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SATLC: HAPPY 20TH ANNIVERSARY!

Temechegn Engida
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Dear AJCE Communities,

Welcome to the special issue of AJCE. This is special for many reasons:

1. SATL (systemic approach to teaching and learning chemistry) is getting 20 years old. So those researchers who passionately researched and implemented it are sharing their results to you. So happy 20th anniversary!

2. AJCE is now included in (indexed and abstracted by) the Chemical Abstracts Service (CAS), a division of the American Chemical Society, database starting the 2017 January edition. Congratulations!

3. AJCE’s impact factor has improved from the SJIF 2012 value of 3.963 to the SJIF 2013 value of 4.567. Thanks to your contribution in submitting manuscripts for possible publication and also for reading and citing the published articles!

This special issue has therefore brought to six research articles covering different aspects of chemistry using the SATL approach.

In addition, it brought to you a feature article entitled “The thumb rule reveals: facilitating the transition from electron geometry to molecular geometry and vice versa”

Enjoy reading them all!

SJIF IMPACT FACTOR EVALUATION [SJIF 2012 = 3.963]
SJIF IMPACT FACTOR EVALUATION [SJIF 2013 = 4.567]
INDEXED AND ABSTRACTED BY CAS
THE SYSTEMIC APPROACH TO TEACHING AND LEARNING CHEMISTRY [SATLC]: A 20-YEARS REVIEW

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ABSTRACT

About 20 years ago Fahmy & Lagowski set up SATLC to face (i) the world challenges such as Terrorism, world economic cries, environmental pollution...etc., (ii) the wide spread of the systematization in activities such as tourism, commerce, economy, security, education etc..., (iii) globalization became a reality that we live in and survive with its positive and negative impacts on our life. So, SATL became a must and countries are in an urgent call to prepare their citizens to be able to systemic and creative thinking. During the last twenty years SATL technique has been applied and evaluated in many different knowledge domains at all levels of education (pre-university, university, adult education), but the major teaching applications have been reported on chemistry topics in secondary and tertiary education. In chemistry, we have conducted a series of successful SATL-oriented experiments, at pre-university, and 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 approach on an experimental basis. The results indicate that a greater fraction of students exposed to the systemic techniques, the experimental group, achieved at a higher level than did the control group taught by conventional linear techniques. Also, Fahmy & Lagowsky used SATL techniques to create assessment items [SA] that not only reflect the SATL strategy of instruction, but, perhaps, also probe other aspects of student knowledge that might be learned during the classical linear method of instruction. Systemic thinking (ST) is one of the most important learning outcomes of using SATL. Finally, the above mentioned systemic activities [SATL, SA, ST] constitute the systemic components of any systemic educational reform [SER].

[African Journal of Chemical Education—AJCE 7(3), Special Issue, October 2017]


INTRODUCTION

About twenty years ago Fahmy and Lagowski [1-5] set up SATL after the sudden expansion of globalization in a wide range of human activities, so, this approach has been applied in: basic sciences (chemistry, biology, physics, mathematics), applied sciences (environmental sciences, agricultural sciences, pharmaceutical sciences, engineering sciences), law, medicine, linguistics and commercial sciences (http://www.satlcentral.com). But, however, most of the efforts on SATL methods have been expressed in chemistry subjects at different educational levels. SATL is a new way of teaching and learning, based on the global idea that nowadays everything is related to everything [1-5]. Lagwski & Fahmy [6] believe that SATL technique has additional benefits to the societies that face issues of globalization. Economics, media, politics, global warming and Terrorism, are among the human activities that have achieved a global perspective. Science education, that process by which progress in science is transmitted to the appropriate mass of world citizens—must be sufficiently flexible to adapt the global future. As a start the uses of systemics can help students begin to understand interrelationships of concepts in a greater context, a point of view, once achieved, that ultimately should prove beneficial to future citizens in the global age. Moreover, if students learn the basis of the systemic process in the context of learning chemistry, we believe that they will doubly benefit; learning chemistry and learning to see all subjects in a greater context. SATL 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.

Golmi et al [7] stated that the important changes in the way of organization of concepts intend to increase the yield and quality of the teaching process beside the role of teacher as organizer and the student as an active part in this process. SATL is a new approach contrasted to
the common approach of the concept map which involves the creation of a hierarchy of concepts. The systemic approach creates somewhat closed system of concepts, a cluster concept, which highlights interrelations between concepts. This method contradicts the linear method which is currently used in our educational systems. Nazir et al [8] stated that teachers can minimize the difficulties in concept building by providing better perspective related to the basics of the subject. This can be accomplished through novel efforts involving personal input.

The recently emerged concept based teaching methodology, systemic approach to teaching and learning chemistry (SATLC), is a fascinating route to meet this noble endeavour. This new teaching method has been discovered to play an essential role, towards the efforts for promoting better understanding of chemical concepts. In addition to that, the results reported from the evaluation of SATL technique have been very promising as far as the improvements in students’ academic achievements are concerned. Herin et al [9] stated that it is more difficult to obtain a global view of a collection of concepts with a concept map or linear representation than with a systemic (“closed-cluster “representation of concepts), which stresses all relationships among the concepts.

According to Cardellini et al [10] through the use of a systemic approach, we believe it is possible to teach people in all areas of human activity; economic, political, ethical, scientific; to practice a more global view of the core science relationships and of the importance of science to such activities. Usually, the classic SATL chemistry concept maps show relationships between disciplinary concepts only; in any case, links with global topics are not graphically recognisable.
in a clear way. Cardellini shows that it is possible to plan a new systemic way of teaching starting from the SATL, pointing out either the connections ‘internal’ to the discipline or the ‘external’ ones related to the interactions with the surrounding environment in a global systemic perspective. Also, technical high school students represent a target suitable for SATL strategy because they need to learn chemistry fundamental concepts in a shorter time without losing the connections between them and their role in real situations. John Bradley [11] stated that an emphasis of SATL is the interrelatedness of things, especially the cross-links between vertical developments of concepts as are most often presented in concept maps [12]. Indeed, Fahmy and Lagowski have emphasized the importance of “closed cluster concept maps” in their school curriculum, but seem well suited to chemical education for human development in Africa. Also Bradley added that 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.

Why SATLC?

1. To face the global challenges that faces the world today such as global terrorism, global warming, etc. That requires preparation of human calibres to be able to systemic and creative thinking that stops such phenomena for the sake of a better and safer world for all.

2. To face the Global changes of most of human activities. Economics, media, commerce, security, politics, education, communications, tourism, are among the human activities that have achieved a global perspective.
3. To change our educational systems from surface to deep learning that prepare our graduates to meet the needs of the global markets beside high skills that enable them to live and act positively in the global age.

4. To enhance our teaching and learning capacity by converting our students to active, creative learning and teachers to good facilitators during the learning process.

5. To enhance working memory of our students by grab their interest with finding ways to connect information that helps with forming and retrieving long-term memory.

6. To appreciate the huge contribution of chemistry in human welfare.

Criteria of Learning and Teaching Processes in SATL

1. Learning is an active process:
   SATL-based learning is an active process where learners are encouraged to discover principles, concepts, and facts and arrange them in a systemic relationship.

2. Role of the teacher in an SATL environment:
   - The teacher's role is not only to observe and assess students, but also to engage them while they are completing their systemic diagrams.
   - Teachers also facilitate the students’ resolution of decisions and their self-regulation.

3. Role of Learner in an SATL Environment:
   - In SATL, significant learning interactions occur between learners, between learners and teachers, and between learners and context.

Shortcomings of the Current Educational Systems

Our educational systems suffer from the following shortcomings:

1. Low Performance of the current Curriculum System
Due to the linearity of each component of the curriculum system. In order to get a maximum performance of the systemic curriculum, it is necessary that each of its components should be written systemically and acts as a sub-systemic (Fig. 1a)

1. Slight Interaction of the Current Educational Domains:

![Systemic curriculum diagram]
Core Idea of SATL

SATL stands on the holistic vision for phenomena where linking different facts and Concepts take place into a dynamic systemic network. This reflects the relationships which settles them into the cognitive construction of the learner and enables him to use it by a systemic way in different situations. It also helps learner to deduce new relations that enrich the operation of teaching and learning from its cognitive, psychomotor and emotional sides. SATL was based on the systems analysis and the theory of constructivism. The following diagram illustrates the linear and systemic illustrations of concepts (Fig.2a, b). [7]
Systemic Teaching Strategy: [Systemic Constructivist Strategy (SCS)]

In practice, the systemic building strategy was based on the systemic constructivist [SC] of the systemic arrangement of concepts and 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. Figure 3 shows this strategy for building the closed cluster of chemistry concept map (systemic; SD1-SD5) involving the five concepts entitled E, F, X, Y, Z [7].
The instructor has in mind the concept linear structure shown in Figure 2a, which he/she wants to develop into the closed cluster (systemic), shown as Figure 2b. The prerequisites are simple bi-directional relationships between the concepts. Thus, initially, there are four unknown (to the student) relationships in the [SD1] cluster of concepts; Figure 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 (SC) nature of systemic arrangement of the course content materials. This building strategy could be used in different branches of chemistry. The products of learning by SATL are correct systemic cognition, high skills, positive attitudes and systemic thinking.
We can implement systemic teaching strategy in designing any course of chemistry. We have created SATLC units on general, analytical, aliphatic, aromatic, and heterocyclic chemistry. Golmi et al [7] created unites in Biochemistry, Nazir et al [8] created unites in physical chemistry and Cardellini et al [10] created unites in general school chemistry. In this review, various examples of systemic teaching materials addressed to pre-university and the university levels of education will be illustrated.

SATL- APPLICATIONS IN EGYPT

I. 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, Pharmaceutical, sciences. In chemistry, we have conducted a series of successful SATL-oriented experiments, at pre-university, and 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 approach on an experimental basis.

1.1. PRE-UNIVERSITY EXPERIMENT

Our experiment for probing the usefulness of SATLC to learning Chemistry at the pre-university level was conducted in Egypt at Cairo and Giza school districts.

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. Nine SATL-based lessons in organic chemistry Figure (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 standard (linear) methods Fig.5 [2,6].

![Diagram](image)

**Fig.4:** Systemic based teaching and learning.

![Diagram](image)

**Fig.5:** Linearly based teaching and Learning.

The results of experimentation indicate that a greater fraction of students exposed to the systemic techniques, the experimental group, achieved at a higher level than did the control group taught by conventional linear techniques. Students who had been taught by instructors using SATL Technique were more successful in the final examination in comparison to the students who had been taught linearly? Success was defined as achievement of at least 50% in the final examination. Approximately 80% of the experimental group was successful, but only 15% of the control group reached the level of success.
The experimental group was taught by SATL-trained teachers using SATL techniques with specially created SATL materials, while the control group was taught using the conventional (linear) approach. 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. Teachers feedback indicated that the systemic approach seemed to be beneficial when the students in the experimental group returned to learning using the conventional linear
2. Teachers from different experiences, professional levels, and ages can be trained to teach by the systemic approach in a short period of time with sufficient training. The training program in systemic seems to impact teachers’ performances during the experiment.

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

I.2. UNIVERSITY EXPERIMENTS

I.2.A. Aliphatic Chemistry

This is about a study of the efficacy of the systemic approach applied to the first semester of the second year organic chemistry course (16 lectures, 32 hours) at Zagazeg University [6]. The details of the transformation of the usual linear approach usually used to teach this subject that involves separate chemical relationships between alkanes and other related compounds (Figure 8) and the corresponding systemic closed concept cluster that represents the systemic approach were illustrated (Figure 9).

Fig.8: The classical linear relationship involving the chemistry of the alkanes organized to begin to create a systemic diagram of the corresponding chemistry.
Fig. 9: Systemic diagram (SD0) that represents some of the major chemistries of alkanes

In the systemic diagram some chemical relationships are defined whereas others are undefined. These undefined relationships are developed systematically. After a study of the synthesis and reactions of alkenes the students with the help of teacher can modify the systemic diagram (SD0) shown as Figure (9) to accommodate other chemistries as shown in (SD1), Figure (10).
Fig. 10: SD1 Shows the SATL chemistry of alkanes as expanded to include the alkenes

Note that reactions 5-12 (and the reagents involved) are the key issues

After study of the chemistry of acetylene students with the help of teacher can convert the systemic diagram (SD1) in Figure (10) to (SD2) shown in Figure (11).

Fig. 11: SD2 the SATL relationship between the hydrocarbons and the derived compounds.
Systemic diagram SD2 shown in Figure (11) can accommodate to the chemistries of ethyl bromide and ethanol yielding a new systemic diagram. So, it can be used for further studies.

The systemic diagrams developed in Figures (9) through (11) were used as the basis for teaching organic chemistry course to experimental group at Zagazeg University Egypt. The experiment was conducted within the Banha 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 success of the systemic approach to teaching organic chemistry was established by using an experimental group, which was taught systemically, and a control group, which was taught in the classical linear manner. The success of the learning process was measured by the difference in the pre-test and post-test achievement. Both tests contained linear& systemic questions. The results of the study confirmed that the experimental group, which was taught by using the SATL technique, performed better than the control group taught in the traditional way. Figures (12) and (13) show the final data in terms of student achievement. These data indicate a marked difference between the control and experimental groups.
Fig. 12: 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>32.09%</td>
<td>21.54%</td>
<td>24.38%</td>
</tr>
<tr>
<td>After Intervention</td>
<td>33.33%</td>
<td>22.73%</td>
<td>27.08%</td>
</tr>
</tbody>
</table>

Fig. 13: 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>12.10%</td>
<td>20.30%</td>
</tr>
<tr>
<td>After Intervention</td>
<td>65.60%</td>
<td>59.10%</td>
<td>62.10%</td>
</tr>
</tbody>
</table>
I.2.B. HETEROCYCLIC CHEMISTRY

We use heterocyclic chemistry [13] to illustrate, again, how a subject can be organized systemically, to help students to fit the new concepts into their own mental framework. Figure 14 summarizes all the significant reactions of furan, the model heterocyclic compound.

Fig. 14. The classic linear relations involving chemistry of furan.

