THESYSTEMIC 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 student 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)

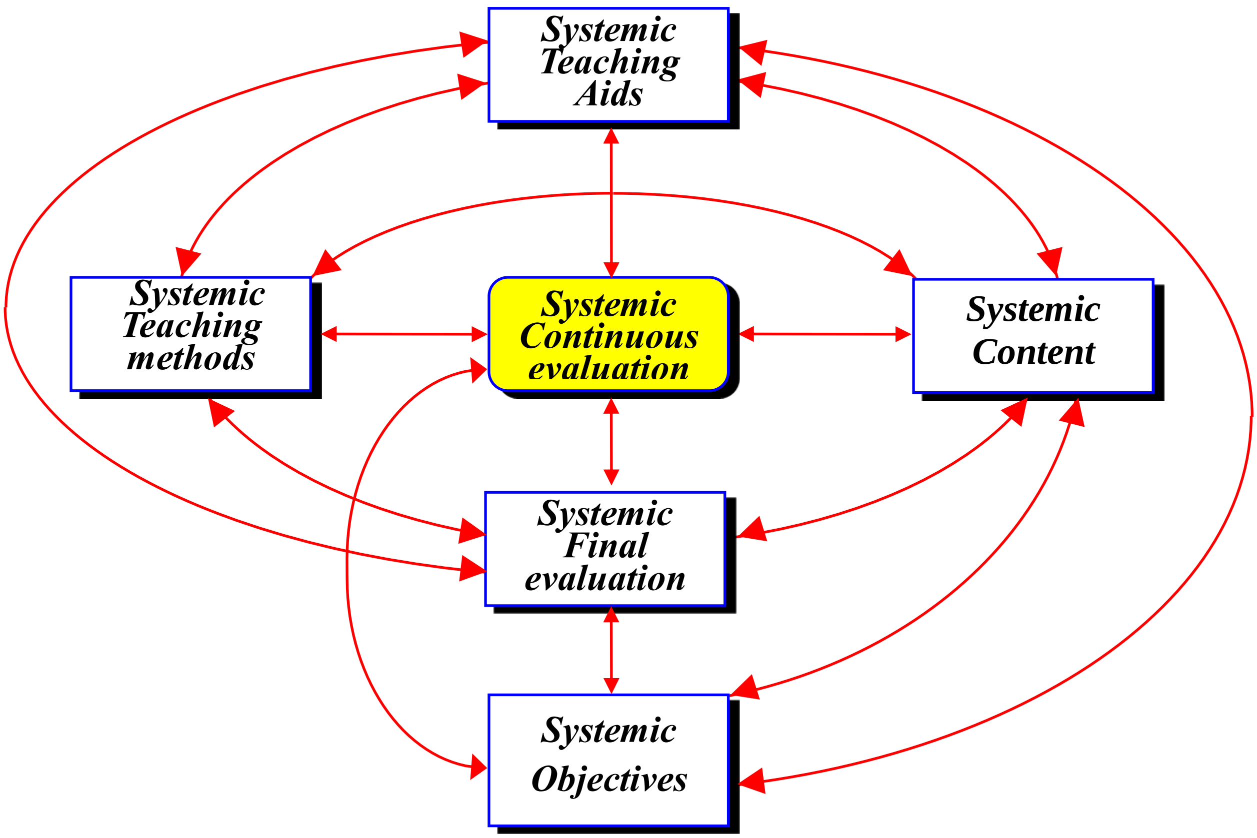


Fig.1a: Systemic curriculum.

1. Slight Interaction of the Current Educational Domains:

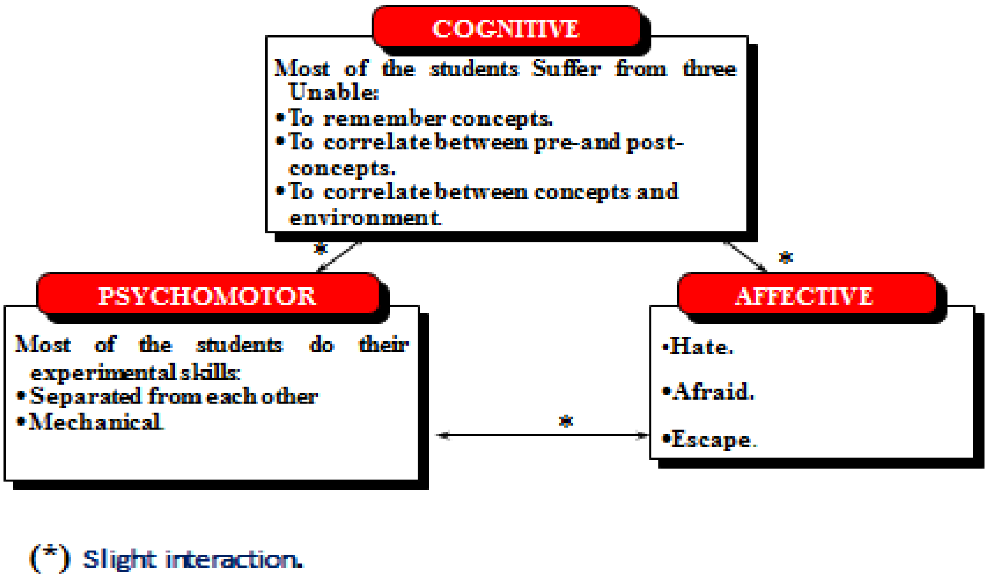


Fig.1b: Systemic learning domains.

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]

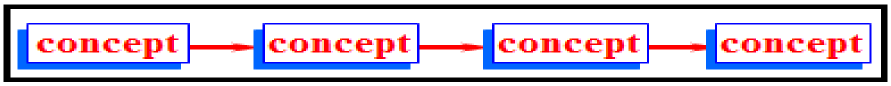


Fig: 2a: Linear representation of concepts

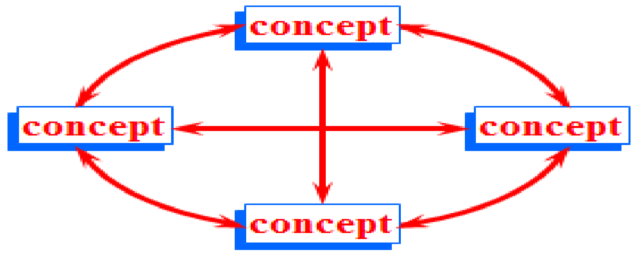


Fig: 2b: systemic representation of concepts

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].

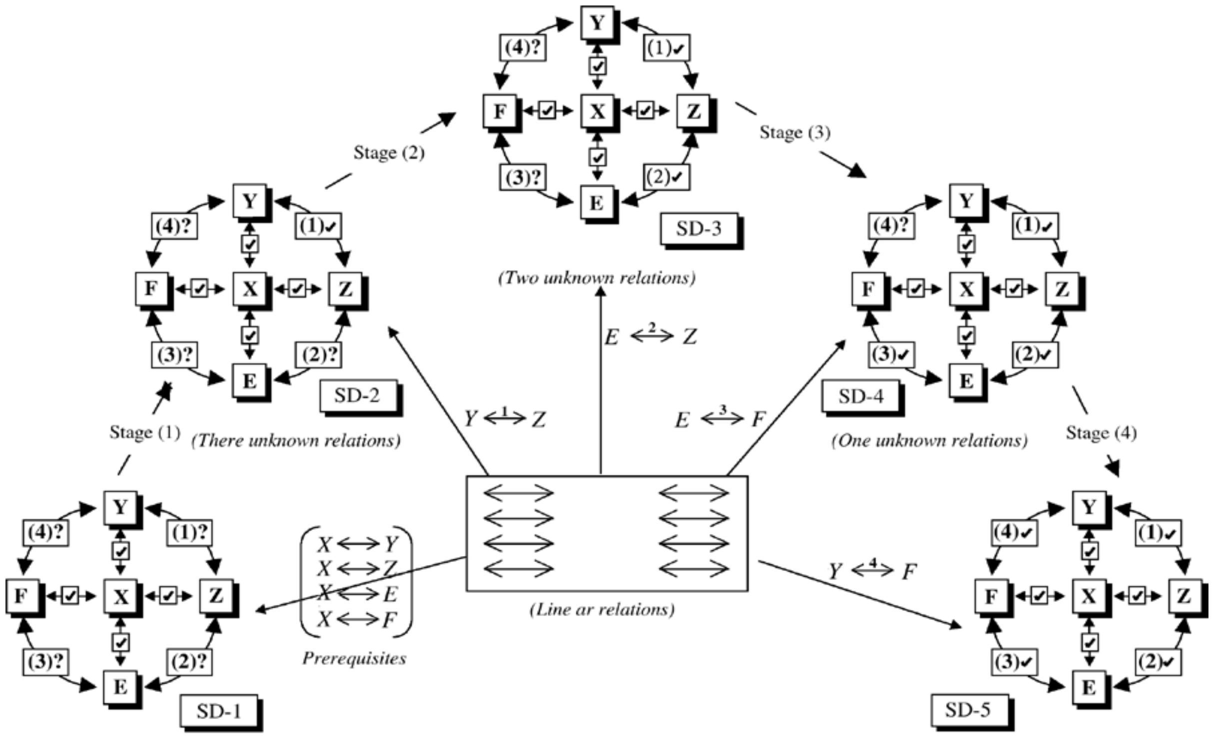


Fig. 3. The evolution of a completed closed chemistry concept cluster from a starting point

The instructor has in mind the concept linear structure shown in Figure 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.

I.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].

