceptions: that is, addressing students’ initial understanding and preconceptions about topics; the assumption being that students do not come into the classroom as "tabula rasa.", rather learners have got some forms of entry behaviours prior to exposure to any course of instruction; such preconceived knowledge may sometimes
tend to limit what can be learnt by students. Thus the need for the identification, confrontation and resolution of students’ preconceptions be identified, confronted, and resolved.

2. Organizing knowledge around core concepts: this implies the provision of a foundation of factual knowledge and conceptual understanding. The underlying principle is that a powerful way to increase understanding and retention is through organizing of information.

3. Supporting metacognition and student self-regulation. This involves teaching strategies that will help students take control of their learning. It is felt that teachers’ best pedagogical practices should enable students to be made mindful of what they already know as well as what they do not know. A means of ascertaining this is through appropriate evaluation strategies such as the use of pre-test and demanding that students should summarize what they have learned.

4. Cooperative Learning: this involves allowing students to learn together.

A scrutiny of the suggested best practices in teaching and learning indicates that essentially, best practices in teaching and learning should aim at making learning interesting to learners as well as aiding assimilation and recall of learnt concept. There is no doubt that various innovative methods of teaching have been suggested which are felt to be capable of enhancing meaningful learning, such include concept mapping, peer tutoring, guided discovery and use of mnemonics [1, 2, 4, 23 and 24].

Considering the fact that one of the main problems encountered by students in learning chemistry is that of inability to organize taught concepts in such a way as to facilitate ease of recall, it is thus felt that one vital means of enhancing learning of chemistry is through a method
that would aid students’ memory. This is where mnemonics comes in as a “best practice”; an innovative pedagogical approach to creative teaching and learning of chemistry

WHAT IS A MNEMONIC DEVICE

Psychologist World [26] explains that the word mnemonic (pronounced nee.MON.ik) is used (a) as a noun meaning a device, such as a formula or rhyme, that helps a person remember something or (b) as an adjective meaning aiding memory. Iza, & Gil [27] describes mnemonic as memory-enhancing pedagogical methods aimed at improving learning and information recall through the use of imagery. The Wikipedia defines mnemonics as any learning technique that aids information retention. The Awake! [28] explains that “a mnemonic is a strategy or device that helps us store information in the long-term memory and recall it when needed” (p.29). Iza & Gill’s definition however appears to be the most suitable definition of mnemonics as an instructional strategy. All these simply implies that mnemonic or mnemonic device is any pedagogical device involving the use of imagery and associations to enhance learning and aid easy recall of learnt concepts.

The vital role of mnemonics as an effective pedagogical technique had long been established [24-29]. As an example, Butcher [30] explains that the mnemonic techniques had long been in use by the ancient Greeks and Romans to improve their memory. Congos [25] [citing a study by Miller (1967)] asserted that mnemonics increased recall and that students who regularly used mnemonic devices increased test scores by as much as 77%! Mastropieri, & Scruggs, [31] inform that mnemonics can be modified to fit a variety of learning content and especially beneficial to students with learning difficulties. Hayden [32] reported of medical students’ use of mnemonics in committing anatomical terminologies to memory. According to
Mcalum & Seay [29], psychologists believe that mnemonic techniques are so effective in learning because they impose meaning and structure to material that otherwise would be unstructured or less meaningful. Among others, studies by Wang, Thomas, & Ouellette [24], Iza, & Gil [27], Hayden [32] and Mastropieri, & Scruggs [33] have justified the positive effects of the usage of mnemonic devices in facilitating learning as well as its effects on students’ abilities to recall learnt facts.

THEORETICAL BASIS OF MNEMONICS AS A TEACHING METHOD

Shawn, Thomas & Coleman [34] inform that in many of the science classes students do have to recall enormous amounts of information in somewhat short period of time. They then suggest that mnemonics as aids for science students to be able to connect various scientific facts and procedures to more familiar words and phrases that would then enhance easy learning and recall of learnt scientific facts.

This is in agreement with Ausubel [35] psychology of meaningful learning. In the preface to his book *Educational Psychology: A Cognitive View*, Ausubel [35] strongly asserted that “If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly” (p. vi). This view is also supported by Novak [36], Novak & Cañas, [37] that meaningful learning requires the learner to assimilate new concepts and propositions into existing cognitive structures.