These are the reactions that are generally discussed in a linear fashion (Figure 2a) in the conventional teaching approach. Figure 14 summarizes all the linear significant reactions of furan chemistry. We can convert the linear conventional diagram to the systemic diagram [SD0] which indicates 7 unknown relations.

Fig. 15 [SD0]: Systemic diagram of furan chemistry
After study of the chemistry of furan students with the help of their teacher can modify SD0 to SD1 [Fig. 16]

Fig. 16. [SD1]: The result of completing the undefined relations that appears in Figure 15

The data summarized in Table 1 show that students taught systematically improved their scores significantly after being taught by using SATL techniques [13].

Table 1. Percentage increase in student scores.

<table>
<thead>
<tr>
<th></th>
<th>Percent increase in student scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before intervention</td>
</tr>
<tr>
<td>Linear questions</td>
<td>37.32%</td>
</tr>
<tr>
<td>Systemic questions</td>
<td>21.19%</td>
</tr>
<tr>
<td>Total</td>
<td>32.52%</td>
</tr>
</tbody>
</table>

These results are statistically significant at the 0.01 level.
II. SATL-CHEMICAL EQUILIBRIA

We can teach chemical equilibrium in the frame of systems at equilibrium (physical systems in nature, and biochemical systems in our bodies). Teachers write the concepts of this unite (equilibrium, chemical equilibrium, factors affecting rate of reaction, conc., pressure, hydrolysis, pH, etc.). Then teachers build the following systemic diagram (SD0) with their students Figure 17. SD0 is considered as the starting point of the unite.

![Systemic diagram (SD0)](image)

**Fig.17:** Systemic diagram (SD0) shows systemic physical relations (1 and 2) between concepts

In SD0 we have the unknown physical relations between concepts (3 – 16). Then teachers will guide their students in an active learning according to the following building steps:

- After study of the following physical concepts, (chemical equilibrium, rate of reaction, factors affecting the rate of chemical reaction), the students with the help of teacher can modify (SD0 to SD1) by adding relations (3 – 9) figure.18.
Fig.18: SD1 shows systemic physical relations (1-9) between concepts.

- After studying of the chemical equilibrium and factors affecting the chemical equilibrium, the students with the help of teacher can modify (SD1 to SD2) by adding relations from (10 – 12) figure 19.
After studying of the ionic equilibrium and its related concepts (types of chemical bonding in the molecules, concentration, pH, hydrolysis), the students with the help of teacher can modify (SD2 to SDf) by adding relations (13-16) figure 20. -SDf-means the end point for the systemic study of the Chemical equilibrium, in which all physical relations between concepts are identified.
III. GREEN CHEMISTRY: SATL VISION

Applying Systemics to laboratory instruction reveals the following advantages, which constitute the principles of benign analysis related green chemistry aspects:

- Smaller amounts of chemicals are used
- Recycling of chemicals
• Experiments are done with less hazards and more safety
• Experiments are done more rapidly
• Students easily acquire a working sense of the principles of green chemistry

Classical laboratory-oriented subject of qualitative analysis involves the application of linearly obtained chemical information to an unknown solution in a linear way. 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 Figure 21[14].

Fig.21: Systemic Investigation:

The formulas of chemical species of interest are expressed in the Figure (21) but reagents that bring about these conversions are not given. These reagents are revealed experimentally in a series of reactions shown in systemic, which the students can do in the laboratory on a small single sample of the species (A+).


The students follow the plane (SI -1) to investigate (Pb2+) in a series of experiments (1-4) in a single test tube on a small sample of lead nitrate (0.5 ml), then they recycle the product of (Exp. 4) to Pb(NO₃)₂ (cf. SI - Final) [14].

The students follow the plane (SI-2) to investigate (Ag⁺) in a series of experiments (1-3), then recycle the product of (Exp.3) to AgNO₃ (Cf. SI-2-Final).

**Result of Experimentation:**

The experimentation results showed that the benign scheme reduces the consumption chemicals in comparison with the classical scheme as shown in table (2). This means low cost, and less pollution.
Table (2): 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(NO$_3$)$_2$</td>
<td>100</td>
</tr>
<tr>
<td>Al(NO$_3$)$_3$</td>
<td>200</td>
</tr>
<tr>
<td>CrCl$_3$.6H$_2$O</td>
<td>200</td>
</tr>
<tr>
<td>NiCl$_2$.6H$_2$O</td>
<td>200</td>
</tr>
<tr>
<td>Co(NO$_3$)$_2$.6H$_2$O</td>
<td>200</td>
</tr>
<tr>
<td>CdCl$_2$.5H$_2$O</td>
<td>150</td>
</tr>
<tr>
<td>BaCl$_2$.2H$_2$O</td>
<td>200</td>
</tr>
<tr>
<td>MgSO$_4$.7H$_2$O</td>
<td>200</td>
</tr>
</tbody>
</table>

Statistical Data

Statistical data showed that the students of the experimental group are significantly improved towards the principles of qualitative benign analysis however no improvement in the students results of the control group after applying traditional methodology. This is shown in the following tables (3, 4).

Table (3): Students Mean, standard deviation, (t) Value and Effect Size of the results of an achievement test for the experimental and control groups.

<table>
<thead>
<tr>
<th>Learning Levels</th>
<th>Experimental group $n=60$</th>
<th>Control group $n=26$</th>
<th>$t$</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Means</td>
<td>SD</td>
<td>Means</td>
<td>SD</td>
</tr>
<tr>
<td>Knowledge</td>
<td>4.08</td>
<td>0.69</td>
<td>3.5</td>
<td>0.89</td>
</tr>
<tr>
<td>Comprehension</td>
<td>11.73</td>
<td>1.97</td>
<td>10.98</td>
<td>1.55</td>
</tr>
<tr>
<td>Application</td>
<td>3.25</td>
<td>1.03</td>
<td>2.31</td>
<td>1.32</td>
</tr>
<tr>
<td>Analysis</td>
<td>6.23</td>
<td>2.06</td>
<td>2.46</td>
<td>1.31</td>
</tr>
<tr>
<td>Synthesis</td>
<td>10.13</td>
<td>1.87</td>
<td>2.38</td>
<td>1.60</td>
</tr>
<tr>
<td>Evaluation</td>
<td>5.18</td>
<td>1.07</td>
<td>2.12</td>
<td>1.33</td>
</tr>
<tr>
<td>Total</td>
<td>40.53</td>
<td>3.77</td>
<td>23.49</td>
<td>5.28</td>
</tr>
</tbody>
</table>

Notes: * $t > 0.01$ ** $t > 0.5$
Table 4: 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</td>
</tr>
<tr>
<td>Control</td>
<td>33</td>
<td>20.30</td>
<td>1.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant at < 0.01

IV. SYSTEMIC ASSESSMENT [SA]

Fahmy & Lagowsky [15-19] used SATL techniques to create assessment items that not only reflect the SATL strategy of instruction, but, perhaps, also probe other aspects of student knowledge that might be learned during the classical linear method of instruction. Recent studies indicated that Systemic Assessment Questions [SAQs] are valid and reliable evaluation tools for 11th grade high school students. SAQs consider several concepts at once applying them in a new situation which requires the synthesis of a comprehensive answer [20].

IV.1. Why Systemic Assessment?

Systemic assessment (SA) has the following advantages:

i. it measures the cognitive structure from the quantitative through the qualitative (domains);

ii. it assesses student’s higher-order thinking skills where they are required to analyse, synthesize, and evaluate;

iii. it measures the students’ ability to correlate between concepts;

iv. it enables the students to discover new relationships among concepts;

v. it gives the students rapid feedback during the term about how well they understand the course material;
vi. it assesses the students in a wide range of concepts in the course units (earning outcomes (ILOs);

vii. it develops the ability to think systemically, critically, and creatively, and to solve problems;

viii. it is very easily scored;

ix. it is objective, realistic and valid.

IV.2. TYPES OF SYSTEMIC ASSESSMENT QUESTIONS [SAQS]

SAQs are the building questions of any systemic assessment [SA], namely, systemic multiple choice questions [SMCQs], systemic true-false questions [STFQs], systemic matching questions [SMQs], systemic sequencing questions [SSQs], systemic synthesis questions [SSynQs], and systemic analysis questions [SAnQs].

Students answering SAQs are able to;

- Connect several concepts at once, applying them in a new situation, and synthesize them to create a comprehensive meaningful conceptual structure.

- Select specific concepts that fit the particular item and combine them into integrated meaning in their systemic cognitive structure.

- Illustrate systemic meaningful understanding of scientific concepts.

IV.2.1. Type-1: Systemic Multiple choice questions (SMCQs)

MCQs are the traditional choose one from a list of possible answers [21,22]. However, (SMCQs) are choose of one systemic from a list of possible systemic. Each systemic represents at least three to five physical or chemical relations, between concepts, atoms, or molecules. Various
types of systemic multiple choice questions from the fields of general, organic, heterocyclic, and physical, chemistry are published by Fahmy & Lagowski [15,16].

Examples

Form-1: Choose from Triangular Systemics

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

- **(a)**
  - Fe
  - FeCl₂
  - FeSO₄
  - Fe₂(SO₄)₃
  - Fe₃O₄

- **(b)**
  - Fe
  - FeCl₂
  - FeCl₃
  - Zn
  - Cl₂/Δ

- **(c)**
  - Fe
  - FeO
  - CO/700°C
  - CO/400-700°C
  - Fe₂(SO₄)₃

- **(d)**
  - Fe
  - FeSO₄
  - FeO
  - Fe₂O₃
  - Fe₃O₄

**Answer:** (c) ✓ (……)
Q2-The systemic diagram represents the correct chemical relations between Ethylene, Ethanol, Ethyl bromide is one of the following

![Diagram]

Answer: (b) √

Q3. The systemic diagram represents the correct chemical relations between benzene, chlorobenzene, and phenol is one of the following:

![Diagram]

Answer: (c) √
**Form (II): Choose from quadrilateral systemics**

- Put (\(\checkmark\)) in front of the correct systemic diagram:

Q4. The systemic diagram represents the correct chemical relations between (Fe) and its related compounds are one of the following:

![Systemic Diagram](image)

**Answer:** (b) \(\checkmark\)

Q5. The Systemic diagram represents the chemical relations between Oxirane, Aziridine, Ethanolamine, and Ethylene is one of the following:

![Systemic Diagram](image)

**Answer:** (b) \(\checkmark\)
IV.2.2. TYPE-2: -Systemic True False Questions [STFQ, s]:[17]

STFQ, s are well suited for testing student comprehension, synthesis and analysis, and require a student to assess whether a systemic is true or false. Advantages of [STFQ, S] are students can respond to many STFQ, s, covering a lot of concepts & facts and their relations in a short time, can assess higher-order thinking skills in which students are able to analyze, synthesize, and evaluate, and Teachers can easily score STFQ, s [17].

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

Answer: True systemics (a, d) (✓); False Systemics (b, c) (X)
IV.2.3. Type-3: -Systemic Sequencing Questions: [SSQs]

SSQs require the student to position text or formula in a given Sequence in a systemic diagram, and can assess higher-order thinking skills [17].

Examples:

Q-1-Arrange iron and its related compounds in the right places of the following systemic diagram:

\[
\text{[Fe, FeCl}_2\text{, FeCl}_3\text{, Fe}_2\text{(SO)}_4\text{]} \]

Answer:

Q-2-Arrange the given organic compounds in the right places of the following systemic diagram:

\[
\text{CH}_3\text{COOH , CH}_2=\text{CH}_2\text{, C}_2\text{H}_5\text{OH, CH}_3\text{CH}_2\text{Cl , CH}_3\text{CH}_3,} \]
IV.2.4. Type-IV: Systemic Matching Questions [SMQ, s]:[18]

Measure the student's ability to find the relationship between a set of similar items, each of which has two components.

Guidelines for Writing [SMQ, s]:

1. The items in the left (Column A) are usually called premises and assigned numbers (1, 2, 3, etc.).
2. The items in the right (Column B) are called responses and designated by capital letters (A, B, C etc.).
3. The arrangement of premises and responses are in a given systemic diagram (Column C, in the middle).
4. The given systemic diagram could be triangular, quadrilateral, or Pentagonal.
5. All of the premises and responses for a matching item should appear the same page with the given systemic diagram.

I. Matching on Triangular Systemics [18]

Q1) Choose aliphatic compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C):
Answer (1):

- C₂H₄
- CH₃CH₂OH
- CH₃CH₂Br

Conc H₂SO₄/180°C
HBr

Aq. KOH/Δ

Answer (2):

- CH₃CH₃
- C₂H₄
- CH₃CH₂Br

H₂/cat.
Br₂/hv

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

Q3) Choose compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C):

<table>
<thead>
<tr>
<th></th>
<th>(A)</th>
<th>(C)</th>
<th>(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>CH₃COOH</td>
<td>Soda lime/heat</td>
<td>KMnO₄/ H₂SO₄</td>
</tr>
<tr>
<td></td>
<td>CH₃CHO</td>
<td>Cl₂/hv</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CH₃CH₂Cl</td>
<td>Aq. KCN/heat</td>
<td></td>
</tr>
<tr>
<td>CH₃Cl</td>
<td>CH₃OH</td>
<td>HI/P-200°C</td>
<td></td>
</tr>
<tr>
<td>CH₃CH₂OH</td>
<td></td>
<td>Dil. HCl/heat</td>
<td></td>
</tr>
</tbody>
</table>
V-2.5: Type-V: Systemic Synthesis Questions [SSynQs][18]

Measure the student's ability to find the relationship between a set of given compounds.