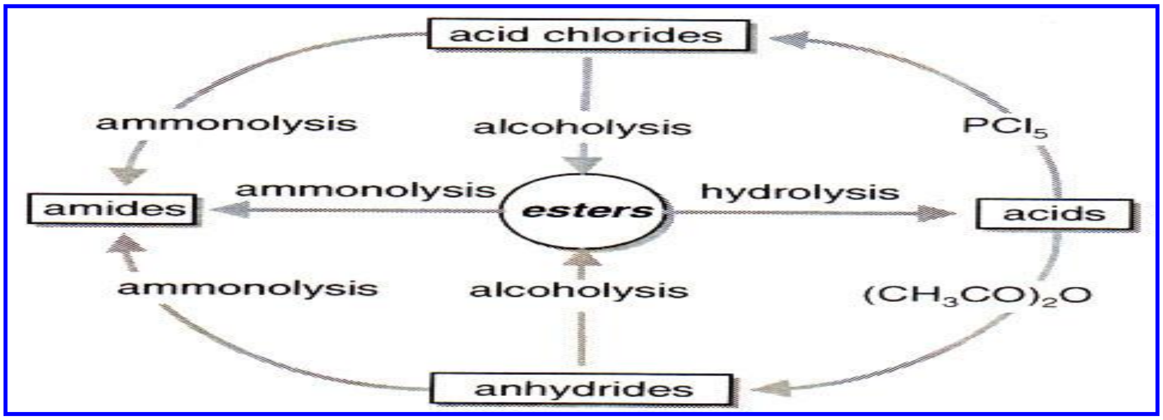


Fig.4: Systemic based teaching and learning.

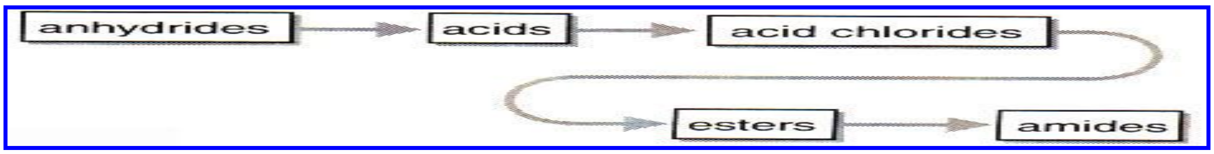


Fig.5: Linearly based teaching and Learning.

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.

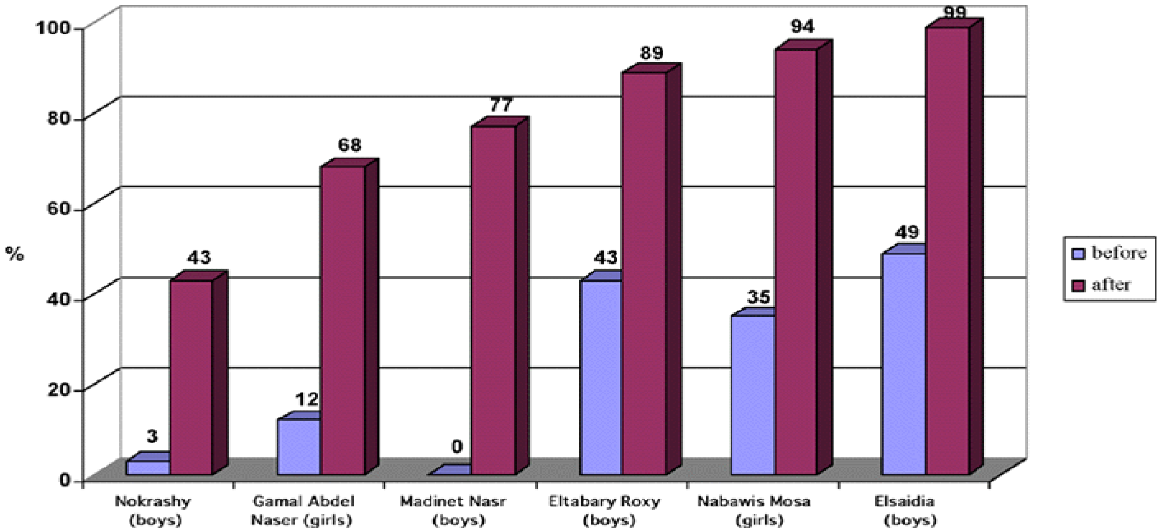


Fig.6: Percent of students in the experimental classes who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the systemic intervention

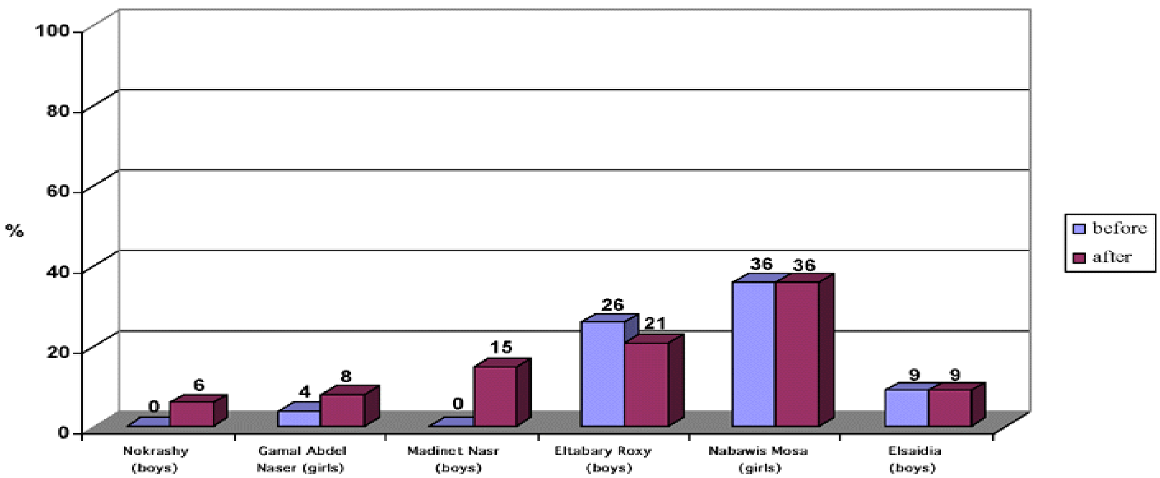


Fig.7: Percent of Students in the control classes who succeeded (achieved at a 50% or higher level).The bars indicate a 50% or greater achievement rate before and after the linear intervention

The experimental group was taught by SATL-trained teachers using SATL techniques with specially created SATL materials, while the control group was taught 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

approach.

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).

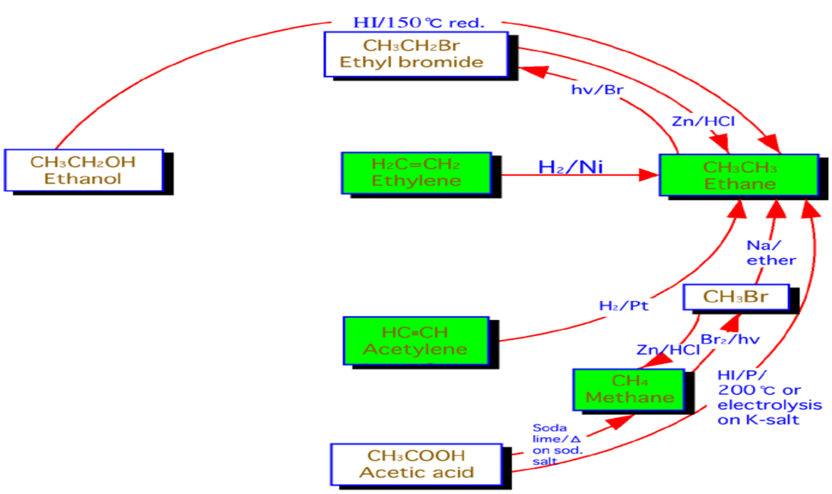


Fig.8: The classical linear relationship involving the chemistry of the alkanes organized to begin to create a systemic diagram of the corresponding chemistry

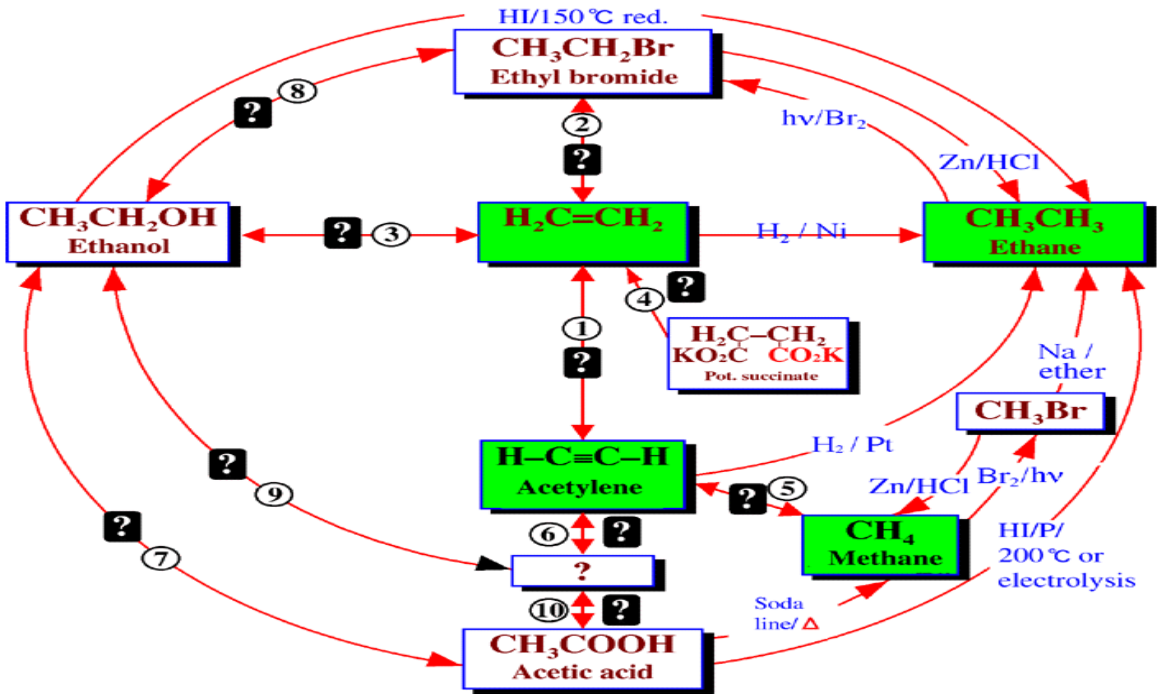


Fig. 9: Systemic diagram (SD0) that represents some of the major chemistries of alkanes

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).