The difficulties experienced by science students in learning large chunks of scientific facts and recalling them is aptly summarized by Novak & Cañas [37] based on reviews of psychological foundations of learning and memory:
the human memory is not a single “vessel” to be filled, but rather a complex set of interrelated memory systems… all incoming information is organized and processed in the working memory by interaction with knowledge in long-term memory. The limiting feature here is that working memory can process only a relatively small number of psychological units (five to nine) at any one moment … this means that relationships among two or three concepts are about the limit of working memory’s processing capacity. For example, if a person is presented with a list of 10-12 letters or numbers to memorize in a few seconds, most will recall only 5 to 9 of these. However, if the letters can be grouped to form a know word, or word-like unit, or the numbers can be related to a phone number or something known, then 10 or more letters or numbers can be recalled. In a related test, if we give learners 10-12 familiar but unrelated words to memorize in a few seconds, most will recall only 5-9 words. If the words are unfamiliar, such as technical terms introduced for the first time, the learner may do well to recall correctly two or three of these. Conversely, if the words are familiar and can be related to knowledge the learner has in her/his cognitive structure, e.g. months of the year, 12 or more may be easily recalled (pp 5-6).

This quotation, although used by Novak & Canas [37] to justify the use of concept mapping as a tool that facilitates meaningful learning, it needs be mentioned that it equally provides the rationale for the effective usage of mnemonics as a teaching method. As could be inferred from Ausubel [35] theory of learning and Novak and Canas’ [37] assertion of the value of using familiar words and concepts to facilitates meaningful learning of bulky facts and as well as to aid ease of recall, then mnemonics would serve as that scaffold providing the link between what is already familiar and easy to recall and that which is to be learnt. This no doubt would enhance the utilization of the retention of the knowledge for long periods of time as long as that scaffold can be remembered [38].

Asides being an effective aid to learning and recalling of scientific facts, one other significant advantage of mnemonic devices is that they can be used in a wide array of situations involving learning of large pieces of information, “from behaviour to academics to careers to hobbies” [39]. While acknowledging that mnemonics are considered as cognitive strategies,
Spackman [40] and Scruggs & Mastropieri [41] lament that the use of mnemonics fell into disuse and are not taught in schools today. They then ascribe ignorance of the techniques being a possible factor responsible for lack of its usage.

Literatures abound with different classification scheme for mnemonics (25, 29, 34 & 40). According to McAlum, & Seay [29] mnemonics techniques can be classified into two: organizational and encoding. Congos [25] informs that there are several types of mnemonics and that what works best is dependent on the individual learner. He further identified nine basic types of mnemonics which were: Music, Name, Expression/Word, Model, Ode/Rhyme, Note Organization, Image, Connection, and Spelling Mnemonics. Shawn, Thomas, & Coleman [34] identified six types of mnemonics methods the method of loci, acrostics, acronyms, clustering, sayings, and rhymes.

USE OF MNEMONICS IN TEACHING SECONDARY SCHOOL CHEMISTRY

From a review of the psychological basis for the use of mnemonics in teaching, it could thus be asserted that to facilitate meaningful learning and to enhance recall of scientific facts, as well as to aid long term memory through the use of mnemonics, the tasks of chemistry teachers would be that of helping our students to relate the new concepts we are to teach with that that they are already familiar with or would find interesting and easy to remember. All that chemistry teachers would need to do is to assist students in remembering the new materials using mnemonic devices. As mentioned earlier, mnemonics enhance recall of stored information by providing a scaffold that links what the students are familiar with to that which they are to learn. This aids the students in making mental snapshots of the information to be learned [29].
Chemistry as a secondary school subject is replete with several contents to be learnt by students. Mnemonics come in very useful in teaching and in aiding students to learn and to recall. In the following section we will illustrate with examples (mostly from personal anecdotes as a chemistry teacher) how mnemonics can be used in teaching chemistry contents.

The first approach has to do with what the use of **Expression or Word** mnemonic. To make an expression or word mnemonic, the first letter of each item in a list is arranged to form a phrase or word. There is no doubt that the expression or word mnemonics are the most popular form of mnemonics [24, 28] and possibly the easiest to use. Personal experience and literature reveal that this type of mnemonic device is very appropriate in enhancing learning of complex and abstract information [24, 28].

**The first twenty elements**

The learning of the first elements according to their atomic number is an indispensable content to be learnt by every beginning chemistry student as it serves as the foundation upon which several concepts in chemistry is built on. To teach this content we have developed the mnemonics based on the first letter of the names of the elements (or perhaps more from their symbols), but for the elements such as sodium and potassium whose symbols were derived from their Latin names, the mnemonic device entails the usage of the first letter of their Latin names. The rationale for this is to ensure consistency with the learning of the symbols of these elements. The mnemonics also include what we termed two “error checkers” which are the actual names of the elements chlorine and calcium. If for any reason, chlorine and calcium do not stand placed in the 17th and 20th positions respectively, then there is an error.
Element | Atomic No | Mnemonic
--- | --- | ---
Hydrogen | 1 | Hi
Helium | 2 | Helen
Lithium | 3 | Listen
Beryllium | 4 | Before
Boron | 5 | Boys
Carbon | 6 | Call
Nitrogen | 7 | Nita
Oxygen | 8 | Or
Fluorine | 9 | Florence
Neon | 10 | Never
Sodium | 11 | Nastically
Magnesium | 12 | Magnetize
Aluminum | 13 | All
Silicon | 14 | Silly
Phosphorous | 15 | People
Sulphur | 16 | Soldering
Chlorine | 17 | Chlorine
Argon | 18 | Around
Potassium | 19 | Killer
Calcium | 20 | Calcium