Form I: Synthesis of Triangular Systemic Chemical Relations:

Q1) Draw triangular systemic diagram illustrating the systemic chemical relation between Thiophene and the following related compounds:

![Triangular Systemic Chemical Relations](image)

**Answer:**

![Systemic Chemical Relations Diagram](image)

Form II: Synthesis of Quadrelatral Systemic Chemical Relations:

Q2) Draw systemic diagram illustrating the systemic chemical relations between the following compounds:

![Quadrelatral Systemic Chemical Relations](image)
Form III: Synthesis of Pentagonal Systemic Chemical Relations:

Q3) Draw systemic diagram illustrating the systemic chemical relations between the following Pyrrole compounds:

Answer:

\[
\begin{align*}
\text{Cl}_2 (2 \text{ mole})/ \text{AlCl}_3 & \quad \xrightarrow{\text{BuLi}} \quad -40^\circ \text{C} \\
\text{N} & \quad \xrightarrow{\text{Cu/Quinoline}} \quad \Delta \\
\text{CO}_2 & \quad \xrightarrow{i) \ \text{CO}_2} \\
\text{H}_2\text{O} & \quad \xrightarrow{\text{H}_2\text{O}} \\
\end{align*}
\]
V. SYSTEMIC THINKING [ST]

Systemic thinking is a simple technique for gaining systemic insights into complex problems. Conventional [Linear] thinking techniques are fundamentally analytic. Systemic thinking is a combination of analytic thinking with synthetic thinking. It is based on the facts that everything is Systemic & Interact by all other the things around it.

V.1. Do we need another way of thinking?

Our society’s way of thinking is analysis by taking things apart. Analysis is a strong way of thinking for understanding all the parts of a situation. When we break things down into smaller parts, we will lose the insight of the interactions between them. Analysis makes; the interactions less visible, and the insight decreases. So we analyse things further & things goes from bad to worse. However, in synthesis thinking we see how things work together.

V.2. Analytic thinking VS Synthetic Thinking

1. Analytic thinking enables us to understand all the parts of the problem. However, Synthetic thinking enables us to understand how they work together.

2. Synthetic thinking is harder than Analytic thinking due to the fact that; the interactions are harder to deal with and they are dynamic, changed all the time and affects each other every time.

V.3. How we think systemically?

The first step in analytic thinking is by listing as many elements as we can think of. The second step is synthetic: by finding the common theme repeating pattern across those elements.

V.4. How we enhance systemic thinking?

Vachliotis et.al [20,23] stated that systemic assessment questions [SAQs] were designed to be used effectively to assess meaningful understanding and systems thinking, after students become familiar with a particular teaching theme. They examined secondary school students’ systems thinking skills in an organic
chemistry domain. For this purpose they constructed and evaluated fill-in-the blank systemic assessment questions [SAQs].

Herin et al [24,25] explained the fact that instruction via [SSynQs] brought students to a level in which they could not only identify the initial concepts (organic compounds) and simple relations, but also effectively “transform” such concepts within the selected system. These findings could be considered as valuable for the future research, in which some another types of [SAQs] should be constructed and examined as tools for assessing different aspects of systems thinking construct.

V.5. Advantages of the systemic thinking

1. Enables us to deal with the elements of any situation in harmony rather than in isolation.
2. It offers the potential to find systemic focus in any situation.
3. Enables anyone can use it to gain deeper insight about anything.

CONCLUSIONS

1. SATLC improved the student’s ability to view the chemistry from a more global perspective.
2. SATLC helps the students to develop their own mental framework at higher-level cognitive processes such as application, analysis, and synthesis.
3. SATLC increases student’s ability to learn subject matter in a greater context.
4. SATLC increases the ability of students to think systemically.
5. SATLC helping students to see the pattern of pure and applied chemistry rather than isolated concepts, and facts
6. SATLC in Egypt could be used as a successful model for teaching and learning Chemistry in other countries.
SUMMARY

We can summarize the above mentioned systemic activities [Systemic approach to teaching and learning chemistry (SATLC), Systemic assessment (SA) and Systemic thinking (ST)], in the following systemic diagram under the title of systemic education reform [SER].

![Systemic Education Reform Diagram]

Each systemic component interacts with the other components systemically. SA was used to assess students’ achievements after exposed to SATLC. However, SA is used to enhance ST. Also, ST is one the important learning outcomes of SATLC.

REFERENCES


**ACKNOWLEDGEMENT**

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THE SYSTEMIC APPROACH TO TEACHING AND LEARNING CHEMISTRY AND THE BIG IDEAS OF SCIENCE EDUCATION

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ABSTRACT

The systemic approach to teaching and learning chemistry has been implemented and researched for a number of years. There is substantial evidence of learning benefits from its application in the context of specific chemistry topics. In the wider context of science curricula however, the ambition of Fahmy and Lagowski to change curricula from linearity to systemic seems yet to be realized. We suggest that such a change could be initiated by introducing the Big Ideas of Science Education into existing curricula in a systemic manner. We exemplify our proposal with the case of the Grade 7-9 Natural Sciences curriculum in South Africa. [African Journal of Chemical Education—AJCE 7(3), Special Issue, October 2017]
FROM LINEARITY TO SYSTEMIC

‘Normal science’ was characterized by Kuhn [1] as puzzle-solving within a framework of established paradigms. For this reason he advocated that future scientists should follow a normal science education that built basic subject knowledge and skills. This logic has been widely adopted in school science curricula, but in more recent times criticism has grown. This can be illustrated by van Berkel’s commentary [2] that school chemistry curricula:

“tend to be isolated from common sense, everyday life and society, the history of science, the philosophy of science, technology, school physics and from chemical research”

The evidence is that such curricula are not attractive to the majority of learners. Their content, according to Aikenhead [3], is “socially sterile, impersonal, frustrating, intellectually boring, and/or dismissive of students’ life-worlds”.

Curriculum designers, noting the lack of enthusiasm of many school learners, have responded in various ways. Chemistry in the Community [4], Salters Chemistry [5] and, more recently, Chemie im Kontext [6], for example, are some of the variants of curricula that try to reach out to learners and their interests, whilst delivering basic chemistry knowledge and skills.

Attending to the need to capture the interest of school learners is clearly a sound objective. However, the need to deliver useful scientific knowledge that can inform and empower school leavers in their later life, regardless of the career they choose, is also important (as the above-mentioned curricula recognise). So what is offered to interest the learner needs to be coherently planned. A systemic approach to teaching and learning chemistry (and science in general) can be a way to do this. In the last two years of the 20th century, Fahmy and Lagowski made a case for “the use of a systemic approach in teaching and learning chemistry for the 21st century” [7]. Their
meaning was a “study of chemistry concepts through interacted systems in which all relationships between concepts are clear”. They sought “to change our educational systems from linearity to systemic”. Linearity is one of the features of normal science education as traditionally implemented, so their proposal also represents a challenge to that tradition.

Since then several papers have reported on research in the classroom focused on the achievement of students when taught by traditional and by systemic approaches. Considerable evidence has been accumulated, demonstrating superior achievement by learners taught systemically about a number of chemistry topics [8].

Following a suggestion by Bradley [9], the approach has evolved to incorporate the ‘chemist’s triangle’, leading to the Systemic Chemistry Triangle [SCT] as a teaching and learning strategy [10].

The Systemic Approach to Teaching and Learning Chemistry (SATLC) has demonstrated its worth in the context of the school chemistry classroom. However, it remains a teaching and learning approach applied to selected topics and working within the framework of an existing curriculum. It is therefore an open question as to whether national school curricula themselves have yet been touched by the approach. It is also not clear whether the criticisms of curricula that provide ‘normal science education’ have been addressed through this approach. It seemed appropriate therefore to investigate how in a school curriculum the ideals of the systemic approach to teaching and learning might be achieved more comprehensively. As we shall argue in the next section, the Big Ideas of Science Education [11], seem to offer a solution.
A SYSTEMIC APPROACH IN SCIENCE CURRICULUM DESIGN

We became interested in this possibility after undertaking the design of study guides for qualified Grade 7-9 teachers studying towards an Advanced Diploma in Education by distance learning. For that purpose we engaged with the ‘Principles and Big Ideas of Science Education’, a report published by the Association for Science Education (ASE) in 2010 [11]. In this publication many of the same sentiments about student science learning for the future are cited as motivation for the concept of Big Ideas. On the one hand is the almost irresistible tide of new information arising from continuing scientific research and development; on another hand is swelling numbers (globally) of children of school age, and on yet another hand there is growing awareness of global stresses due to expanding populations and economic activity. All these were alluded to in the original SATLC article of Fahmy and Lagowski, [7] of more than a decade previously. Designing school science curricula that have a different aim from those providing ‘normal science education’, remains a challenge.

The ASE report [11] declared:

“Current school science leaves many students untouched in developing broad ideas of science that could help understanding of things around them and enable them to take part in decisions as informed citizens.”

“The goal of science education is not knowledge of a body of facts and theories but a progression towards key ideas which enable understanding of events and phenomena of relevance to students’ lives.”
The Big Ideas of Science Education report, simply put, argues that these problems and ambitions demand, that we should teach science by first identifying the Big Ideas of Science and then planning our teaching accordingly. Hence in every grade you teach the prescribed content, but with awareness that, as you do so, you also are developing one or two Big Ideas of Science. This awareness is not just an abstract idea but something you include in your teaching and learning program, and even your lesson plans. By focusing upon a limited number of Big Ideas of Science, the feeling (and the reality!) of a mass of disconnected facts can be avoided and learners can acquire a more coherent knowledge of the subject.

In the ASE report, 10 Big Ideas of Science and 4 Big Ideas about Science are identified (and re-confirmed with slight wording changes in a recent up-date, Working with Big ideas of Science Education [12]). No explicit distinction is made amongst the different sciences, although it is fairly easy to relate a Big Idea of Science with a traditional school science subject. Four of the Big Ideas of Science seem attributable to the Physical Sciences, with others being attributable to Biology and Geology. Chemistry educators would probably claim that the Big Idea:

All matter in the Universe is made of very small particles

is of particular relevance to them, although it certainly cannot be an exclusive claim. This being accepted we describe in the following section how this Big Idea of Science can lend further weight to the case for a curriculum that is more systemic.

BIG IDEAS IN A SYSTEMIC SCIENCE CURRICULUM

The diagram below shows how a Big Idea of Science can function to link concepts and topics that may themselves show little or no linkage – a situation that often arises within the context of national school curricula!
To help clarify the idea, we shall take a concrete example from the South African Natural Sciences curriculum for Grades 7-9 [13]. The curriculum content of this is organized into ‘strands’ called Life & Living, Matter & Materials, Energy & Change, and Planet Earth & Beyond. Very roughly, these ‘strands’ can be identified with science content typical of biology, chemistry, physics and geology, respectively. Consequently for present purposes we select the Matter & Materials ‘strand’ as our example, to explore how the Particle Big Idea can make links.

In Grade 7 we find the following topics, listed in the prescribed sequence for teaching during the second term:

1. Physical properties of materials
2. Separating mixtures
3. Acids, bases and neutrals
4. Introduction to the Periodic Table

It is relevant to our understanding that we also take account of the preceding grade (6) content of the Matter & Materials ‘strand’:

- Solids, liquids and gases (arrangement of particles)
- Mixtures
- Solutions as special mixtures
- Dissolving
It is then, in Grade 6 that a simple particle model of matter is introduced. The three states of matter are compared in terms of what is described as ‘the arrangement of particles’. The particles are undefined in any way, except that they are said to be all the same and that they move. Concepts such as energy, forces and particle structure are not referred to.

This then is the immediate background to the Grade 7 content and concepts of the Matter & Materials ‘strand’. It might seem that the first step had been taken towards the development of the Particle Big Idea in Grade 6, and that in Grade 7 a further step or steps would be seen. This is however not the case: there is no reference to the particle concept anywhere in Grade 7. Some continuity between Grade 6 and 7 topics may be seen of course, in the attention to mixtures, and in the physical properties topic (which includes reference to melting and boiling points of materials). The other Grade 7 topics have no links with any previous topics.

The diagram below shows the Grade 7 Matter & Materials topics linked with the Particle Big Idea. We consider the four topics as systems, previously not interacting with each other, as brought into interaction through the Particle Big Idea. The relationships involved are indicated by the linking concepts.
The new particle concept that can be introduced through these topics is shown above the linking lines. Following the given topic sequence, it shows that the new aspects of the particle model that can be introduced are:

1. Particles have a structure and the structures can be classified as discrete, macromolecular, or infinitely extended.
2. There are forces between the particles/molecules, sensibly termed intermolecular forces (IMF).
3. The structures of particles/molecules can be changed; the process is termed chemical reaction.
4. Atoms joined by chemical bonds, constitute the particles/molecules and give rise to their varied structures.

How then can the links be established? The following paragraphs briefly indicate this.

1. **Physical Properties of Materials**, in the South African science curriculum document, deals with a variety of physical properties: strength, flexibility, boiling and melting points, electrical conductivity and heat conductivity. The materials suggested for study include everyday ones, mostly solid: paper, cardboard, copper wire, rubber, plastic, stone/clay, brick, glass, aluminum
foil, wax paper, rope/string, water.

In our view, experiencing observations with such materials, should create a crisis of confidence in the simple particle model of matter described in Grade 6. The model of ‘arrangements of particles’ to account for the three states of matter is not capable of dealing with the realities presented by this topic. The simple (or simplistic) model needs diversification in ways that relate to the realities. The term molecule needs to be introduced and the structure types identified by Jensen [14] (discrete, macro, and infinitely extended), offered as a working hypothesis.

2. **Separating mixtures** is a topic that follows on from the Grade 6 topic of mixtures and highlights the observation of both homogeneous and heterogeneous mixtures.

The particle model can explain the phenomena in terms of intermolecular forces (IMF) between discrete molecules, which result in attraction between like molecules being either stronger or weaker than between unlike molecules. Substances with infinitely extended molecules will not form solutions without molecular break-up, which may be translated as requiring chemical reaction.

3. **Acids, bases and neutrals** deals with the use of an indicator (litmus) to identify such materials, for example in the home. This study uncovers a new type of phenomenon, that is chemical reaction. The color change of the indicator is due to a color change of the indicator molecules. This happens because the molecules undergo a structure change. This is seen to be reversible. The molecules of the test material must also experience a structure change.
4. Introduction to the Periodic Table arises in the curriculum, before the concepts of element and atom have been defined! Definition and explanation follows only in the Matter & Materials strand in Grade 8. From our point of view however, introducing the concept of atom closes the circle in developing the Particle Big Idea in Grade 7. Atoms are the building blocks of molecules, wherein they are chemically-bonded together. Different atoms bond together in different ways to constitute the diversity of molecular structures, which in turn explain the diversity of materials in our environment.