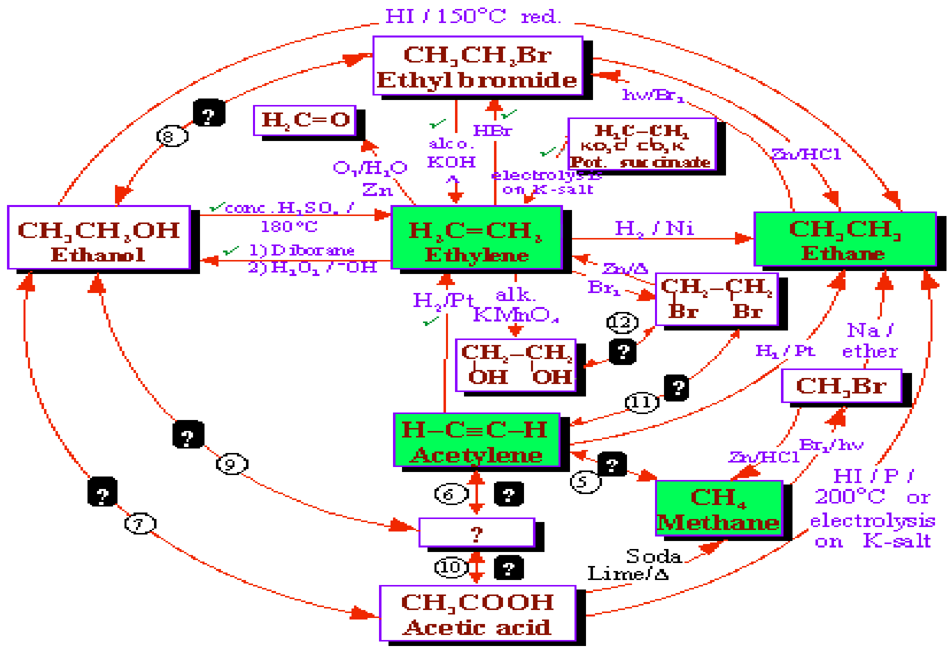


Fig.10: SD1 Shows the SATL chemistry of alkanes as expanded to include the alkenes

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).

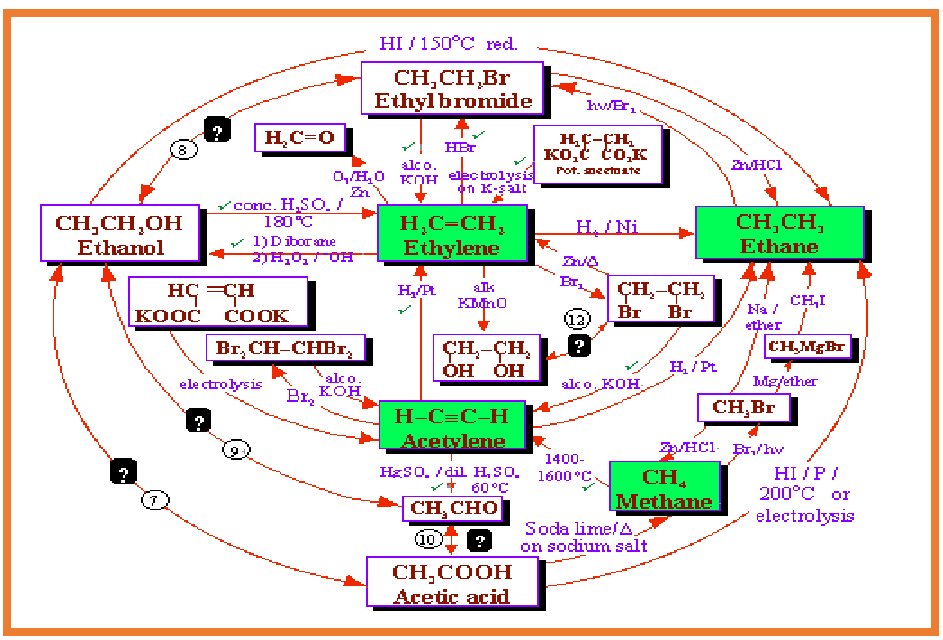
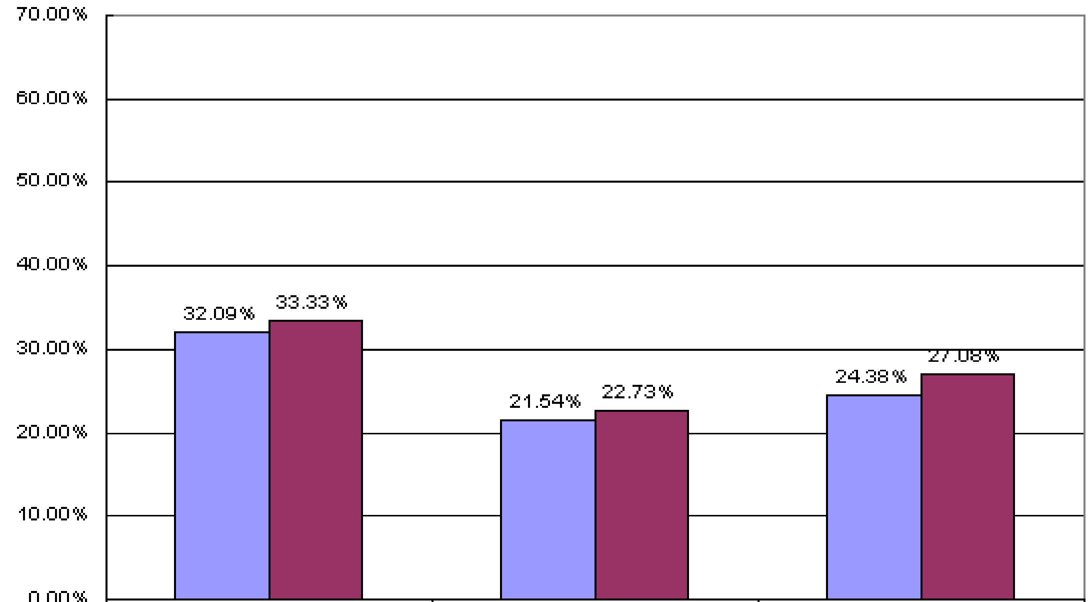


Fig. 11: SD2 the SATL relationship between the hydrocarbons and the derived compounds.

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.

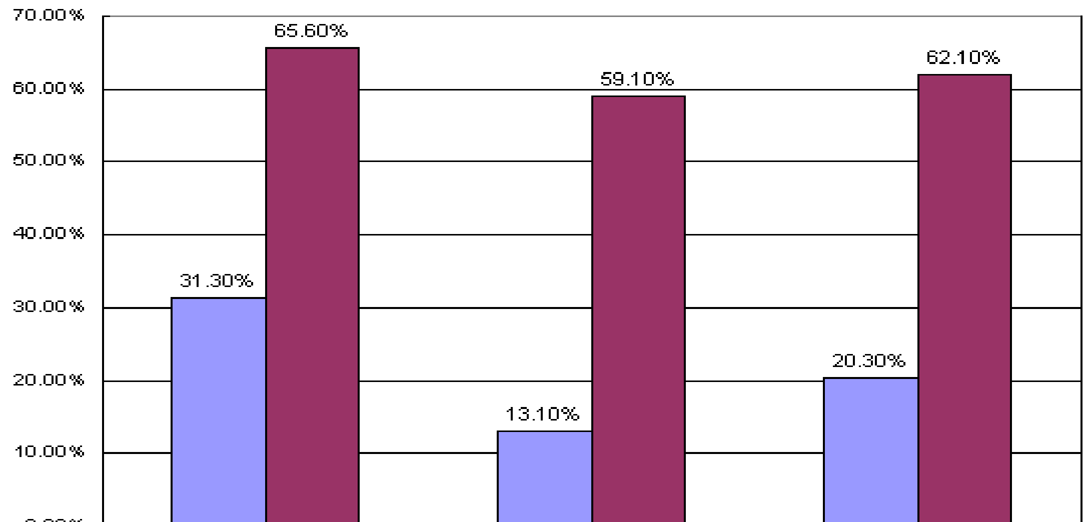
The systemic diagrams developed in Figures (9) through (11) were used as the basis for teaching organic chemistry course to experimental group at Zagazeg University Egypt. The experiment was conducted within the Banha Faculty of Science, Department of Chemistry with second year students. The experiment 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.



	Linear Questions	Systemic Questions	Total Exam results
Before Intervention	32.09%	21.54%	24.38%
After Intervention	33.33%	22.73%	27.08%

Fig. 12: Average scores for control group before and after intervention



	Linear Questions	Systemic Questions	Total Exam results
Before Intervention	31.30%	13.10%	20.30%
After Intervention	65.60%	59.10%	62.10%

Fig.13: Average scores for experimental group before and after intervention

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.