Activity series

The activity series is the arrangement of metals in the order of their reactivity. This is also another concept in chemistry that provides the framework for the understanding of various other related concepts. To teach the activity series, we make use of “the popular scientist” mnemonics. This is also an Expression or Word mnemonic. K, Na, Ca, Al, Zn, Fe, Pb, H, Cu, Mn, Ag, Hg

<table>
<thead>
<tr>
<th>Mnemonics</th>
<th>Name of elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Popular Scientists Can Make A Zoo In Low Humid Country More Successfully with Gold</td>
<td>potassium sodium calcium magnesium aluminum zinc iron lead hydrogen copper manganese silver gold</td>
</tr>
</tbody>
</table>
Interestingly these were the same mnemonics used in teaching me about the activity series which my teacher also claimed was used in teaching him and which I have been using in teaching my students!

**Diatomic Molecules**

Diatomic molecules are molecules formed when two atoms of the same or different elements bond to each other. Only seven elements naturally form diatomic molecules; these are hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine and iodine. Their molecular formulas would be written as $\text{H}_2$, $\text{N}_2$, $\text{O}_2$, $\text{F}_2$, $\text{Cl}_2$, $\text{Br}_2$, and $\text{I}_2$. In the teaching of this content, we often use these mnemonics which is also another form of expression mnemonics:

**Hi Nike Of Florida, Clearly Bridge Iodine.** Attempts were also made to include an “error checker” (by making the mnemonic for Iodine to be the name of the element) as well as to ensure consistency of the mnemonics with the symbols of the elements. The suggested mnemonics of Wikkianswer.com (41): **Oh I Have Nice Closet For Brooms** have also been found useful.

**Reduction-Oxidation (Redox) Reactions**

The Wikipedia (42) explains that the key terms involved in redox reactions “are often confusing to students” (para 42). A probable reason being the fact that both reduction and oxidation reactions occur simultaneously in any redox reaction.
Definitions of Basic Concepts in REDOX reactions

1. Cations and Anions

Cations are positively (+) charged ions while anions are negatively (-) charged ions. This following mnemonics can be of help to students in remembering these definitions and in avoiding a mix up.

**Cats have paws and Anegativeion**

This is actually a combination of a form of imagery and association mnemonics. To remember the definitions of cations and anions, all the student would have to do is to remember that cats have paws (that is Cations are pawsitive, and that the letter t in cation looks like a + (plus) sign (Ca+ion). The cat also has a negative ion that is: An anion is a negative ion (Anegativeion). Usually in redox reactions all that the student needs to do is to get a concept right, once this is done, then the converse is true for the other concept.

2. Anode and Cathode

Anode is the electrode in which oxidation takes place while cathode is the electrode in which reduction takes place. We have found the mnemonics RED CAT and AN OX very useful in remembering the definitions. RED CAT to imply: Reduction at cathode and AN OX stands for: Anode for oxidation.

3. Oxidation and Reduction

To memorise the definitions of oxidations and reduction reactions in which it is common to mix up oxidation and reduction, the suggested short phrase by Wikipedia (n.d.): "**LEO the lion says GER**" has been found very useful. That is LEO stands for “Lose Electron” Oxidation.”
and GER stands for “Gain Electron Reduction”. The acronym "Oil Rig" is also another common useful mnemonics. This acronym stands for “Oxidation is losing”, “Reduction is gaining”.

4. Redox reactions

A redox reaction is a chemical reaction in which there is a change in oxidation state of atoms participating in the reaction. An atom (or ion) whose oxidation number increases in a redox reaction is said to be oxidized (and is called a reducing agent). It is accomplished by loss of one or more electrons. The atom whose oxidation number decreases gains (receives) one or more electrons and is said to be reduced. This relation can be remembered by the following mnemonics.

To teach this concept and to aid memorization, we have found it useful to firstly reduce the definition into simpler sentences: oxidation involves an increase in oxidation number by loss of electrons while reduction involves a decrease in oxidation number by decrease in oxidation number. We have developed the mnemonics IONLEO is in DONGER.

These mnemonics stand for: Increase in Oxidation Number by Loss of Electrons (Oxidation reaction definition) and Decrease in Oxidation Number by Gain of Electrons (Reduction reaction definition).