It must be emphasized that the linking new particle concepts described above, which appear on the link-lines of the diagram, are proposed to be introduced in a simple manner. For example, the possible different types of molecular structure require no more than rational thought. There is no intention of a thorough discussion of how and why these structures form, for example. It is a question of thinking like a scientist, who brings to the study of the physical properties of materials, the simple particle model (as introduced in Grade 6). Because it is inadequate in explaining these new observations, the scientist asks how the simple model can be improved to do so. Discrete molecules (as with water) exist, but we have to allow for other types if we are to understand much of our environment.

Arising from this we see a systemic approach to the teaching and learning of the Grade 7 topics, which of themselves seem unconnected. The systemic approach is made possible by identifying a Big Idea of Science, which can be seen to have links with each topic. In the process of teaching these topics it should also become obvious that some of the Big Ideas about Science, set out in the ASE document, are also exposed, such as:

*Science is about finding the cause or causes of phenomena in the natural world.
Scientific explanations, theories and models are those that best fit the facts known at a particular time.*
Observing physical properties of materials, testing for acids and bases, etc, may have some interest for Grade 7 learners, especially if they can engage in simple practical activities. But there can be a deeper purpose to these if the particle idea is to be developed from them. We have designed and adapted several microscale experiments for teachers to explore this purpose in their self-study. Thus teachers on the course can recognise that, they are experiencing how science and scientific models develop. They may also consider that some of their learners may show heightened interest through the same or similar practical activities. This possibility of opening doors to new interest in science is of course part of the motivation for inquiry-based science education.

We have made similar analyses of the content of the Matter & Materials ‘strand’ in Grades 8 and 9, and constructed systemic diagrams based upon the Particle Big Idea. Thus we may say that we have designed a systemic curriculum for the Matter & Materials ‘strand’ Grades 7-9. This is at least a step towards one of the goals envisaged by Fahmy and Lagowski for the teaching and learning of chemistry for the 21st century [7].

CONCLUSIONS

The systemic approach to teaching and learning chemistry, first proposed in 1999, has been under development for several years. It represents an approach to teaching and learning that can be introduced by individual teachers on a topic by topic basis, within the framework of a national curriculum they are obligated to deliver. This possibility has enabled the testing of the approach, and student achievement has been enhanced.

A comprehensive transformation of the curriculum itself from linearity to systemic seems not to have been attempted yet. It is our feeling that such attempts should begin.

The concept of the Big Ideas of Science Education may offer a way forward for this
ambition. A Big Idea of Science can help the construction of systemic diagrams for sections of the curriculum, even when the curriculum content itself suggests there is no possibility. In addition, by adopting a Big Idea of Science as the central concept in a systemic diagram, important Big Ideas about Science can be highlighted. From such a beginning, if successful, more far-reaching systemic diagrams may be conceived that actually bring about an overall reconsideration of the curriculum.

REFERENCES

SATL BASED LESSON FOR TEACHING METABOLISM IN BIOCHEMISTRY

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ABSTRACT

The implementation of teaching through SATL method is being suggested to be preferred to discuss the content of metabolism in an effective and meaningful way. It provides a better understanding of the metabolic reactions, their importance in the regulation of body’s function and in understanding the associated diseases of improper metabolic reaction. This teaching technique will open new thinking approach and develop interest in students rather being getting confused and wary of learning. Teaching through connectivity will present the basic concepts in a cognitive way and students will be able to correlate it to the issues and clarify them at a glance. [African Journal of Chemical Education—AJCE 7(3), Special Issue, October 2017]
INTRODUCTION

Traditional method of teaching is prone to inefficient delivery. It is practiced by teaching the context without any meaningful learning outcome. The learner would not be able to relate the existing knowledge with the previous information on the subject and thus would be unable to apply the knowledge in a purposeful way. It is therefore desired to deliver the context through connectivity in a meaningful, easier and thoughtful way. Concept mapping is a methodology for the delivery of facts, concepts and skills in one package. It makes teaching and learning; easier and purposeful. SATL is a basic idea of teaching by an arrangement of concepts or issues through interacting systems in which all relationships between concepts and issues are made clear, up front, to the learner using a concept map-like representation. It involves establishing a hierarchy of concepts striving for underscoring a more or less closed system of concepts to clarify the interrelationships among these concepts. Lesson modeled on the basis of SATL diagrams help to overcome the traditional snags.

To Ausubel, meaningful learning is a process in which new information is related to an existing relevant aspect of an individual’s knowledge structure and which, correspondingly, must be the result of an overt action by the learner. Teachers can encourage this choice by using tools such as concept maps. Some theories postulate that continued learning of new information relevant to the previous information produces constructive changes. Meaningful learning presupposes that the learner has a disposition to relate the new materials to his or her cognitive structure and that new material will be potentially helpful for the learner. SATL is a method that can be used to communicate to the learner as well as providing a vehicle to help the learner with meaningful learning tasks. It provides the basis of relating new knowledge to previously assimilated knowledge in a systemic way. Concept mapping also incorporate a strong element of
constructivism; in the sense that a student can build his/her understanding of newer inputs over and above that which he/she is already having a deep familiarity.

A number of issues pertaining to chemistry have been thus addressed in our previous discourses [1-7].

A lesson model for teaching biochemistry has been developed for the first time and presented herein. This may lead to teach various other topics of biochemistry via SATLC approach.

Step-1: Linear connections of different metabolic terms

“Metabolism” is one of the most difficult and conceptually hard contexts of biochemistry which often causes the students to get confused or withdraws them. It involves different terms which themselves have to have a detailed mapping of their own like organs, enzymes, biomolecules, energy, nutrition or diet and nutritional states (fed/starvation) etc. It is understandably hard to relate the concept of metabolism to these various terms. Let us first indulge into a linear connection to start mapping these ideas. In the linear connection these terms can be defined and explained through a liner diagram as shown in figure 1.
Step-2: Systemic relations related to the various terms of metabolism

Step-2-1: Build SDo

Teaching metabolism through SATL method makes it easier for the students and it will provide them meaningful and purposeful outlays. Figure 2 illustrates the connectivity of metabolism with the each of the stake holders. Students usually have previous knowledge regarding organs, diet, and energy through linear connections. However they may or may not have concepts developed enough to approach enzymes and their functions in the body, formation of biomolecules and the wholesome response of body. Enzymes are the substances that are regarded as a biocatalyst. An enzyme will determine which metabolic pathway a cell will undergo. Enzymes act on biomolecules, basic components of a cell, known as substrate and after the biochemical reaction they form products thus a connection to enzyme with metabolism and other metabolic terms like biomolecules gets established. As a consequence of enzymatic action in different biological states (fed/starved) also grasped in same manner. In figure 2, the initial systemic diagram, SD0, these vital contributors towards the life process are indicated and highlighted for an ensuring classroom discussion. Through this connectivity diagram the students understand metabolism better and let him/her delve into the beneficial effects. As from the diagram it is apparent that metabolic processes that energizes the human body has many inputs, one of these being the enzyme action. Mode of action of enzymes that is based upon lock and key concept can also be built upon at this stage. Each enzyme works on a specific site i.e. its substrate molecules to induce a specific function just like a key works for its specific lock. Hence an interest is developed which helps a student to relate the other terms with this enzymes function in further details.
Step-3: advanced pictorial diagram to connect the advance topics of metabolism with the previous knowledge.

**Step-3-1: Build SD1**

Students will be able to appreciate the role of each of the identified components related to metabolism. He/she will be able to understand how our body organs work, where different enzymes are located and how they perform their actions, what are biomolecules and what are their nutritional importance in the diet, how much energy the body can get when taking particular amount of biomolecules in the diet, also student will be able to understand effects of nutritional status (fed/starvation) on our body organs. Through the discussion involving interconnectivity of the individual unfamiliar contents, students will be able to grasp metabolism. All the discussed and clarified contents are tick marked in figure 3. Figure 3 illustrates the correlation of salient
variables that relate to the metabolism and with each other. Clarifying all the individual contents by teacher will let the students to correlate each of these with the other and now they will be able to understand and value each of the individual parameters that are important for the regulation of metabolic processes in the body. When a person takes in diet or in the fed state; organs will respond by activating particular enzymes which act on different biomolecules present in the diet and provide energy. It will be anabolic category of metabolism. Whereas in starvation condition the organs of our body respond differently by activating different enzymes which will start the catabolic processes of biomolecules to provide energy to the body.
Step-4: advanced pictorial diagram to connect the advance topics of metabolism with the previous knowledge.

**Step-4-1: Build SD2**

Now when all the previous knowledge of metabolism is summarized through connectivity, at this stage advanced level thinking can be built in students’ minds through systemic learning in the form of SD3 as shown in figure 04. In this figure the idea that how diet that is utilized in the form of biomolecules is important in playing a vital role in the energizing sequences of the body that are related to various biological states fed or starved condition and ultimately towards affecting organs and over all metabolism of the body. Now this idea is represented in the figure 04.
Step-5: final pictorial diagram to show all the aspects of metabolism.

**Step-5-1: Build SD final.**

At this stage all concepts of metabolism are now revealed. And a final map of metabolism is thus established through SATL diagram.

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**CONCLUSIONS**

A model lesson for teaching and learning the concepts underlying metabolism has been developed on the basis of systemic building strategy. We feel that a lecture delivered through this SATL Scenario is going to be more useful for the undergrads students. This mode of teaching and learning is likely to open new avenues for appreciating the knowledge of biochemistry. As this is the first ever SATL designed lecture of biochemistry.
REFERENCES
EXAMINING SYSTEMS THINKING THROUGH THE APPLICATION OF SYSTEMIC APPROACH IN THE SECONDARY SCHOOL CHEMISTRY TEACHING

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ABSTRACT
This study was conducted during the second semester of 2012/2013 school year, with the aim to investigate two possible applications of systemic synthesis questions, SSynQs: as instructional and assessment tools observing the construct of systems thinking in organic chemistry. In order to achieve this aim, the secondary school students were divided into two groups, one experimental (E: systemic classroom training) and one control (C: traditional classroom training). The final testing was conducted after instruction on three teaching themes: “Alcohols, phenols, ethers”, “Carbonyl compounds” and “Carboxylic acids and their derivatives”. The instrument for assessing students’ systems thinking skills contained isomorphic and analogical SSynQs, while the results focused on E and C group students’ percentage distribution through the four levels of systems thinking construct, as well as differences in their performances. Namely, the results obtained from both isomorphic and analogical SSynQs indicated that male and female students subjected to systemic classroom training developed systems thinking skills in a more effective way than students from control group. Perceiving analogical SSynQs and gender as independent variable, the statistically significant difference appeared in E group within the most complex IV level of systems thinking, for the benefit of females. However, contrary to our previous research, E group male students were as much successful as female students in III level, and this finding led us to the conclusion that male students might benefit from longer lasting instruction with SSynQs. [African Journal of Chemical Education—AJCE 7(3), Special Issue, October 2017]
INTRODUCTION

In the science education literature it was noted that systems thinking is a very important higher-order thinking skill that students should develop, but simultaneously one of the most difficult to master [1]. Salisbury [2] defined systems thinking after observing the disadvantages of traditional science education. Science education at schools still concentrates on isolated concepts and facts [3] that are fragmented instead of linked with others and integrated in larger, meaningful wholes [4]. Thereby it is not possible to properly understand the new problem, or unit, by taking it apart and studying the characteristics of each concept individually. Hence, it was noted that such analytical approach should be complemented with synthetic approach and systems thinking [2].

Systems thinking has been mentioned in the many fields, and thereby received different meanings – from discipline to skill [5]. Salisbury [2] defined systems thinking as “discipline for seeing wholes”. On the other hand, many authors agreed with the fact that systems thinking is a highly complex cognitive skill which includes the process of analyzing the system to its fundamental concepts, but also the synthesis of these concepts into a meaningful whole [1, 6]. For example, Burandt [5] considered systems thinking as a skill that allows individuals to better understand interdependencies and processes in the observed system.

Development of systems thinking with adequate instructional method is important [4] at each education level, but there is a need for valid and reliable instruments for its assessment too [3, 6]. In the literature, there are several different qualitative and quantitative tools for systems thinking assessment: video analysis, questionnaires, interviews [3, 7], drawings, and word associations [7]. Recently, systemic assessment questions, SAQs, were designed for this purpose [8-10], and applied in the empirical studies [see 6, 11-13].
Firstly, SAQs were proposed by Fahmy and Lagowski [14] within Systemic approach to teaching and learning chemistry (SATLC) as new objective test questions, or assessment schemas that belong to the broader group of concept mapping technique. Similarly, to concept maps, SAQs include two-dimensional spatial arrangement and representation of concepts and their interrelations [15]. However, there are some crucial differences between concept maps and SAQs. While concept maps have hierarchical structures, or arrangement of concepts, as the main characteristic [16], SAQs present closed, cyclic, interacting, and evolving conceptual structures – the “concept clusters”, in which all existing relations between concepts are highlighted [6, 15, 17].

Depending on the number of concepts that are included in the assessment schema, SAQs were designed following several geometric shapes: triangular, quadrilateral, pentagonal, hexagonal, etc. Nodes correspond to the relevant concepts (Fig.1: Concepts A, B, C, D), while relations (Fig.1: labeled lines with x, y, z, w) between concepts are presented in clockwise or anticlockwise direction [8]. For example, concepts A, B, C and D could be organic compounds, while x, y, z, w (e.g. temperature, light, pressure, catalyst, reagent) explain relations between them [18].

Fig. 1: SAQ with quadrilateral geometric shape and clockwise direction of relations (adjusted from [18, 19])
Fahmy and Lagowski [8] have proposed several types of SAQs: systemic true/false questions, STFQs, systemic multiple choice questions, SMCQs, systemic matching questions, SMQs, systemic sequencing questions, SSQs, systemic synthesis questions, SSynQs, and systemic analysis questions, SAnQs. In our studies, we have applied one specific type of SAQs: SSynQs. However, the differences between original version and our SSynQs can be observed in the request of the question:

i. In the original version, concepts that are parts of a particular SSynQ are mentioned in the request of the question, and students should build diagram by positioning these concepts in the right fields, and highlight relations among them [9];

ii. In our SSynQs students are required to perceive defined relationships and initial concept in unfilled, or partially filled SSynQ, to be able to identify concepts that are missing [18, 19]. Example of SSynQ is provided in “Methodology” section (Fig. 2 and 3).