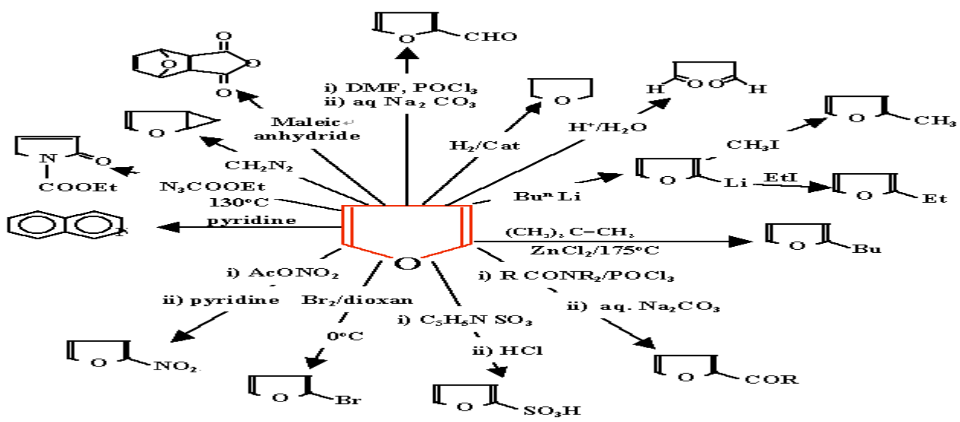


Fig. 14. The classic linear relations involving chemistry of furan**.**

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]

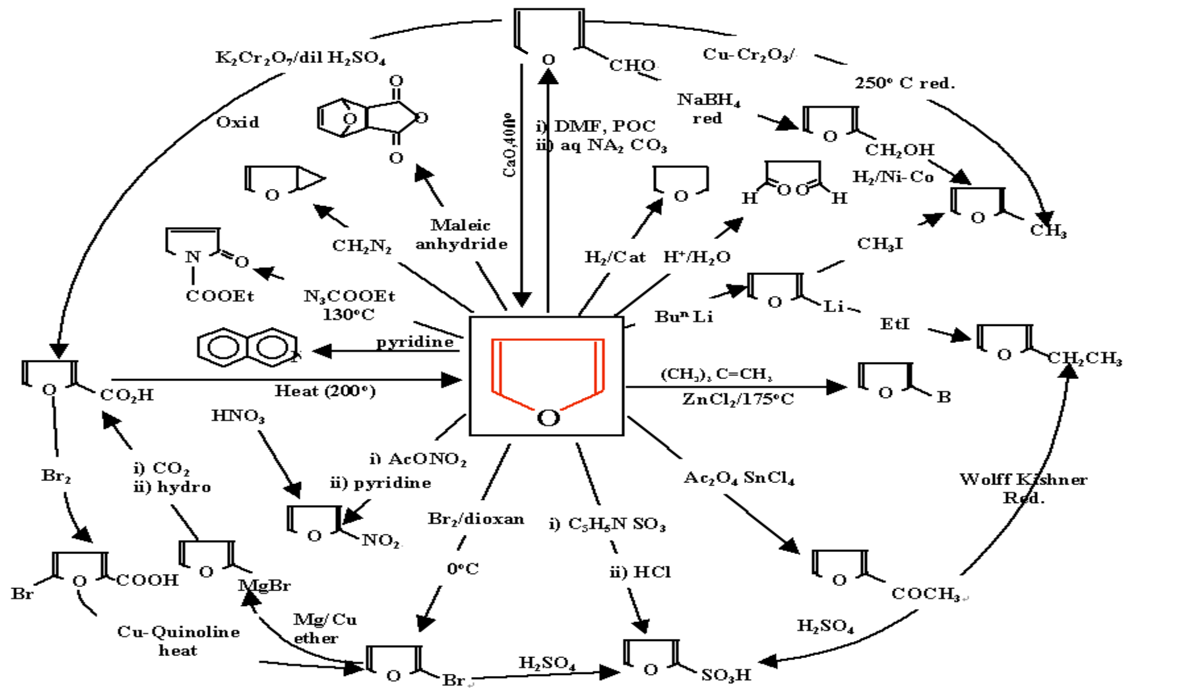


Fig.16. [SD1]: The result of completing the undefined relations that appears in Figure 15

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.

	Percent increase in student scores	
	Before intervention	**After intervention**
Linear questions	37.32%	49.53%
Systemic questions	21.19%	90.29%
Total	32.52%	69.10%

These results are statistically significant at the 0.01 level

II. SATL-CHEMICAL EQULIBRIA

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.

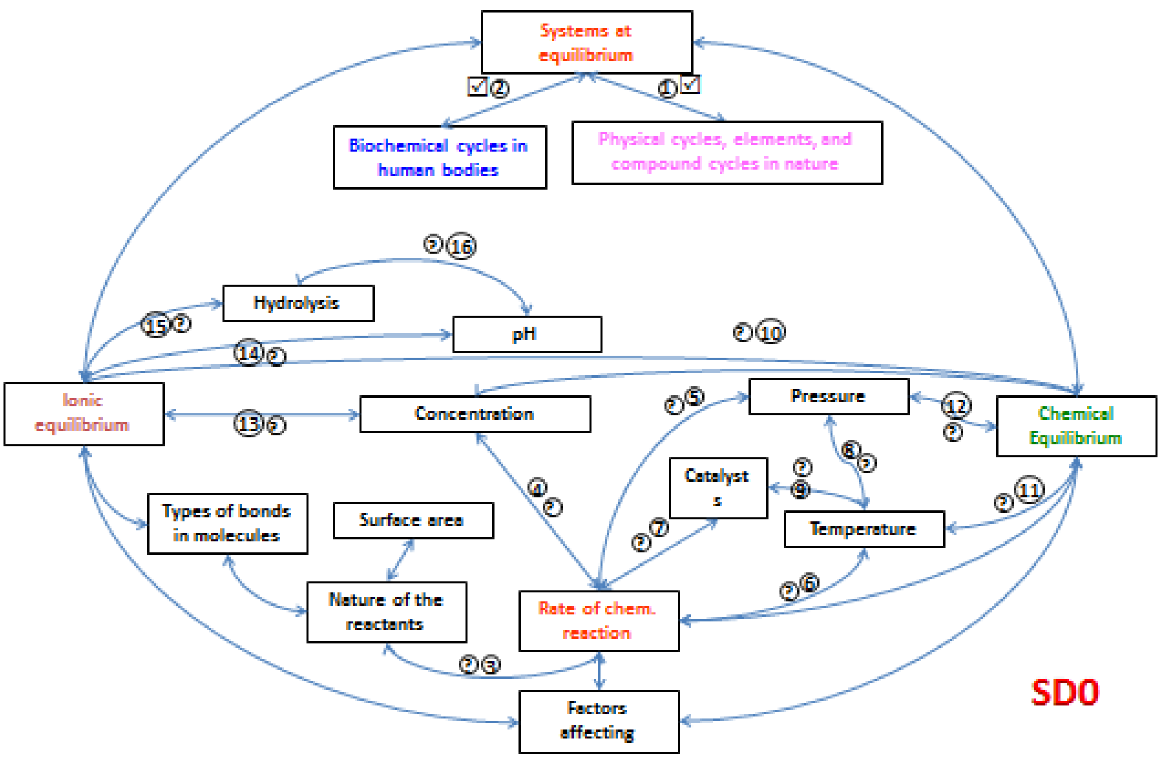


Fig.17: Systemic diagram (SD0) shows systemic physical relations (1 and 2) between concepts

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.

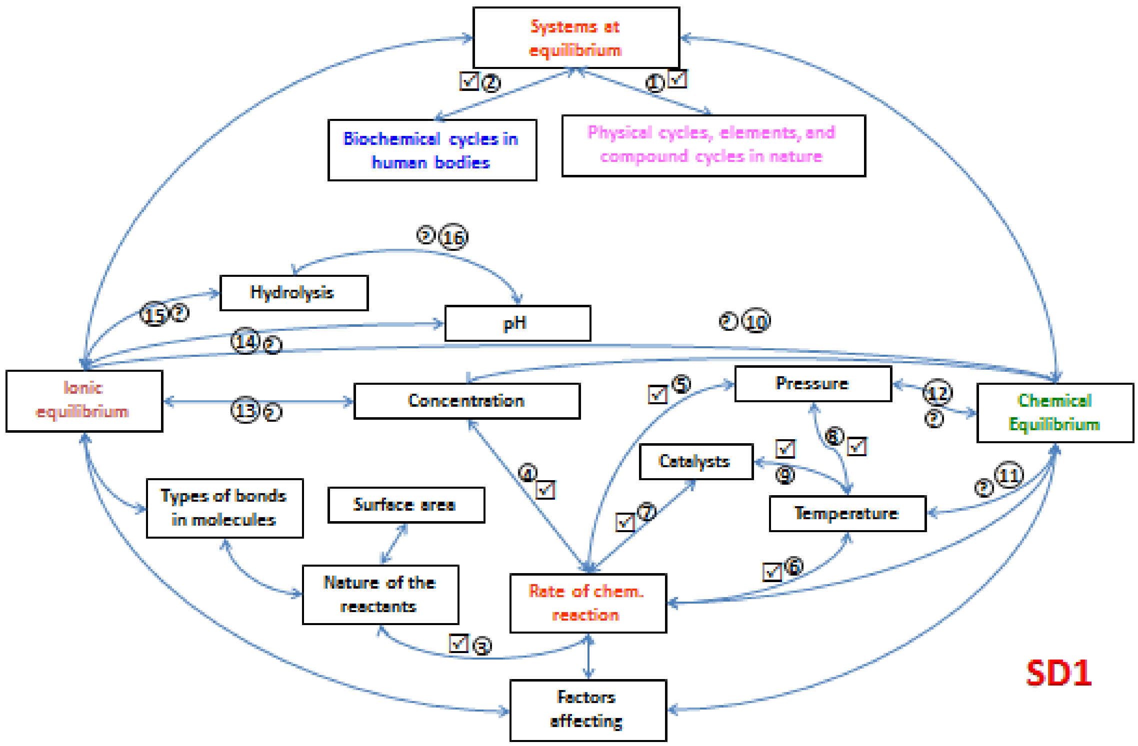


Fig.18: SD1 shows systemic physical relations (1-9) between concepts.