**CONCLUSION AND RECOMMENDATIONS**

Personal anecdotes and research reports have indicated the effectiveness of mnemonics in aiding learning and recall using different subjects and different topics [24, 26, 27 and 33]. Students often report that mnemonics devices not only aid recall of facts and principles but also make learning interesting.
Despite the potentials of mnemonics devices in aiding learning and memory, the use of mnemonics is hardly a part of the methodology taught to teachers-in-training in most teacher education programs. It is also noted that although there a wide array of suggestions as to the use of mnemonics in teaching and aiding memory. A recent internet search of the word mnemonics using Google search engine returned about 1,600,008 results! And these are from all imaginable areas. Despite the vastness of the use of mnemonics, there seems to be a dearth of researches to empirically document the effects of their usages in science teaching generally and especially in chemistry teaching on students’ (cognitive and non-cognitive) learning outcomes.

It would thus be necessary that researchers in the fields of science education, chemistry teaching and learning, educational evaluation, and educational psychology would need to focus attention on empirically documenting the impacts of the use of mnemonics devices on students’ learning outcomes in various areas of chemistry and at various levels. In addition, it would also be worthwhile to investigate various possible learner characteristics as they relate to the effects of the use of mnemonics in learning outcomes.

Teacher education programs would in the same vein incorporate the use of mnemonic devices as one of the teaching methods to be taught in chemistry methodology courses. It would also be important to include the use of mnemonic devices as parts of the contents of chemistry teacher retraining programs.

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SATL MODEL LESSON FOR TEACHING EFFECT OF TEMPERATURE ON RATE OF REACTION

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ABSTRACT
Physical Chemistry is an experimental science based upon theories supported by mathematical input. It is therefore crucial that one who teaches Physical Chemistry should give a wholesome knowledge about any issue relating to this vital discipline in chemistry. To achieve this end, a systematic approach to teaching and learning method is the most appropriate teaching method [1-2]. It helps to ingrain knowledge so that illustrations of different parameters through systematic diagrams are helpful in in-depth transformation of knowledge relating to any concept. [AJCE 4(2), Special Issue, May 2014]
INTRODUCTION

Chemical kinetics is a vital discipline to grasp in order to comprehend a chemical change in its perspective. This makes available essential sources of such information through which a chemical reaction is uncovered. It thus helps to resolve the mysteries behind a chemical change. Subject of chemical kinetics depends upon various physical factors such as concentration, volume, pressure and temperature etc. Temperature dependence of a reaction takes up a central position to move in this reaction. It helps to identify the thermodynamic aspects of the reactions of the participants involved in a desired change. In addition to that for a reaction to be positive, effective collision is required. Effective collisions occur when molecules have critical energy to react with each other.

Chemical kinetics is a vital skill sought for by physical chemists in particular and hence its comprehension is highly desirable. In order to enhance understanding of these complex concepts the best, it is imperative that approach to teaching and learning (SATL) methodology is followed [3-7]. This technique is such that one grasps the knowledge, understands it in its deeper meaning and improves the ability to undertake creative steps for research and development.

METHODOLOGY

For any chemical reaction, the concentration of a reactant or product is controlled by a number of factors in a variety of ways. These include nature of reactant, concentration, pressure, temperature, catalysts etc. Further to that, temperature acts as a backbone in the investigation of any reaction kinetics.

In this presentation we highlight the role of temperature in thermodynamics. SATL lesson is being put designed to underline the concepts behind the involvement of the factors such
as connectivity between different kinetic parameters and temperature. The concepts are being
arranged so that students can enhance their skills towards better comprehension. This in turn will
help them to build their own connection between different phenomena [4-6]. Figure (1) illustrates the linear connections that highlight salient issues related to the effect of temperature on the reaction rate.

Figure 1: Linear Connections

Figure (1) can be converted into SATL pattern diagram (SD-0) as presented in Figure (2)
POSSIBLE LINKAGES OF DIFFERENT FACTORS OF THERMODYNAMICS

The key role of temperature in chemical kinetics can be explained as the increase in temperature causes the more effective collision between molecules. Effective collision is possible only when reacting molecules acquire threshold energy. So the Figure (2) (SD-0) can be modified into Figure (3) i.e., SD-1.

A close look at Figure(3) reveals that still there are some interlinkages which have to be answered through discussion between the tutor and tutees. At this stage correlations developed through this discussion help to develop an improved systemic diagram. Hence Figure(3) transformed into Figure(4) i.e.,SD-2.
Reaction rate gets promoted as the activated molecules collide with each other. Therefore at this step collision theory has to be brought in focus. Step by step discussion on remaining factors can then open some newer doors of knowledge. Accordingly Figure (4) i.e., SD-3, can be changed into SD-f, as shown in figure (5).
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**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.

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**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.