Since the beginning of our research with SSynQs, our interest centered on developing and applying SSynQs as valid and reliable instructional and assessment tools for high school organic chemistry. Firstly, our focus was on students’ meaningful understanding of organic chemistry [18, 19, 20], and recently we have paid more attention on systems thinking [12, 13]. In this particular study, the following main research question was defined:

- Are there statistically significant differences in students’ achievements at defined four levels of systems thinking construct, observing groups (experimental/control) and gender (males/females) as independent variables?
METHODOLOGY

Participants

This study included 119 participants, 61 males (51.26%) and 58 females (48.74%), who were high school students (11th school year, 17-18 years old). Our experiment was conducted in four classes, in one urban high school in Novi Sad, Serbia.

In order to achieve the aim of this study, the experiment with two parallel groups: one experimental (E: systemic classroom training) and one control (C: traditional classroom training), was chosen. Namely, classes were divided into two experimental and two control classes, after equalization by students’ average chemistry grades achieved at the end of first and second school years (E group: M = 4.38, SD = 0.63; C group: M = 4.42, SD = 0.70). Since the data was not normally distributed (Shapiro-Wilk test, E group: W = 0.830, p = 0.000; C group: W = 0.790, p = 0.000), a non-parametric Mann-Whitney test was applied to compare medians of the E and C groups. The results showed that there was no significant difference in average chemistry grades between the two groups (E group: MR = 58.77, SR = 3820.00; C group: MR = 61.48, SR = 3320.00, U = 1675.00, p = 0.653). Thus, formed E group consisted of 65 students and C group consisted of 54 students.

Study context and design

This study was conducted in the second semester of the 2012/2013 school year and students followed the organic chemistry course: “Organic compounds with oxygen”. Three teaching themes were chosen as the material for this experiment:

- “Alcohols, phenols and ethers”
- “Carbonyl compounds”
- “Carboxylic acids and their derivatives”.
Separate studies were conducted within each teaching theme, and each individual study contained two main phases. In the first phase, the two groups were treated equally, by the traditionally-oriented instructions of two chemistry teachers. The selected teachers both hold the Master’s degree in Teaching of Chemistry, and have had approximately 10 years of experience working with high school students.

During the second phase, the E group students were taught in the systemic manner (application of SSynQs), in order to revise and practice what they have learned in the first phase. The authors of this paper prepared learning sheets with SSynQs for each teaching theme (examples are provided in [12, 20]), which required students to recognize relations highlighted on the arrows, as well as initial concepts, in unfilled and/or partially filled SSynQs. The teacher used a PowerPoint presentation, so that all the students might see the correct answer, which was presented by a video projector on white board.

At the same time, during the second phase, C group continued with traditionally-oriented instruction, solving conventional, linear questions (e.g. open-response, completion type, matching, and multiple-choice), in which only two concepts (e.g. two classes of organic compounds) might be linked.

After finishing the second phase of each particular study, the students were subjected to the testing. The results of assessing students’ systems thinking skills were previously published for “Carbonyl compounds” [13] and “Carboxylic acids and their derivatives” [12]. However, at the end of this complex study, E and C groups students were subjected to the final testing in June 2013, and the results of the final testing will be presented in this paper.
Instrument for assessing students’ systems thinking

The final test of knowledge contained nine questions: six linear questions (open-response, completion type, matching, and multiple-choice) and three SSynQs. However, in this paper, one isomorphic and two analogical SSynQs were observed as the instrument for assessing students’ systems thinking skills.

At the beginning, it is worth mentioning that students from both E and C groups were familiar with SSynQs, as they were solving this type of questions during assessment process for mentioned three teaching themes: “Alcohols, phenols and ethers”, “Carbonyl compounds”, and “Carboxylic acids and their derivatives”. Hence, there was no need for additional instructions before final testing, and students of both groups had 45 min (one school class) to solve the test.

Isomorphic SSynQ was identical with previously applied SSynQ, which was part of the instrument for assessing students’ systems thinking skills for one specific teaching theme “Carboxylic acids and their derivatives” (presented in [12], p. 1462). This enabled us to conserve the strict isomorphism between the questions (SSynQs) from previous and final assessment instruments. An important fact to mention regarding the construction of the analogical SSynQs is that they were modified from their original version (version of the questions included in the previous assessment instruments), after students’ first encounter with them. For example, SSynQ presented in Fig. 2 and 3 is analogical with SSynQ included in assessment instrument for “Carbonyl compounds” (presented in [13], p. 179). Thereby, the following changes were made:

- Selected representatives of ketones (original version: propanone; modified version: 3-methyl-2-butanone);
- Number of main fields, or concepts (original version: 6; modified version: 5; exclusion of one unstable product);
Number and nature of relations (links between alkene and alkyne).

The analogical SSynQs were included in the assessment instrument in order to investigate if E and C groups students were able to more actively explore underlying and relatively new problems (SSynQs), and/or to more effectively identify concepts and relations that are relevant to question solutions, if they have some previous knowledge and experience in that sub-domain (according to [21]).

Fig. 2: SSynQ included in the assessment instrument as analogical question

Fig. 3: Solution of SSynQ included in assessment instrument as analogical question

Scoring rubric for SSynQs is based on systems thinking construct. Contrary to original three-step scoring rubric with five systems thinking levels (proposed by Vachliotis et al. [11]), modified scoring rubric considered four levels [13], described in Table 1. According to the Table
1, each student could obtain maximally 4 points for isomorphic and 4 points for analogical SSynQs.

Table 1. Scoring rubric for SSynQs (adjusted from [13])

<table>
<thead>
<tr>
<th>Level</th>
<th>Scores</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Lack of scientific knowledge; black fields in SSynQs, or irrelevant answers</td>
</tr>
<tr>
<td>I</td>
<td>1</td>
<td>Identifying the relevant, but unrelated concepts as individual parts of the sub-system, and/or system</td>
</tr>
<tr>
<td>II</td>
<td>2</td>
<td>Identifying semantically correct relations between two concepts of the systems (sub-systems)</td>
</tr>
<tr>
<td>III</td>
<td>3</td>
<td>Organizing (relating) more than two systems concepts in the larger conceptual sub-system</td>
</tr>
<tr>
<td>IV</td>
<td>4</td>
<td>Recognizing all concepts, relations and sub-systems by forming a meaningful whole – a system</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

In order to examine students’ performances at four levels of systems thinking, percentage distribution by group and gender was observed, separately for isomorphic (Fig. 4) and analogical SSynQs (Fig. 5). At the beginning, perceiving isomorphic SSynQ, it should be highlighted that all E group students managed to reach I level of systems thinking – identifying individual and conceptually unrelated concepts (Fig. 4). On the other hand, observing analogical SSynQs, the same could be said for E group female students, while 16% of male E group students did not reach I level of systems thinking in these questions (Fig. 5).

Additionally, 42.4% of C group male students and 45% of C group female students have not managed to reach I level of systems thinking while solving isomorphic SSynQ (they remained on 0 level). Similar percentages of C group students (52.4% males and 46% females) were not able to reach basic level of systems thinking in solving analogical SSynQs neither. According to this, it might be said that only about half of the C group students of both genders developed abilities to
identify and present individual, fundamental concepts (compounds) in organic chemistry conceptual system.

Furthermore, the highest percentage of E group male students was characterized by prominent ability to correlate multiple concepts. Namely, according to their performances in SSynQs, 40% (isomorphic question) and 36% (analogical questions) of E group male students retained on III level of systems thinking (Fig. 4 and 5). These findings were in accordance with Vachliotis et al. [11], who also noted high number of students who reached III level of systems thinking, connecting three or more concepts and forming larger conceptual sub-systems. However, significantly lower percentage of E group male students reached expected IV level of systems thinking, which was especially noticeable in analogical SSynQs (only 12% of E group male students reached this level). Contrary, 52.6% E group female students have managed to reach the highest level of systems thinking while solving isomorphic SSynQs, or 36.9% while solving analogical SSynQs.

The results also showed a percentage decrease of male and female students in the defined levels of systems thinking within the C group. Hence, high percentage of students of both genders was positioned within “0 level” (Fig. 4 and 5), as they were not able to provide any answer, or the provided answers were incorrect in both isomorphic and analogical SSynQs. The lowest percentage of male and female C group students was observed in III and IV levels of systems thinking. For example, only 4.8% of male and 5% of female C group students reached IV level of systems thinking (i.e. interconnection of all concepts and sub-systems), while solving analogical SSynQs (Fig. 5).
Fig. 4: Distribution of E and C group students through the systems thinking levels in isomorphic SSynQs

Fig. 5: Distribution of E and C group students through the systems thinking levels in analogical SSynQs
In order to statistically compare the E and C group students’ performances in four levels of systems thinking the nonparametric Mann-Whitney test was done. The results for isomorphic SSynQ are presented in Table 2, while for analogical SSynQs in Table 3.

Observing students’ performances at I, II, and III level of systems thinking, the results of conducted test showed the significant differences between E and C groups, for both genders. These results were found perceiving both isomorphic (Table 2) and analogical SSynQs (Table 3). Additionally, statistically significant difference did not appear between males and females neither within E, nor within C group students. According to this, it might be said that systemic approach in teaching and learning organic chemistry (i.e. solving SSynQs on classes) provided better opportunity for both male and female E group students to develop I, II and III level systems thinking skills, than traditional instructional method for both male and female C group students.

Furthermore, the results of E and C group students’ performances on IV level of systems thinking are consistent with those previously analyzed (for I, II, and III levels), however only within isomorphic SSynQs. Within analogical SSynQs, it was found that E group females developed higher IV level systems thinking skills than E group males (Table 3: \( U = 178.50, p = 0.044, p < 0.05 \)). While 36.9% of E group females managed to perceive complex interrelations among all the concepts (Fig. 5), only 12% of E group males were successful at this level of systems thinking. What more, statistically significant difference in IV level of systems thinking did not appear between E and C groups males (Table 3: \( M(Em)=12\%, \ M(Cm)=4.8\%, \ U = 243.50, p = 0.391, p > 0.05 \)). These results are logical sequence of our previous study about application of SSynQs as instructional and assessment tools for students’ systems thinking skills, observing “Carbonyl compounds” as teaching theme [13]. However, in our previous study, E group female students outperformed males in two levels of systems thinking: III level (identification of multiple,
dynamic relations between concepts) and IV level (identification of most complex, cyclic relations between concepts) [13]. Perhaps, what is needed for male students in order to achieve greater benefit from systemic approach could be provided by longer lasting instruction with SSynQs. This might be reflected even in reaching the most desired and most complex IV level of systems thinking.

Table 2. Results of Mann-Whitney test for comparing performances of E and C groups students in defined levels of systems thinking observing isomorphic SSynQs

<table>
<thead>
<tr>
<th>Systems thinking level</th>
<th>Performance</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E(m)/E(f)</td>
<td>C(m)/C(f)</td>
<td>E(f)/C(f)</td>
<td>E(m)/C(m)</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>M(m)=100%</td>
<td>M(m)=57.1%</td>
<td>U=237.50</td>
<td>U=104.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M(f)=100%</td>
<td>M(f)=55%</td>
<td>p=1.000</td>
<td>p=0.001*</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>M(m)=88%</td>
<td>M(m)=28.6%</td>
<td>U=221.50</td>
<td>U=95.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M(f)=94.7%</td>
<td>M(f)=45%</td>
<td>p=0.447</td>
<td>p=0.001*</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>M(m)=72%</td>
<td>M(m)=23.8%</td>
<td>U=196.00</td>
<td>U=67.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M(f)=89.5%</td>
<td>M(f)=25%</td>
<td>p=0.159</td>
<td>p=0.000*</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>M(m)=32%</td>
<td>M(m)=9.5%</td>
<td>U=188.50</td>
<td>U=118.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M(f)=52.3%</td>
<td>M(f)=15%</td>
<td>p=0.175</td>
<td>p=0.014*</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Results of Mann-Whitney test for comparing performances of E and C groups students in defined levels of systems thinking observing analogical SSynQs

<table>
<thead>
<tr>
<th>Systems thinking level</th>
<th>Performance</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E(m)/E(f)</td>
<td>C(m)/C(f)</td>
<td>E(f)/C(f)</td>
<td>E(m)/C(m)</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>M(m)=84%</td>
<td>M(m)=47.6%</td>
<td>U=199.50</td>
<td>U=104.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M(f)=100%</td>
<td>M(f)=55%</td>
<td>p=0.071</td>
<td>p=0.001*</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>M(m)=60%</td>
<td>M(m)=23.8%</td>
<td>U=205.00</td>
<td>U=107.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M(f)=73.7%</td>
<td>M(f)=30%</td>
<td>p=0.348</td>
<td>p=0.007*</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>M(m)=48%</td>
<td>M(m)=14.3%</td>
<td>U=236.00</td>
<td>U=128.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M(f)=47.4%</td>
<td>M(f)=15%</td>
<td>p=0.967</td>
<td>p=0.031*</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>M(m)=12%</td>
<td>M(m)=4.8%</td>
<td>U=178.50</td>
<td>U=129.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M(f)=36.9%</td>
<td>M(f)=5%</td>
<td>p=0.044*</td>
<td>p=0.015*</td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSIONS

This study presented the results of the final testing of the experiment that lasted for the entire second semester of 2012/2013 school year, within secondary school organic chemistry. Observing systems thinking as four levels construct, the results of this study indicated that SSynQs might be applied in secondary school organic chemistry teaching as effective instructional and assessment tools.