- 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.

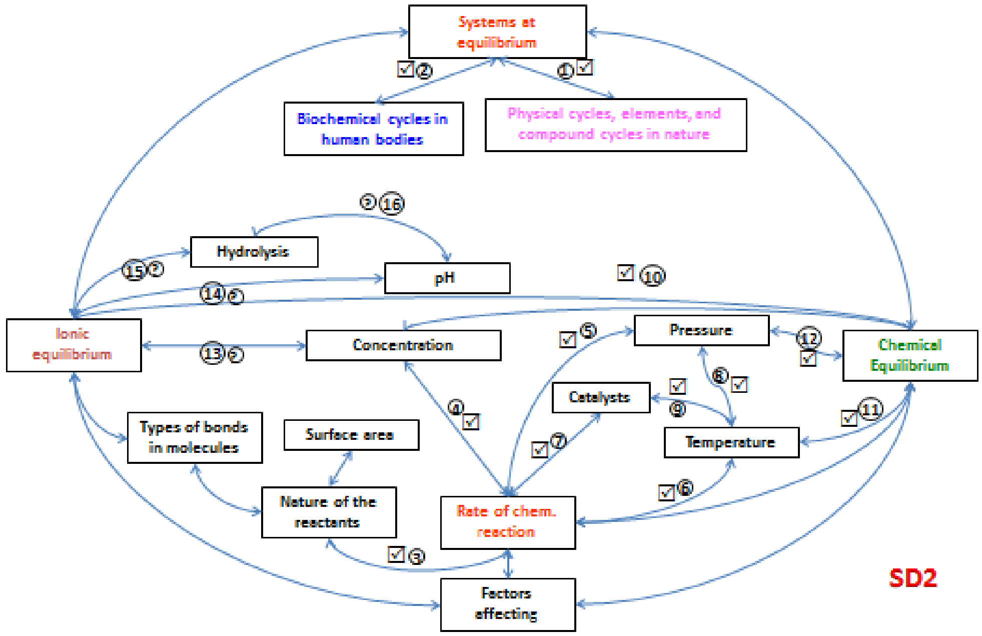


Fig.19: SD2 shows systemic physical relations (1-12) between concepts.

- 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.

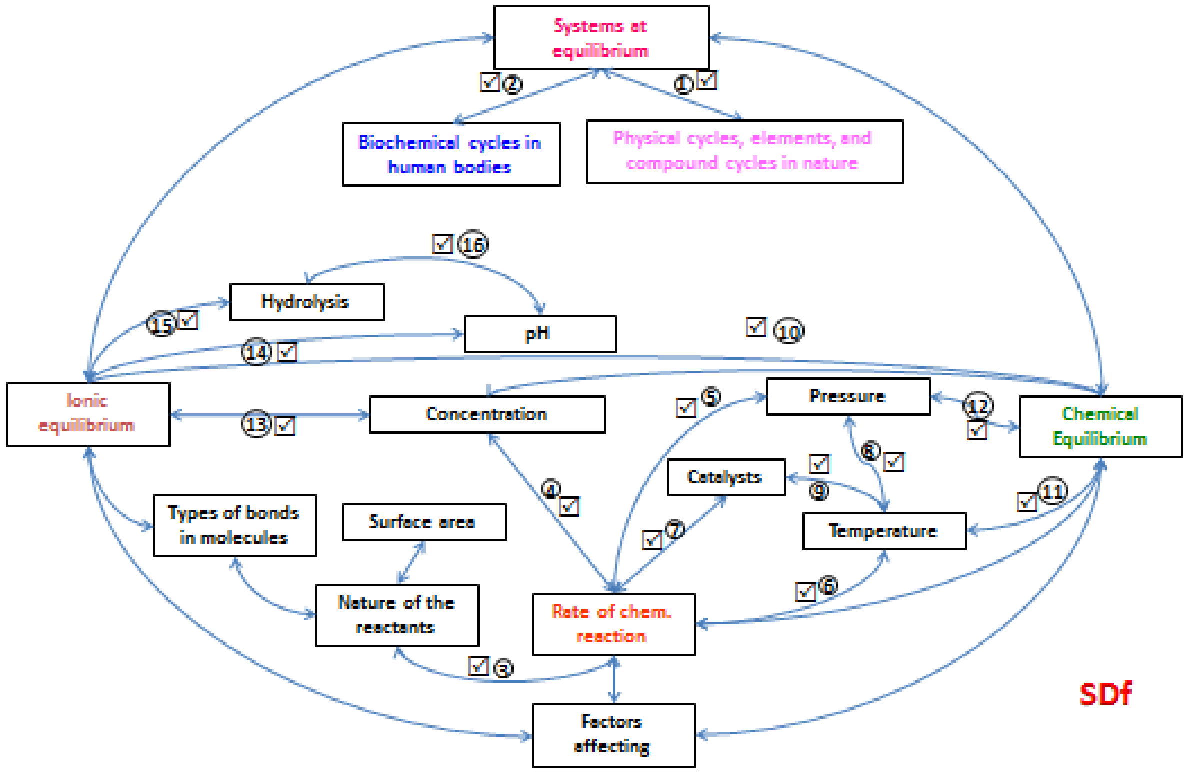
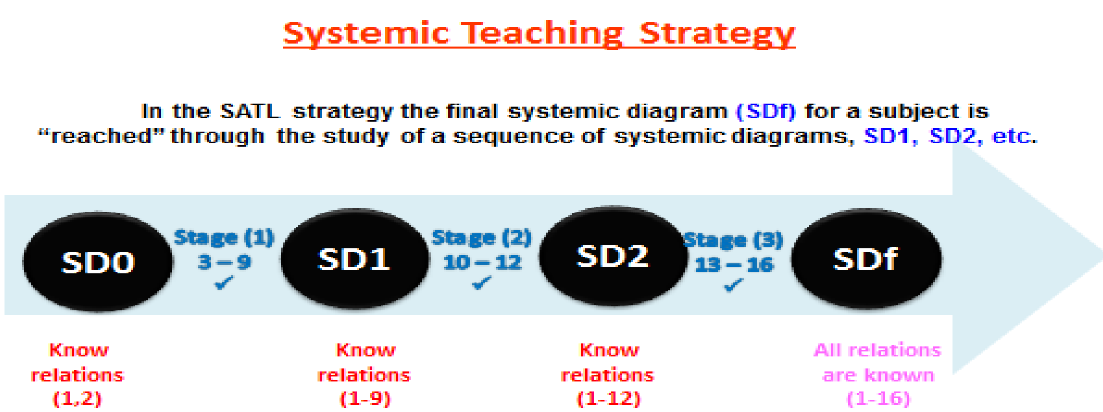


Fig.20: SDf shows all systemic physical relations between concepts



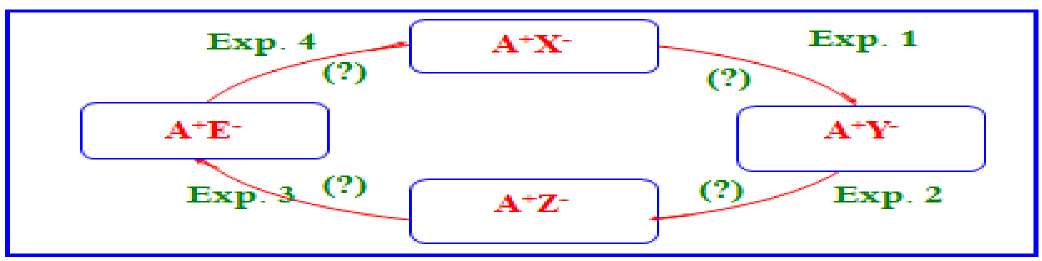
III. GREEN CHEMISTRY: SATL VISION

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].



Systemic Investigation of species A^+(SI-Plane)

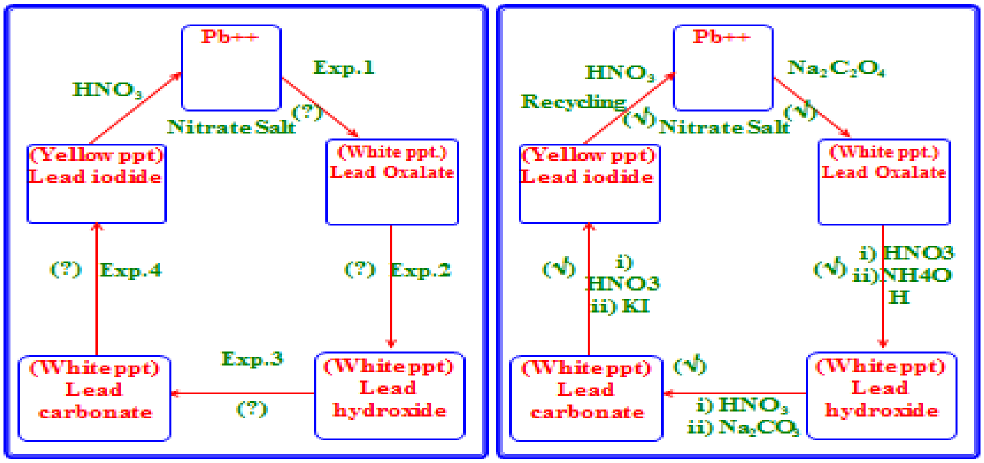
The diagram shows the Plane for qualitative investigation of the species (A^+), the preparation of (A^+) Compounds, and the interconversion of the species.

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+).

III.1. Systemic Investigation of [Pb^{++}] (SI-1): Lead Cycle

The students follow the plane (SI -1) to investigate (Pb^{2+}) 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 $Pb(NO_3)_2$ (cf. SI - Final) [14].



(SI -1 - Plane) (SI -1 - Final)

III.2. Systemic Investigation of [Ag^+] (SI-2): Silver Cycle

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 $AgNO_3$ (Cf. SI-2-Final).

(SI-2 Plane) (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)

Salts	Amount required (gm/50 students)	
	Classic scheme Solid/(g)	Benign Scheme 0.1 M Solution (1/2 liter)
$Pb(NO_3)_2$	100	16.5
$Al(NO_3)_3$	200	11.0
$CrCl_3.6H_2O$	200	13.5
$NiCl_2.6H_2O$	200	12.0
$Co(NO_3)_2.6H_2O$	200	15.0
$CdCl_2.5H_2O$	150	13.5
$BaCl_2.2H_2O$	200	12.0
$MgSO_4.7H_2O$	200	12.0

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.

Learning Levels	Experimental group n=60		Control group n=26		t	Effect size
	Means	SD	Means	SD		
Knowledge	4.08	0.69	3.5	0.89	3.24*	
Comprehension	11.73	1.97	10.98	1.55	1.71**	
Application	3.25	1.03	2.31	1.32	3.52*	
Analysis	6.23	2.06	2.46	1.31	8.52*	
Synthesis	10.13	1.87	2.38	1.60	18.24*	
Evaluation	5.18	1.07	2.12	1.33	11.17*	
Total	40.53	3.77	23.49	5.28	16.71*	3.65 Large

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

Groups	No. of students	Means	SD	t-value	Effect size
Experimental group	60	23.81	1.95	10.77	2.26
Control group	33	20.30	1.22		

Significant at < 0.01

IV. SYSTEMICASSESSMENT [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 SAQ, s 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)

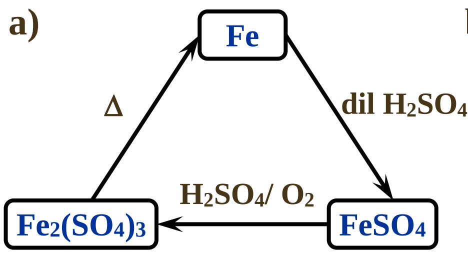
MCQs are the traditional choose one from a list of possible answers [21,22]. However, (SMCQs) are choose of one systemic from a list of possible systemic. Each systemic represents at least three to five physical or chemical relations, between concepts, atoms, or molecules. Various types of systemic multiple 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

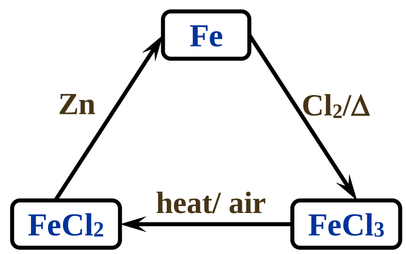
Q1. The systemic diagram represents the correct chemical relations between (Fe) and its related compounds are one of the following:

a)



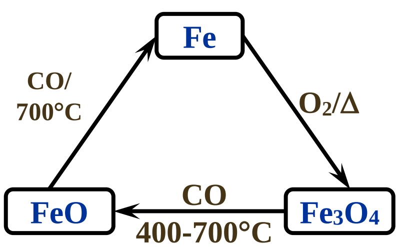
(……)

b)



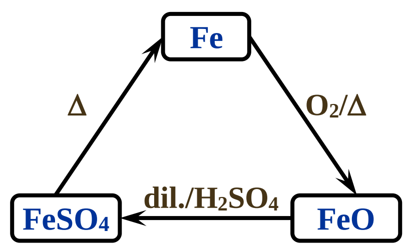
(……)

c)



(……)

d)

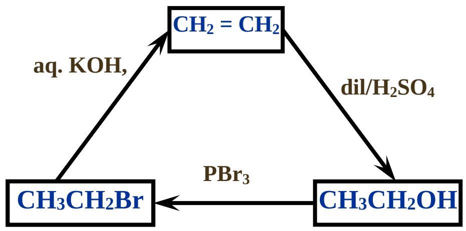


(……)

➢ **Answer:** **(c) √**

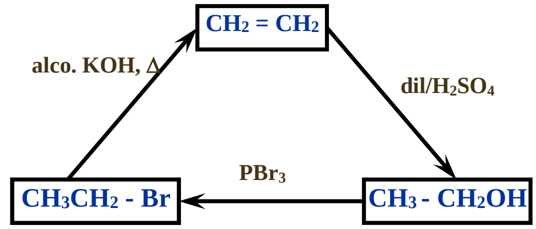
Q2-The systemic diagram represents the correct chemical relations between Ethylene, Ethanol, Ethyl bromide is one of the following

a)



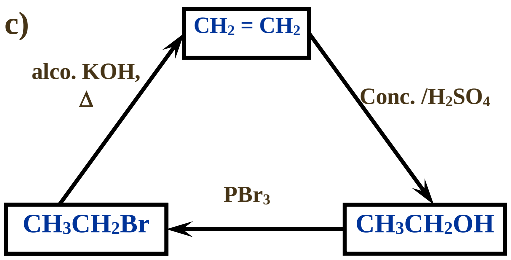
(..........)

b)



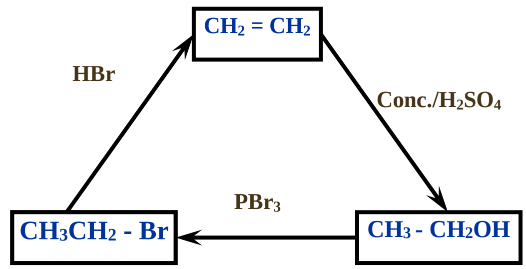
(...........)

c)



(..........)

d)

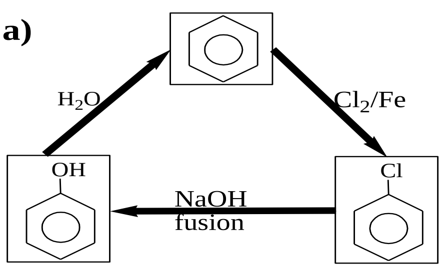


(..........)

- **<u>Answer:</u> (b) √**

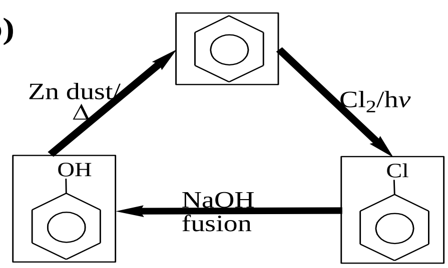
Q3. The systemic diagram represents the correct chemical relations between benzene, chlorobenzene, and phenol is one of the following:

a)



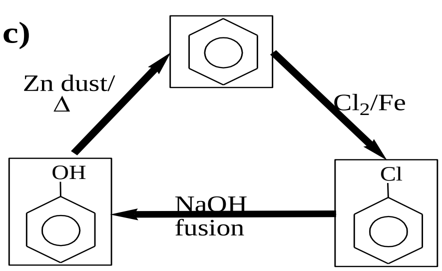
(.......................)

b)



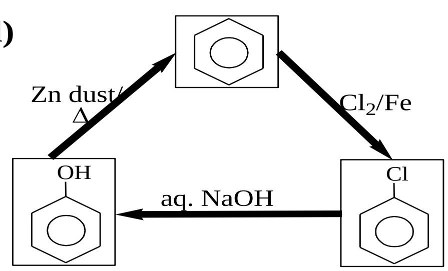
(.......................)

c)



(.......................)

d)



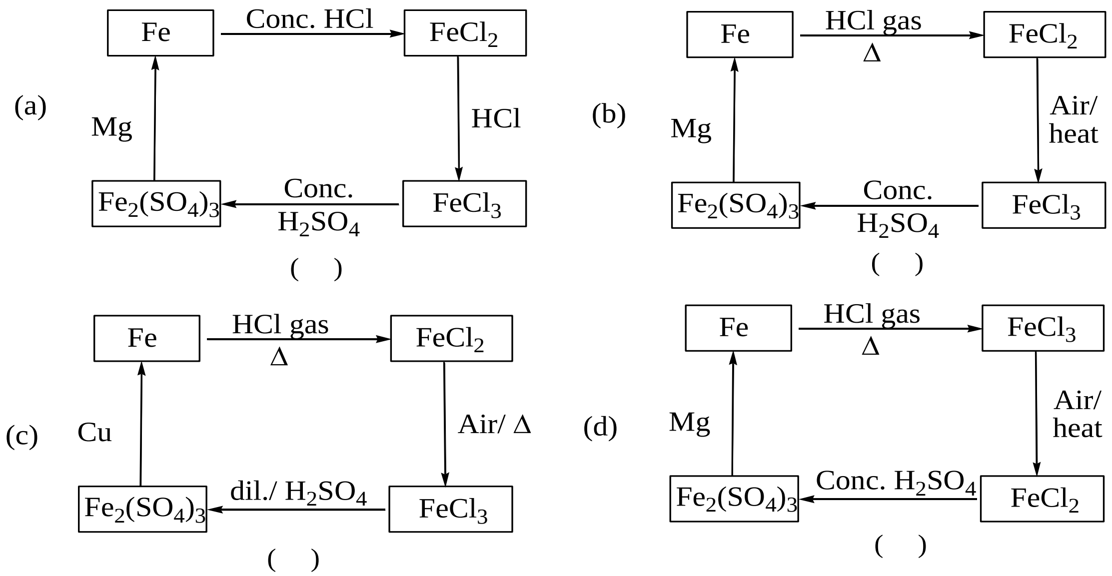
(.......................)