Firstly, it is important to note that E group students, who were subjected to systemic classroom teaching, outperformed C group (traditional classroom teaching) in all four levels of systems thinking. These results are different from those published in [13], where all the students who participated in the study performed relatively high on the I level of systems thinking. One of the more important facts, which did not appear in our previous research [13], is that instruction with SSynQs could lead to the development of higher systems thinking skills (e.g. organizing and relating multiple systems concepts in the larger conceptual sub-system) within male students also, if they are provided with longer lasting systemic oriented instruction. Namely, statistically significant difference between E group males and females appeared only at the highest level of systems thinking (i.e. recognizing all concepts, relations and sub-systems by forming a meaningful whole – a system) in analogical SSynQs, where females outperformed males. Hence, longer lasting instructions with SSynQs that might result in development of higher-order thinking skills such as systems thinking, creative thinking, critical thinking, posing questions, formulating arguments [22] within both genders, are worth future investigation.

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ATTRACTIVE EDUCATIONAL STRATEGIES IN TEACHING AND LEARNING CHEMISTRY

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ABSTRACT
The main objectives of this article is to find attractive and appropriate educational strategies and methodologies that could be used in teaching and learning chemistry in order to attract new generations to appreciate studying the most important discipline in science; chemistry. Chemistry is considered as the central backbone for science since its concepts and theories can explain all the scientific phenomena. Since science is the core of the human sustainability, therefore improvement of chemical education would definitely result in improvement of social sustainability. Attractive educational strategies in teaching and learning chemistry can be achieved by using attractive and interactive appropriate methodologies such as Systemic Approach (SATLC), E-learning, M-learning, and any other tools in which modern technologies are integrated. [African Journal of Chemical Education—AJCE 7(3), Special Issue, October 2017]
INTRODUCTION

Chemistry is the central part of all science subjects due its special concepts and importance. But Chemistry is a very complicated discipline of science, starting from atomic structure, reaction kinetics, energetics of bond breaking, formation, micro-molecules, to macromolecular compounds. All of chemical processes require deep understanding of the chemical concepts and basics, training on scientific inquiry and problem-solving skills. There are some challenges facing teaching and learning chemistry, so that the word "chemicals" has become linked with environmental pollution, unsustainable growth and unhealthy toxins, many students prefer to avoid studying chemistry, even if they have an interest in science: because of its reputation for lowering grade point averages. Moreover, many teachers are not up to the job of inspiring and not enthusing to their students, due to their traditional lecturing style as it allowed for maximum content coverage and it was the mode with which they were most familiar. In recent years, the effectiveness of the traditional unbroken lecture method has come under the scrutiny of science teachers for its inability to reach students with a wide range of abilities and learning styles, and the passive atmosphere it creates in a classroom. When an instructor chooses to use an alternative pedagogy, there is often concern about whether portions of the course content are sacrificed. However, to make chemistry easy, funny to learn, important and applicable we always need to find strategies that make the above parameters are well addressed.

Among the mechanisms method of teaching and using appropriate instructional materials are the important strategies used to make chemistry attractive and effective. This is a common concern, though it is our impression that many faculties involved in curriculum reform feel that the benefits provided by alternative instruction.

This article will focus on some attractive educational strategies and methodologies that
enhance teaching and learning chemistry through, Systemic approach, ICT; e-learning, virtual class rooms, video streaming, and self-paced education, Satellite; Videoconferencing, and m-learning, in order to outweigh the loss of attraction towards chemistry education. Following are some attractive educational strategies that empower teaching and learning chemistry.

1. **Systemic Approach in Teaching and Learning Chemistry**

   1.1. **Differentiation Between Systemic and Systematic Approach**

   At the beginning we should differentiate between systematic and systemic approach. Systematic, means something is well organized and arranged according to a set of plan or is grouped into systems. Whereas, systemic means that something has or can affect the entire system. Systemic approach describes something that belongs to, work together with, or can affect the entire body or system as a whole [1]. We represent Figs. 1 and 2 to simplify the difference between systemic and systematic approach in a system consisted from items A, B, C, and D. In the systemic approach (Fig. 1) the items (A-D) are well arranged in an organized order so that you cannot see A through D, whereas in the systemic approach (Fig. 2), all the items (A-D), are affecting each other and seen synchronously.

![Fig.1 (Systematic Approach)](image1)

![Fig.2 (Systemic Approach)](image2)
1.2. Systemic approach in Teaching and Learning Chemistry

Systemic Approach in Teaching and Learning provides inter-relationships between concepts, methodologies, or/and disciplines. It leads to more global thinking, and enhances the quality and quantity of chemistry understanding. It proves to be very effective in the assessment of the educational processes [2].

The Systemic Approach in Teaching and Learning (SATL) is based on constructivist principles and involves the creation of closed cluster concept maps called systemic diagrams. The SATL technique encourages deep learning, as opposed to rote learning. Examples in the use of SATL methods in teaching chemistry are presented. Experimental evidence collected in Egyptian schools is presented to illustrate the efficacy of SATL methods on student achievement. It is suggested that SATL methods mimic current understanding of how the human brain functions, as the basic reason that SAL methods are successful. The authors reported success in students’ achievement using SATL methods in chemistry courses has been reported for the following subjects: aliphatic chemistry, aromatic chemistry, heterocyclic chemistry, analytical chemistry and physical chemistry [3-11].

2. Using Technology to Enhance the Effectiveness of Chemistry teaching and learning

Chemistry is dynamic; molecules are constantly moving, even when they are not reacting so that it could not be explained as static. However, through 3D molecules, animations and graphic, it becomes possible to show how chemical reactions take place, both at the macroscopic and the molecular level, resulting in the incorporation of attractive chemistry in action.
3. Using Information Technology (IT) to Enhance Teaching and Learning Chemistry

This article will focus on some methodologies that enhance teaching and learning chemistry through the use of IT; e-learning, virtual class rooms, video streaming, and self-paced education, Satellite; Videoconferencing, and m-learning.

3.1. E-Learning

Over the past few years, education has been improved by rapid developments of the ICT. There is an increasing demand for both web-based courses and for additional online materials to supplement and enhance classroom learning (blended learning). As a result, the availability of E-learning options has become an essential component of educational ability to attract students. E-Learning is a tool for designing new learning technique at anyplace or pace (24/7) using ICT. E-learning becomes a powerful recruitment tool, particularly for global education, and empowers teaching and learning science in general, and chemistry in particular. It enhances the understanding of scientific concepts through providing rapid access to knowledge and information.

3.2. Empowerment of Chemistry Education using E-Learning

The purpose of e-learning is the dissemination of information about the uses of technology to enhance teaching and learning chemistry and to stimulate discussion on these issues within our learning community. E-Learning makes education available at any place and pace. It also allows collaboration discussions between students and instructors and among students themselves synchronously through virtual classrooms, streaming videoconferences, video-conferences, white boards, etc., or asynchronously through self-paced education, forums, online education, e-mailing,
bulletin boards, etc.

3.3. Advantages of the Virtual Classrooms:

While current research shows that asynchronous online learning can be as effective as a traditional classroom, I found that addition of synchronous interaction in a blended environment provides significant advantages in teaching and learning chemistry.

In these methodologies, we are teaching chemistry, techniques and skills that chemists use out in the real world. Synchronous e-learning allows students to interact with computer modeling programs while they are in class. Students will be able to present sketches, graphs and drawings on the course Web site, download the files when they get to class, and also improve collaboration between professors and student, and among students themselves.

The most advantage of the virtual class room is the ability of the instructor to view those files synchronously, while students are still working, unlike a traditional paper notebook which would have to be turned in after.

3.4. Impact of Using ICT on Teaching and Learning Chemistry

Chemistry study requires a lot of memorization. The ideas and concepts that are developed during E-learning can be captured by the students and help to broaden their understanding of the theories, reactions, and mechanisms presented. Many approaches to this is the enhancement of teaching chemistry, through guided inquiry, 3D molecules, equations, graphics, animations, quizzes, etc., which have been developed to help increase student participation in classroom activities with the goal of increasing their understanding and skills. Also e-learning helps in teaching and learning green chemistry, educational materials, including laboratory exercises,
course syllabi, lecture demonstrations, case studies, lecture content, textbooks, and interactive learning modules could be presented using new technologies (Multimedia, CDs, web-enabled content, video-conferencing, etc.).

"Good teaching is good teaching, no matter how it's done". E-learning proves to be flexible, provides content synchronously (virtual classrooms), asynchronously (self-paced), or blended. It allows content to be available and convenient for everyone at any place or pace, 7/24. It enhances teacher's skills and performance and student’s understanding, decision making and problem solving. It allows interactivity and collaborative discussions, assessments, assignments, through forums, virtual classrooms, e-mails, white board, blogs, repository etc. It is designed around the learner, fosters greater student interaction and collaboration and also student/instructor contact. Enhances computer and Internet skills, and eliminates geographical barriers and allows broader education options. The most important impact is to attract students to study chemistry. It allows also teaching of green chemistry which is basically the design of products and processes, with reduction or completely elimination of hazardous substances in order to reduce the amount of pollution reactions produced.

The most important impact of using E-learning in teaching and learning chemistry was verified by the high attraction of students to register in the courses of chemistry and studying them with great satisfaction and getting high scores with achievement of deep understanding.
3.5. **Key Issues for High Quality E-Learning**

To create an attractive high quality e-learning, we should take into consideration the following:

1. High quality successful web-based course.
2. Appropriate Learning Management System (LMS).
3. Successful online instructor.
4. Successful online student
5. Successful virtual classroom
6. Appropriate technology; information and communication technology (ICT) and computer networks.
7. Complete Integrated Solutions.
3.6. Disadvantages of E-Learning

The most notable disadvantages of e-learning are:

1. Lack of face-to-face interaction between students and teachers.
2. Expensive Web and software development
3. Lack of security, copyrights and policies
4. Lack of Infrastructure
5. Minimal interpersonal conduction
6. Some health and social problems

4. Improvement of Chemistry Education through M-Learning

The mobile technology that our students are using every day, 24 hours-a-day, deserves some consideration for potential use to help students learn chemistry. Use of mobile phones and tablets as a medium for learning is defined as M-Learning. This can be achieved by the use of mobile and portable devices such as PDA, cell phones, portable computers and Tablet PC. They must have the ability to connect to other computer devices, to present educational information and to realize bilateral information exchange between the students and the teacher. Mobile learning (m-learning) offers a whole new concept of learning for those who want immediacy and real interactive learning opportunities. M-Learning must include the ability to learn everywhere at every time without permanent physical connection to cable networks.

Regardless of existing disadvantages till now, the m-Learning will became more and more popular with the progress of information and communication technologies. Its common use with the traditional education will correspond to the needs of educational quality improve. The
educational process will become more flexible and will fulfill to the needs of lifelong learning. M-Learning also can assure good educational opportunities for disabled people.

4.1. How Can Apps Improve Teaching and Learning Chemistry?

Apps are application software designed to run on smart phones and other mobile devices. The Apps provide new ways of interaction with information. Interaction happens anytime, anywhere, with anyone or anything. The challenge to teachers is how to take advantage of the Apps, in the context of the course, to help students learn chemistry.

Apps that provide lessons on reactions mechanisms and stoichiometry and reaction animations are highly attractive and appreciated by students. There are Apps with lots of exams with difficulties ranging from easy to hard and include answers for each.

There are Apps that can be used to edit and build molecules in 2D and 3D, others with screen casts for analytical chemistry calculations of molarity and dilutions, games for experiments, dictionaries of chemistry terms, and titration simulators. Others provide features to perform complex calculations on topics ranging from gases, solutions, thermodynamics, electrochemistry, and acids and bases.

Regardless of existing disadvantages till now, the M-Learning will become more and more popular with the progress of information and communication technologies. Its common use with the traditional education will correspond to the needs of educational quality improve. The educational process will become more flexible and will fulfill to the needs of lifelong learning. M-Learning also can assure good educational opportunities for disabled people.

However, M-Learning has some pros and cons:

**PROS:** Flexible and affordable, since most students have their own device, portable, “anywhere,
“anytime” learning, enables a personalized learning experience, allows immediate feedback.

**CONS:** Some students do not have a phone, classroom distraction, Potential for unethical behavior (cheating), privacy concerns, health concerns, raise questions about how to evaluate, lack of competence.

### 4.2. Pedagogical Implication of M-Learning

Helps to break down the financial and mobility constraints of learning.

- Provides learners with instructional materials and interaction whenever or wherever they need it.
- Allows instructors to access services and interact with students while on the move.
- A flash-based mobile interface is now being produced for m-Learning.
- Instructors should adapt to the m-learning environment whenever it is appropriate.
- Helps teaching and learning chemistry in rural areas and disables, etc.
- Allows the borderless enhancement of teaching and learning chemistry in the Middle East.
- Supports students and teachers (administrative tasks, etc.).
- Mobile learning would not replace traditional, online, or distant learning.
- Engages students that are addicted to their mobile devices in chemistry education

### 4.3. Technical Delivery Support for Mobile Learning

- 3GP for compression and delivery method of audiovisual content associated with Mobile Learning
- GPRS mobile data service, provides high speed connection and data transfer rate
- Wi-Fi gives access to instructors and resources via internet
• Cloud computing for storing and sharing files
• Authoring
• Learning Mobile Author e.g. for authoring and publishing WAP, Java ME and Smartphone

4.4. Technical Challenges of M-Learning

• Connectivity and battery life
• Screen size and key size
• Meeting required bandwidth for nonstop/fast streaming
• Number of file/asset formats supported by a specific device
• Content security or copyright issue from authoring group
• Multiple standards, multiple screen sizes, multiple operating systems
• Reworking existing E-Learning materials for mobile platforms
• Limited memory
• Risk of sudden obsolescence
• Lack of M-Learning tools
• Temptation to hit the new HTML5 publish button that allows the existing desktop courses as they are for E-Learning, and make them available for M-Learning

4.5. Future Technology for M-Learning

1. Processors in mobile devices will get faster
2. Connections will become more ubiquitous
3. The right infrastructure will provide Wi-Fi everywhere in the most cities in the near future
4. As for the batteries in our smart phones, they will last longer or better yet, can be replaced
all together by solar power technology

5. New tools are required for mobile learning, including a new mindset, new templates, simple, yet powerful and beautiful, that can display these learning experiences in a personalized way and on every screen

6. Start thinking mobile-first and then go back to desktops and apply the simplicity that is derived from embracing mobile constraints that come with smaller screens

5. E-Learning versus M-Learning

Figure 3 shows that both E-learning and M-learning can be used in enhancement and development of chemistry teaching and learning. M-learning outweighs E-learning in its simplicity, availability, and mobility.