- **<u>Answer</u>: (c) √**

Form (II): **Choose from quadrilateral systemics**

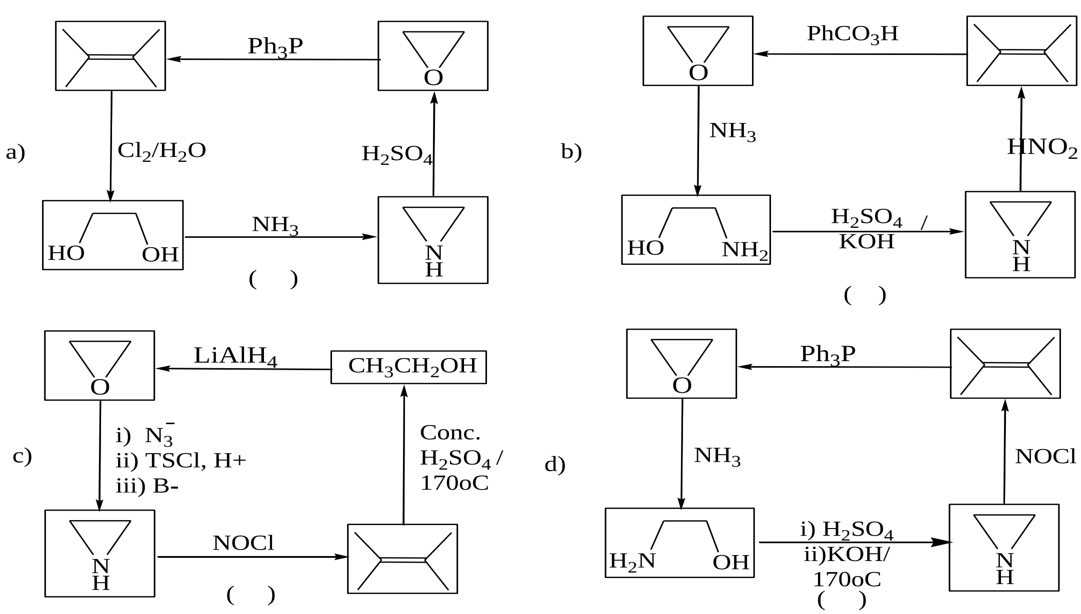
- Put (√) in front of the correct systemic diagram:

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



Answer: **(b) √**

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

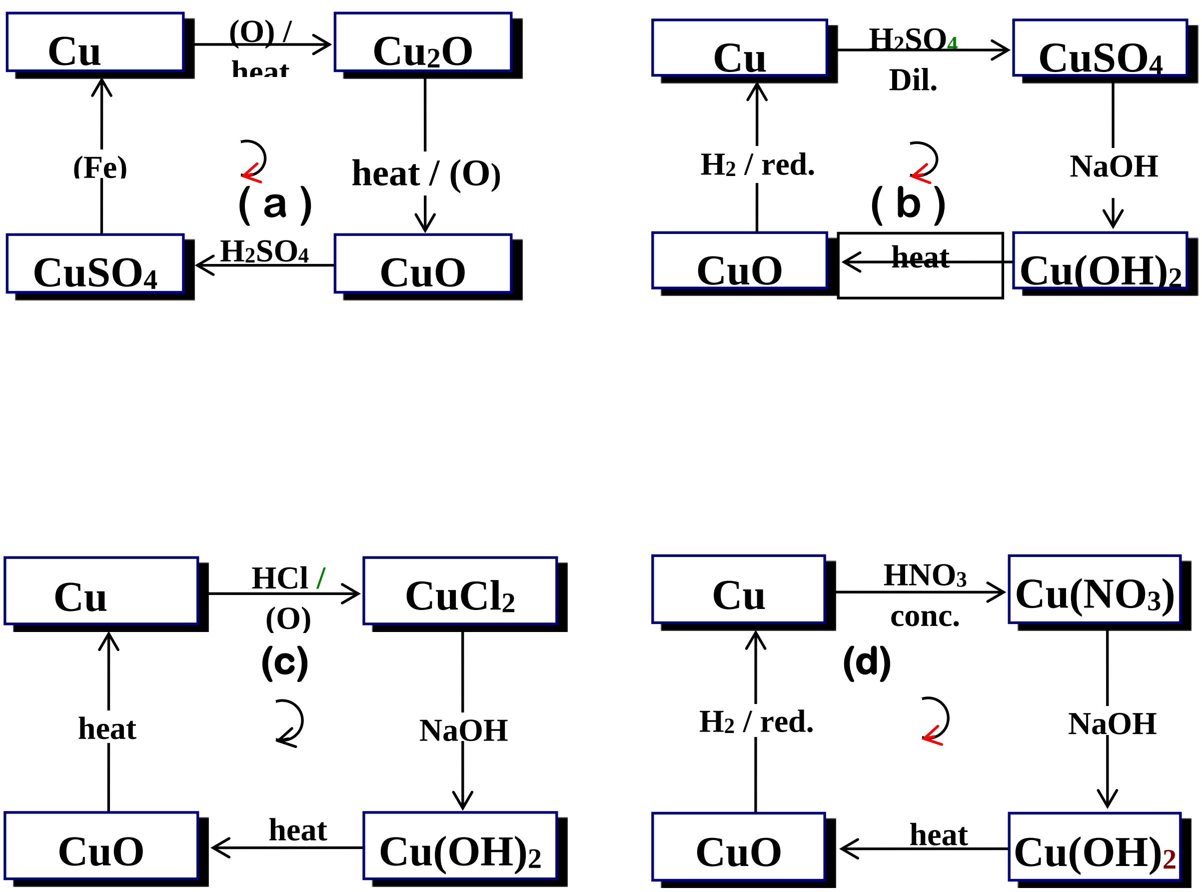


Answer: **(b) √**

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].

<u>Example:</u> Q-Which of the following systemics are true and which are false?



<u>Answer</u>: True systemics (a, d) (√); False Systemics (b, c) (X)

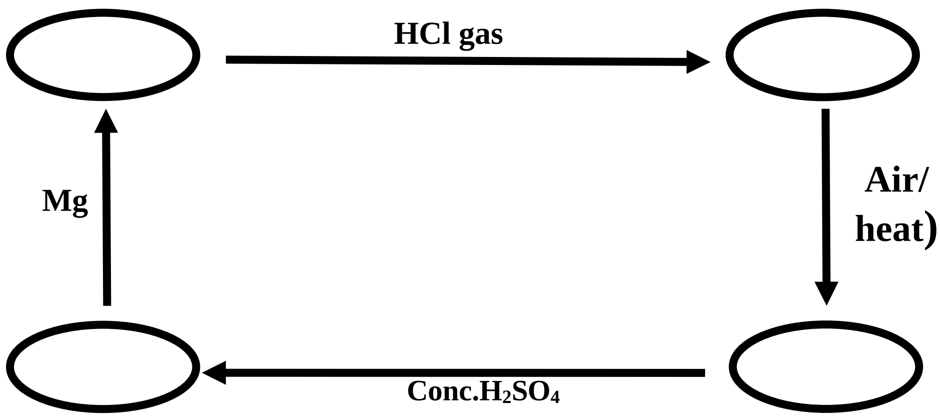
IV.2.3. Type-3: -Systemic Sequencing Questions: [SSQs]

SSQ**s** 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:

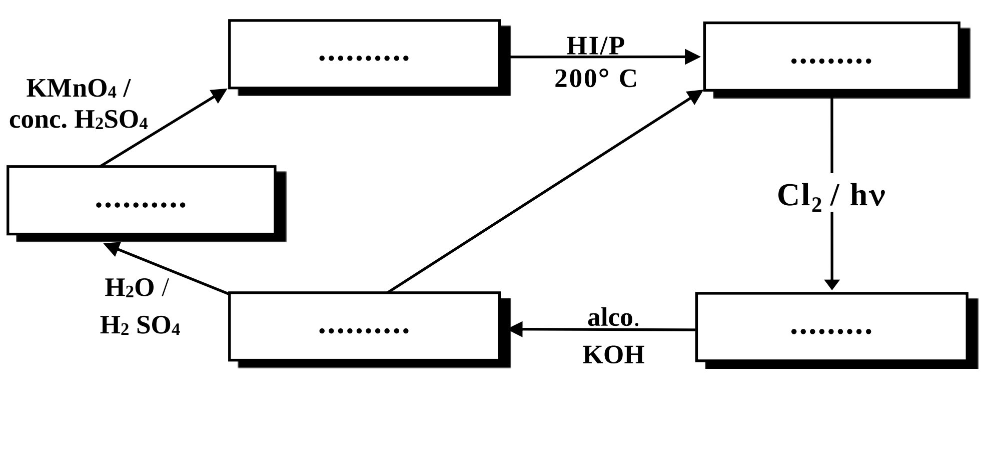
[Fe, $FeCl_2$, $FeCl_3$, $Fe_2(SO_4)_3$]



Answer:

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

CH_3COOH , $CH_2{=}CH_2$, C_2H_5OH, CH_3CH_2Cl , CH_3CH_3,



IV.2.4. Type-IV: Systemic Matching Questions [SMQ, s]:[18]

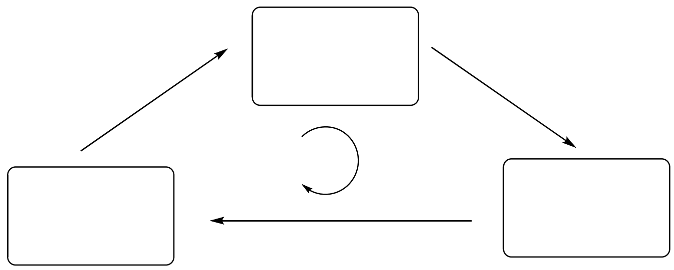
Measure the student's ability to find the relationship between a set of similar items, each of which has two components.