Fig. 3. Comparison of E-vs. M-Learning
6. The Pitfalls of M- and E-Learning

- Lack of Security and policies
- Minimal interpersonal interaction
- Lack of Infrastructure
- Shortage in resources (HR, Funding, etc.)
- Lack of well-articulated flexible content

7. Ten Easy Steps for Successful E- and M-Learning Strategy

Figure 4 represents the different methodologies that attract and empower teaching and learning chemistry

1. The needs for the E- and M-learning should be defined
2. The technological Infrastructure should be established
3. Development of e-content according to the International standards
4. E-content should match the curriculum
5. Storyboard of the e-content is well-articulated
6. Teachers and students are well trained
7. Uncorrupted delivery of the e-content is assured
8. Team of the E- and M-learning developers are professionals
9. Evaluation of using E- and M-learning
10. Sustainability of the system
Fig. 4 Different strategies and methodologies in teaching and learning Chemistry

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IMPLEMENTATION OF THE SYSTEMIC APPROACH IN TEACHING
AND LEARNING BIOCHEMISTRY IN ALBANIA

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ABSTRACT
Though newly introduced, global education has occupied a special place in the glossary of
teaching. It props up both the teachers and students to have a broad view of the problems and issues
and think constructively of the future and their role in modeling it. In this respect, teachers need to
consider themselves as global citizens and take all the responsibilities that accompany the
phenomenon of globalism. At the same time, teachers must regard themselves as members of their
community. The main characteristic of teaching in the framework of global education is the
partnership between the teacher and the student which finds itself expressed in the methods and
numerous interactive techniques and constitutes its content. The teachers who keep teaching by
employing traditional methods find it difficult to promote the active role of the students in the
classroom, see the relationship of their subject they are teaching with others, and perceive the
prospective of their teaching. The philosophy of global teaching integrates exactly those elements
which the traditional method lacks. The focus of the philosophy of global education is the student
and teaching. These days we live in a society which is constantly becoming essentially globalized
and fundamentally affected by both decisions made irrespective of our will and events that take
place far from us. Consequently, we are constantly under the pressure of global, cultural, social,
economic, technologic, and environmental tendencies as well as changes which come about very
rapidly. Therefore, it is our duty and that of the entire society to increase students’ ability to think
systematically in order that they could be able to face this ever globalizing world, think
constructively of their future and the role they are to play to shape it, and learn from the past.
Methodology provides students and lecturers with a global image of the teaching of science. As is
known, teaching is carried out through communication. Teaching all over the world is adopting
this method. Learning process becomes pleasant if better communication skills of the teacher
prevail upon the inherent inertia associated with the students, while they focus upon a difficult
subject. This way of teaching is increasingly being highly appraised by the world academy.
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INTRODUCTION

Global education is an education perspective which arises from the fact that contemporary people live and interact in an increasingly globalized world. This makes it crucial for education to give learners the opportunity and competences to share their own point of view and reflect upon their role within a global, interconnected society, as well as to understand and discuss complex relationships of common social, ecological, political and economic issues, so as to develop new perspectives.

Biochemistry is a multidisciplinary science and as such a hard subject to learn. Teachers should use various methods to assist students to study this subject [1, 4]. This science focuses on the study of the structure and the dynamics of the significant cell components, metabolism of substances and concludes with protein synthesis. Students should not only study the structure and the function of the cell components, but also understand the relationship between concepts in a wider context.

Biochemistry studies chemical processes which occur in the living organisms. Just like machineries, the living organisms, based on the laws of energy conversion, by means of metabolic processes, acquire energy from food diets (proteins, carbohydrates, lipids). The cell “spreads” the energy it acquires to perform chemical operation (biosynthesis), mechanical operation (muscle contraction), and osmotic operation (active transport). These metabolic processes take place inside the cell but in different organelles. Just as organelles are tied up in the cell, so are metabolic processes linked to each other [15].

For this reason, concepts have been explained in detail in a very simple language to be understood and acquired to an optimal degree. In his way, teachers can make biochemistry attractive and not boring for students. Methods and teaching techniques are standard procedures
used by the lecturer in his/her interaction with students to introduce teaching materials and teaching activities in order to reach goals and teaching objectives [7, 17].

Of the diversity of the methods, the lecturer should choose the one that makes teaching more efficient, more compelling, more informative, more varied and more interesting. There are several strategies that make teaching and learning much easier and understandable; the most important strategy is the systemic one which interlinks the lecturer, the student and the environment [45].

The systemic approach in teaching and learning is a new one and is contrasted to the common approach of the concept map which involves the creation of a hierarchy of concepts (9). The systemic approach creates a somewhat closed system of concepts, a cluster concept that highlights interrelations. This method contradicts the linear method which is currently used in the educational system. The technique of the systemic approach in teaching and learning is a good instrument to increase the communicative skills of the teacher [30].

The organization of the lesson by employing the systemic approach in teaching and learning is unique in itself. In essence, the systemic approach includes offering of facts, concepts and skills, all in one unit. In this age, in the 21 century, it is indispensable for us to shift from the linear educational system to the systemic educational system [32].

Systematic approach is an orienting, restructuring means which asks for the explanation of the subject matter by both the student and the teacher through the creation of a diagram about the strategy of the map of concepts [10]. Educating students with materials and approaches to understand such linear processes does not help them to cope with the developing global environment [33].

Accordingly, the development of a systemic approach to teaching and learning (SATL)
treats subjects from an integrated and global viewpoint with the expectation that students would benefit from this approach when they enter the global world society [14]. In contrast with usual strategy concept mapping which involves establishing a hierarchy of concepts, this approach creates closed-cluster of systemic concepts, which help students concentrate on interrelationships and provides them with a global view of the subject (as displayed in figure 1) [8].

![Systemic diagram representation.](image)

**What are some characteristics of this method?**

The following are certain characteristics that typify the Systemic Approach.

- **Systemic approach in learning and teaching chemistry (SALT),** is a method that has found application in all fields of science. It is related to the names of two professors, Fahmy and Lagowski, who gave a global vision to teaching and learning chemistry, and constitutes one of the most significant characteristics of globalism.

- **SATL contradicts the linear method which is currently used in the educational system.** This method contests the linear approach and has found wide acclaim nowadays. It is the teachers’ responsibilities to train their students to think systemically, a characteristic of globalism [26-29]. In this way teachers can ensure effective teaching.

- **(SATL) methodology is holistic in essence and encompasses delivery of facts, concepts**
and skills in one package [23].

- SATL is a new way of teaching and learning, based on the idea that nowadays, anything is related to everything globally, In view of this method concepts and facts are interrelated and arranged in a systemic relationship. Students shouldn't learn isolated facts (by heart), in contrast, they should connect concepts and facts in a logical context and stress the relationships among concepts. In this context, “systemic” means arrangement of concepts or issues through interacting systems where all relationships between concepts and issues are made clear to the learner [9]. In this process, significant learning interactions occur between learners, learners and teachers, and learners and the context.

- Systemic Approach in Teaching and Learning is a means of orientating and restructuring. It demands that teachers’ information be oriented by the strategy of the map of concepts.

- The general strategy of this method has been based on the collection, systematization and presentation of the map of concepts through the interactive system which all who study refer to, in order that they could have their concepts and issued clarified.

- SATL-based-learning is an active process where learners are encouraged to discover principles, concepts, and facts and arrange them in a systemic relationship.

- The systemic approach in teaching and learning is a new approach contrasted to the common approach of the concept map which involves the creation of a hierarchy of concepts. The systemic approach creates a somewhat closed system of concepts, a cluster concept that highlights interrelation.

**What is the instructor’s role in this method?**

The role and knowledge of the teacher are both very important and irreplacable. The main roles the teacher should adapt when applying the Systemic Approach are the following:
Organizer
Leader
Partner in communication and interaction
Motivator
Evaluator

METHODOLOGY

My work presents the application of the systematic method in the lectures, seminars and exercises in the courses of biochemistry, medical biochemistry and the biochemistry of the physical activity that I teach by building a systematic diagram. The method has been applied at the University of Shkodra “Luigj Gurakuqi”, (Albania) in the Faculty of Natural Sciences, at the Department of Biochemistry with the students of the first study degree (BA), in the subject of biochemistry since 2007.

Students were divided into two groups at will. The first group acted as an experimental group whereas the second operated as a controller. The lecturer provided both groups with the necessary explanation. The experimental group has learned by using the systematic method whereas the control group the linear method. Two exams were organized, one before method application, the other after its application. The exams incorporated linear and systematic questions for both groups. The best assessment acquired 100 points; the minimum passing assessment was 35 points. The number of the students who were involved in the study was 2350, of which 1320 were involved in the experimental group and 1030 in the control group. The study lasted for ten years and was focused on:

• Systematic application of the method in biochemistry courses (General biochemistry,
Medical biochemistry, Clinical biochemistry and Biochemistry of the physical activity.

- Systematic evaluation
- Types of systematic questions
- Systematic link between the categories of thinking
- Systematic link between fields of knowledge

**Systematic application of the method in biochemistry courses**

Of the diversity of the methods, the lecturer of the biochemistry courses, (General Biochemistry, Medical Biochemistry, Clinical Biochemistry and Biochemistry of the physical activity), should choose the one that makes teaching more efficient, more compelling, more informative, more varied and more interesting [6]. Methods and teaching techniques are standard procedures used by the lecturer in his/her interaction with students to introduce teaching materials and teaching activities to reach goals and teaching objectives. There are several strategies that make teaching and learning much easier and understandable; the most important strategy is the systemic one which interlinks the lecturer, the student and the environment objectives [23].

One form of the organization of the teaching process is the teaching unit which constitutes the essential unit. Changes in the way of organizing the teaching unit intend to increase the yield and the quality of the teaching process.

The construction of the teaching unit according to the linear method of teaching is based on the transfer of the information step by step to the students, who can afterwards, relate it to their previous knowledge. The teaching unit encourages memorizing, however, in some way, it prohibits the creativity which is very important for their future [31].
Building a systematic diagram in biochemistry courses

The main structural element of the SATLC method is the systemic diagram which bears all the attributes of a closed map of the concept [10]. Systemic Approach in Teaching and Learning (SATL) methodology is holistic in essence and encompasses delivery of facts, concepts and skills in one package. Teaching is carried out through communication. As mentioned above, learning process becomes pleasant if better communication skills of the teacher prevail upon the inherent inertia, associated with the students, while they focus upon a difficult subject (35). SATLC technique is a better instrument for making the teacher’s job easier, as it amply enhances the communication skills of the teacher [41].

With this method, the teaching process has two basic qualities, the indirect student-knowledge interaction, elaborated didactically from the lecturer and the direct knowledge interaction.

The SATL lesson would require a multi-step progress [9]. This diagram, the SD1 (initial systemic diagram) represents students’ knowledge acquired from other subjects related to biochemistry [15]. SD2, SD3 and SDF (final systemic diagram) signifies students’ achievement during the module teaching. In the SDF diagram, all links between concepts, metabolic cycles, cell organs and body organs are familiar and well clarified (as displayed in figure 2).
SYSTEMIC TEACHING STRATEGY

The benefits of this systemic diagram (SATL) are:

- The technique of the systematic unit is a very helpful instrument to make the teacher’s job easier and to ensure that students receive good information. Besides, it offers the core of systematic thinking and ensures the continuous increase of knowledge which is in itself a sign of qualitative education [15, 16, 22, 23, 31, 34].

- The construction of this systemic diagram is multi-step structure and consists of content requirements, content development, and use. The material is divided into levels of detail, so that the student studies until he has reached the level he needs. At each level of detail, the material is treated as a whole, then, it is split in parts, and finally it is recombined into a functional whole.
Systematic link between categories of thinking

Textbooks and teachers of biochemistry have excessive information available. This big quantity of information may affect the explanation of concepts. It can be said that the student thinks systematically if he/she is capable of:

- systemizing concepts, i.e. ranking them in a logical order,
- distinguishing and providing the relationship between categories of thinking in favor of teaching that develops thinking,
- thinking effectively by avoiding mechanical thinking.

The systemic approach in teaching and learning promotes higher levels of thinking, which means, evaluating, analyzing and synthesizing. This way of thinking constitutes one of the most important characteristics of globalism because it increases student’s ability to find the main solution to problems. In this way, students’ capacity to think systematically is improved and their creativity is increased.

The three categories of thinking have been defined as basic criteria in the field of education. They act simultaneously and in an integrated way, which means, they act through the interaction of creative thinking, critical thinking and problematic thinking [27]. Emphasizing the systemic connection in these categories is an outcome of the understanding that a technologic modern society cannot be created without people that understand changes, use information, analyze problems, know how to create and value the solutions.

These findings are of special importance and serve as a message for teachers who are required to use both hemispheres in teaching and learning. This orientation is bears specific significance for the traditional teacher and the schools in Albania where the use of the left hemisphere predominates over the use of the right one, whereas both are less frequently used.
This model demonstrates sparse interaction of the actual fields of teaching. To reveal the relationship of different types of thinking, the systematic diagram can be employed [30]. This diagram shows that the critical, creative and problematic zones are components of thinking and communicate with each other, when creative thinking occurs, critical and problematic thinking cannot be excluded from the process. Hence, just as creative processes predominate in the human brain, so do the critical and problematic ones. Lecturers should integrate the various categories of thinking. They should not put emphasis on one at the expense of the other.

The analysis shows that thinking processes at all levels of education should be improved. For this reason, strategies of teaching and learning methodology which allow for the development of thinking skills and the process of different types of basic thinking should be used at all levels of education. Strategies of the teaching and learning methodology help students to think more and better in order that they could be able to give solutions to problems and think effectively. They will be successful if their systemic relationship can be achieved.

**Systematic questions**

A very important element of the teaching planned is the evaluation of students [37]. Evaluation should be very objective and supported with data. A necessary condition for this kind of evaluation is the way that you make up questions. Such innovation provides systematic evaluation, which is based on the systematic diagram. Testing plays an important role in this system. The objective test is created in a way that a different estimator who assesses independently will achieve the same results for the introduced level of knowledge and abilities based on true answers. In comparison with the traditional objective test, the systemic objective test includes many demands that are completely structured; it covers a huge part of the educational schedule,
and measures high levels of education (synthesis, analysis and estimation). In chemistry, the systemic objective tests (SOT) are prepared and experimented by Prof. A. F. M. Fahmy and Prof. J. J. Lagowski, the founders of the systemic method in teaching and learning chemistry (SATLC). Asking questions is a practice that does not only serve to know who the student that knows the answer is, but also contributes to making the student more competent, capable of finding the right answer through different ways [45].

Nowadays, questioning is not as it used to be in the traditional teaching, where only the teacher used to ask; it’s a mutual process between the teacher and the student. The first thing that they have to do is to set the criteria to support their judgment and the second one is to judge by using these criteria. Construction of systemic questions requires the realization of some requirements such as:

- Determining the types of relations between the given concepts,
- Determining of the size of the building of systemic diagrams,
- Putting the arrows in relationships between concepts or facts,
- Directing the arrow head clockwise or anticlockwise,
- Providing the information in the stem and keeping the options clear and systemic,
- Putting the information in the stem to make the problem clear & specific.

Different tests, such as STFQs, SMCQs, SSQs, SSQs, ASQs, and SCQs, as examples of the systemic objective test in biochemistry, have been presented in my articles [25.36]. Geometric shapes are different. They are triangular, quadrilateral, pentagonal, hexagonal, and so on, depending on the number of the concepts that are incorporated in the diagram. Systemic-learning-based test, presently known as systemic objective test (SOT), could be an instrument for determining the scale of learning level, that is, analysis, synthesis and evaluation.
The benefits of this new positioning are:

- Students develop skills and abilities to recognize problems and participate in their solution.
- Students use their critical thinking, problem solving and decision making abilities.
- Students demonstrate self-management skills.
- Students have a deep critical thinking for the problems that occur.
- Students organize their thinking in the process of systematic diagram completion.
- Students complete difficult systematic diagrams through systemic thinking. They improve their perception by increasing their observation skills.
- Students learn through creation and not through reproduction, therefore, they increase their creativity.

RESULTS

The results of students’ performance in the exams and their elaboration have been displayed in the figures below. Figure 3 shows students’ results before and after the exams of both groups. Graphs have been drawn to display the percentage of the students’ average scores on examination.

The points before the exam have been displayed on the left hand bar of each couple of graphs, whereas the points of the exam after the application of the methods have been displayed on the right hand bar.

Figure 3 displays the distribution of the scores of students of the experimental group and those of the control group after the application of the SALT. The highest frequency for the experimental group occurs in area of the 65-80 points, whereas the highest frequency for control group occurs in area of the 30-40 points.
Therefore, the comparison shows that the experimental group clearly achieved a higher level as measured by the total average score of the examination for the 10 years altogether (as displayed in figure 1). Figure 3 shows the success of the systemic approach to teaching organic chemistry established by using two groups; the experimental group, which was taught systemically, and the control group, which was taught in the classical linear manner.

Figure 3. Total average scores for both groups

Figure 4 clearly displays the success of the systematic method. To see the differences between the two diagrams, the distribution of the scores has been compared to the normal score distribution. The interrupted line represents the distribution of the exam points before method application, whereas the unbroken line represents distribution of the exam points after the application of the SALT. The interrupted line represents the distribution of the exam points of the control group whereas the unbroken line represents distribution of the exam points of the experimental group in exam.
Figure 4. Distribution of the scores of students of the control group and the experimental group

Figure 5 displays the correlation of the points accumulated by the experimental group before and after the application of the SALT. As can be noticed, there is a very good correlation. The correlation coefficient is 0.92. Besides, the graphs show that the students of the control group encounter difficulties in the exam with regard to the systematic questions.
SUMMARY

Based on the result of the study which lasted for ten years, I jumped into the conclusion that the application of the systematic method in teaching and learning biochemistry is successful [12-33]. The application of the Systemic Approach to Teaching (SAT) is a tool designed to help teachers teach and students learn.

During the application of this method, the lecturer:

- is more globally than ethnically oriented,
- shows a special interest to the culture and its perspective,
- is oriented towards the future,
- has profound trust in the human potential,
- considers the student as a process which continuous all the life,
- takes care about the development of the individual in general,
- employs the systematic approach to organize learning/teaching units, establishes new relationships between teachers, between teachers and students, and among students,
- employs the systematic teaching unit which carries a range of innovations and demonstrates the possibilities of overcoming the traditional model which is still currently practiced in our schools,
- employs the systematic relationship of teaching and learning methodologies which allow for the development of thinking skills and different types of the processes of thinking, such as creative thinking, critical thinking and problematic thinking.
The application of this method:

i. promotes students to participate in the organization of the tutorial (teaching unit).

ii. allows revising and expanding students’ knowledge obtained in the previous lessons.

iii. allows students to create rich environment for both quality and quantity information.

iv. helps students develop their skills and provides them with a collection of knowledge through learning by giving up knowledge provision through available sources.

v. prompts students to have a research role in the learning process and enables to express their own ideas and thoughts,

vi. offers new sources of information, motivates students to acquire new information, rely on prior knowledge and deepen it through the various stages of systematic learning.

vii. allows for knowledge construction and not knowledge transmission,

viii. motivates students to learn as well as to identify and correct prior inaccurate understanding.

This analysis shows that the present technological society needs:

- people who do not routinely do what previous generations did, but people who are capable of doing new things
- creators, inventors, discoverers, capable of not accepting ready-made facts, but capable of critically verifying them
- people motivated to learning.

This could be made possible only through the systemic approach in learning and teaching chemistry (SALT). In my opinion, this process should begin at child’s early age through arousing the academic qualities of the child’s mind. In this way, we increase child’s’ responsibility to learn by reflecting a current dimension of learning.
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THE THUMB RULE REVEALS: FACILITATING THE TRANSITION FROM ELECTRON GEOMETRY TO MOLECULAR GEOMETRY AND VICE VERSA

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ABSTRACT

Both 1st and 2nd semester students of General Chemistry are introduced to the concepts of electron and molecular geometry as part of a chapter concerning “Chemical Bonding” (sections following Valence Shell Electron Pair Repulsion Theory). Often, instructors note that students encounter difficulties discriminating between the electron geometry and the molecular geometry of a molecule which is dependent on the presence of lone pairs on the central atom. We propose a “thumb rule” that is designed to “reveal” any difference between the two said geometries and thereby facilitates the transition from electron to molecular geometry and vice versa. The use of this technique is additionally advantageous since it is simple to apply and does not require any materials (and is therefore free of charge). Importantly, it is a fun exercise that facilitates learning.

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INTRODUCTION

Freshmen college students learn about the “shapes” of molecules towards the end of a General Chemistry I syllabus or at the very beginning of General Chemistry II [1]. They are taught that the spatial shapes adopted by molecules are often very different than that which might have been rendered on paper to-date (Fig 1).

The repulsive forces exerted by electron pairs around the central atom in the molecule, be they bonding pairs or lone pairs, is key to the three-dimensional geometry adopted by every molecule. The Introduction to the Valence Shell Electron Pair Repulsion (VSEPR) theory helps students recognize that electron pair repulsion needs to be minimized [2]. According to this theory, single, double and triple bonds each represent only a “single region” of electron density [3]. Furthermore, the repulsive forces around a lone pair are greater than that exerted around bonding pairs. Nevertheless, in each case, the objective is to minimize the repulsive forces between the regions of electron density be they from lone pairs or bonding pairs or a combination of the two.

To achieve this, each bond in a molecule is placed farthest from the neighboring bonding in three dimensional space. The same principle applies when a lone pair of electrons is present. Except, the lone pair exerts a greater repulsion on neighboring regions of electron density than do bonding pairs.

Based on VSEPR principles, students need to be able to render the geometries of molecules. For example, methane contains four bonding pairs via four single bonds around the central carbon. These four regions of electron density repel one another. Therefore, the mechanism that must be adopted to achieve maximum distance between these regions of repulsion is one of a
tetrahedral placement of the bonds around the central carbon. The student recognizes then that the bond angles are all equal and that the geometry of methane is that of a tetrahedron (or that methane is tetrahedral).

At this stage, the student of chemistry learns about the possibility of a difference between the electron geometry of a molecule and its molecular geometry [4-6]. An understanding of both electron and molecular geometries are critical. Both geometries impact the chemical and physical properties of the molecule. They influence its ability to not only participate in chemical reactions but also impact other properties such as molecular polarity, it’s “state” (solid, liquid or gas), color, magnetic tendency and biological activity (if any). Knowledge of both geometries is key not only to the student of General Chemistry but is a basis for organic reactions, and higher progress in Chemistry, Physics and Biology and a career in the STEM fields.

Electron geometry refers to the positions (arrangement) of the regions of electron density around the central atom [1]. Thus, since both bonding pairs and lone pairs represent regions of electron density, their combined presence, if any, would need to be accounted for when discussing its electron geometry.

Molecular geometry only takes into consideration the presence of other atoms that are bonded to central atom in the 3-D structure of the molecule [1, 4-6]. Thus, only bonding pairs need to be accounted for whereas lone pairs do not participate.

Central atoms that do not contain one or more lone pairs would have identical electron and molecular geometries since there are no lone pairs to be excluded when contributions to the molecular geometry are to be considered [1]. However, when the central atom possesses one or more lone pairs, then the molecular geometry differs considerable from the electron geometry.
It is here that students often find application of the concepts confusing. Particularly, they are often unable to correctly transition from one geometrical representation to the other (electron to molecular, and vice versa) whether or not such a difference exists (due to the presence or absence of lone pair(s)).

We propose a simple, manual, tool that helps facilitate the student of General Chemistry to transition from one geometry to the other, viz., the “Thumb rule”.

METHODODOLOGY/EXPERIMENTAL

The Thumb Rule

Elements of the rule

1. Render the 3-D electron configuration structure of the molecule based on VSEPR rule

To transit from electron geometry to the molecular geometry:

2. Inspect the Lewis structure for the presence of lone pairs on the central atom. If no lone pairs exist, the electron and molecular geometries are the same

3. If a lone pair is present on the central atom, use your thumb to conceal it and re-examine the structure of the molecule. At this stage, only bonding pairs of electrons should be visualized (These link the central atom to the partner atoms). The geometry of the molecule is now representative of the molecular geometry.

4. If the central atom possesses more than one lone pair, apply rule (3) so that all lone pairs on the central atom are concealed. Along with your dominant hand thumb, you could avail of the other thumb or take the help of a friend to conceal additional lone pairs.
To transit from molecular geometry to the electron geometry

5. Remove the concealed lone pair on the central atom by retracting your opposable digit from its position in (3). This should reveal the lone pair. If the central atom possesses more than one lone pair, retract the thumbs so that all lone pairs are no longer obscured. The electron geometry now becomes apparent since the lone pairs become exposed along with the previously visible bonding pairs. I.e. all regions of electron density on the central atom are visible, permitting the student to transition from the molecular geometry to the electron geometry.

RESULTS AND DISCUSSION

Consider a molecule such as methane. The student is instructed to draw the Lewis structure of the said molecule and inspect it for lone pairs. If no lone pairs exist, the molecular and electron geometries coincide and are to be rendered taking into account the VSEPR rules.

![Representation of methane by students of General Chemistry after becoming familiar with the “shapes of molecules”. Left: Electron geometry (Tetrahedral); Right: Molecular geometry (Tetrahedral)](image)

Figure 2. Representation of methane by students of General Chemistry after becoming familiar with the “shapes of molecules”. Left: Electron geometry (Tetrahedral); Right: Molecular geometry (Tetrahedral)
The molecule is re-examined, by applying the Thumb rule.

In methane, the search for lone pairs reveals the absence of the same. Therefore, rule 2 (from methods) applies and the electron and molecular geometries of methane are the same.

Next, consider a molecule with a lone pair such as ammonia. The central nitrogen atom possesses four regions of electron density. Three of these manifest themselves as bonding pairs of electrons (N-H bonds) and one as a lone pair. The electron geometry of ammonia is tetrahedral whereas the molecular geometry is trigonal pyramidal.

Note: The ability to differentiate between the electron and molecular geometry in ammonia is not very obvious to the student. The molecules are re-examined now, by applying the Thumb rule.
The thumb rules clearly facilitate discrimination between electron and molecular geometries. This is particularly true when the central atom possesses one or more lone pairs. The use of the thumb to conceal the lone pair when transitioning from electron to molecular geometry helps the student focus on bonding pairs and the atoms in the molecule. Conversely, application of rule 5 when transition from molecular geometry to electron geometry, reveals the lone pair and “all regions of electron density”, permitting the electron geometry to be accurately recognized.

Using a few more examples, we demonstrate the application of the thumb rule to facilitate the transition from electron to molecular geometry and vice versa.

Beryllium Chloride: Central atom, Beryllium; Two bonding pairs and no lone pairs

\[
\text{Cl-Be-Cl} \quad \text{Cl-Be-Cl}
\]

Figure 5. Beryllium Chloride. Rule 2 of the Thumb rule suggests identical electron (Left) and molecular (right) geometries

Water: Central atom, Oxygen; Two bonding pairs and two lone pairs

\[
\begin{align*}
\text{H-O-H} & \quad \leftrightarrow \\
\text{H-O-H} & \quad \text{H-O-H}
\end{align*}
\]

Figure 6. Transition between the electron (left; tetrahedral) and molecular (right; bent) geometry of water facilitated by application of the Thumb rule
Additional Exercises

Sulfur dioxide: Central Atom Sulfur; Two bonding pairs and one lone pair

CONCLUSION

The Thumb rule tool helps the beginner student easily recognize the difference between molecular and electron geometries. This tool is especially effective when there are lone pairs present on the central atom, resulting in a difference between the electron and molecular geometries.

We submit that the application of the thumb rule to transition between the said geometries can be a fun exercise. It can also be applied in a team-learning format in addition to the individual student. It requires no additional material and is therefore widely accessible among all socio-economic backgrounds. It facilitates learning of a very important concept in general chemistry and beyond: The shape of a molecule.

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

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