Guidelines for Writing [SMQ, s]:

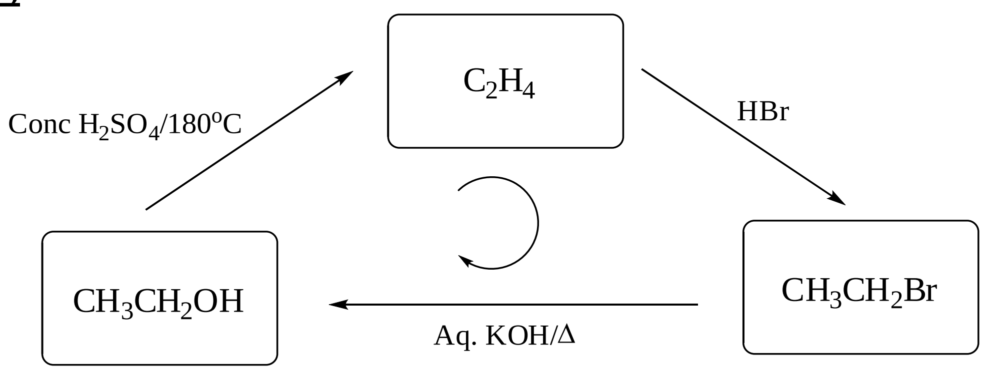
1. The items in the left (Column A) are usually called *premises* and assigned numbers (1, 2, 3, etc.).
2. The items in the right (Column B) are called responses and designated by capital letters (A, B, C etc.).
3. The arrangement of premises and responses are in a given systemic diagram (Column C, in the middle).
4. The given systemic diagram could be triangular, quadrilateral, or Pentagonal.
5. A ll 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]

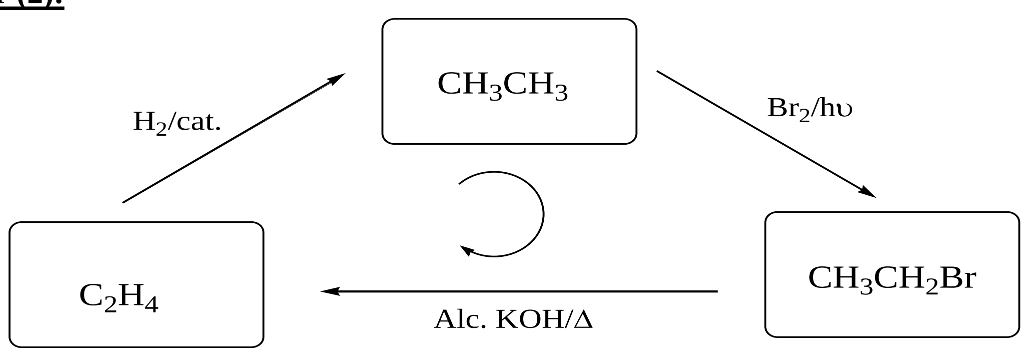
Q_1) Choose aliphatic compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C):

(A)	(C)	(B)
C_2H_4 CH_3CH_3 CH_3CH_2OH CH_3CH_2Br		dil. H_2SO_4 Conc H_2SO_4/180^{O}C PBr_3 Alc. KOH/Δ Aq. KOH/Δ HBr H_2/cat. Br_2/hν

Answer (1)

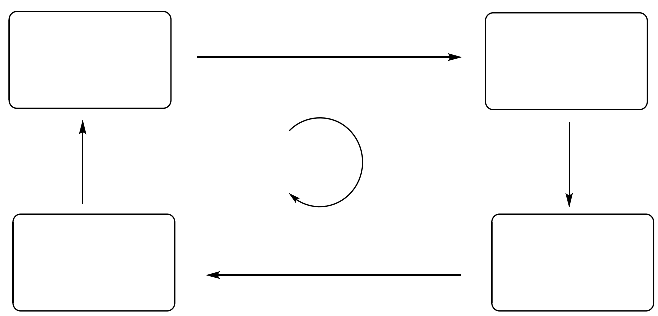


Answer (2):

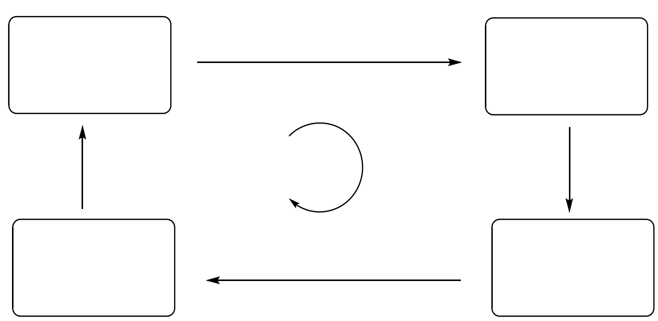


Form II: Matching on Quadrilateral Systemics

Q_2) Choose elements and compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C):

(A)	**(C)**	**(B)**
Na		H_2O
KOH		O_2/heat
NaCl		CO_2
Na_2CO_3		HCl
$NaNO_3$		Electrolysis
Na_2O		HNO_3
NaOH		
K		

Q_3) Choose compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C):

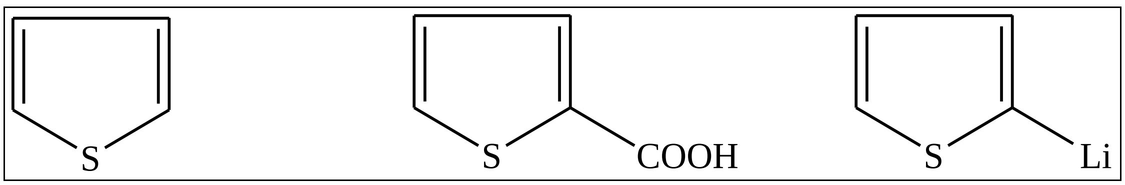
(A)	**(C)**	**(B)**
CH_4		Soda lime/heat
CH_3COOH		$KMnO_4$/ H_2SO_4
CH_3CHO		Cl_2/hν
CH_3CH_2Cl		Aq. KCN/heat
CH_3Cl		HI/P-200^oC
CH_3CH_2OH		Dil. HCl/heat
CH_3-CH_3		
CH_3CN		

V-2.5: Type-V: Systemic Synthesis Questions [SSynQ,s]:[18]

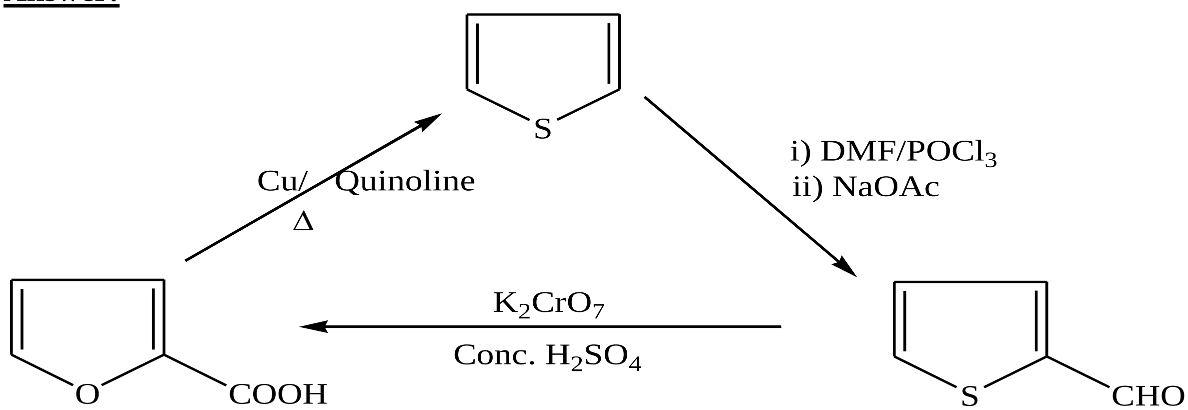
Measure the student's ability to find the relationship between a set of given compounds.

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:

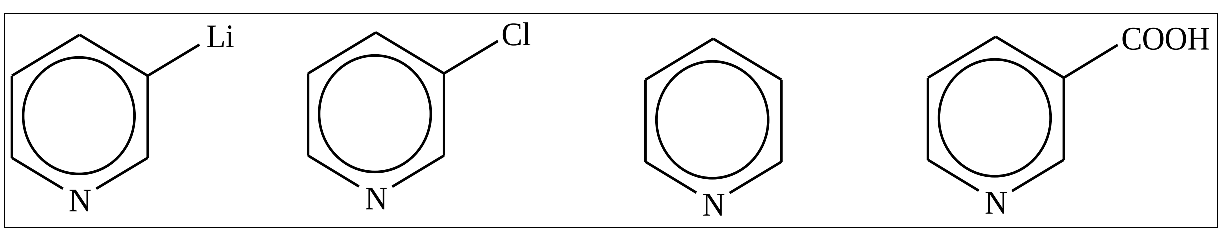


Answer:

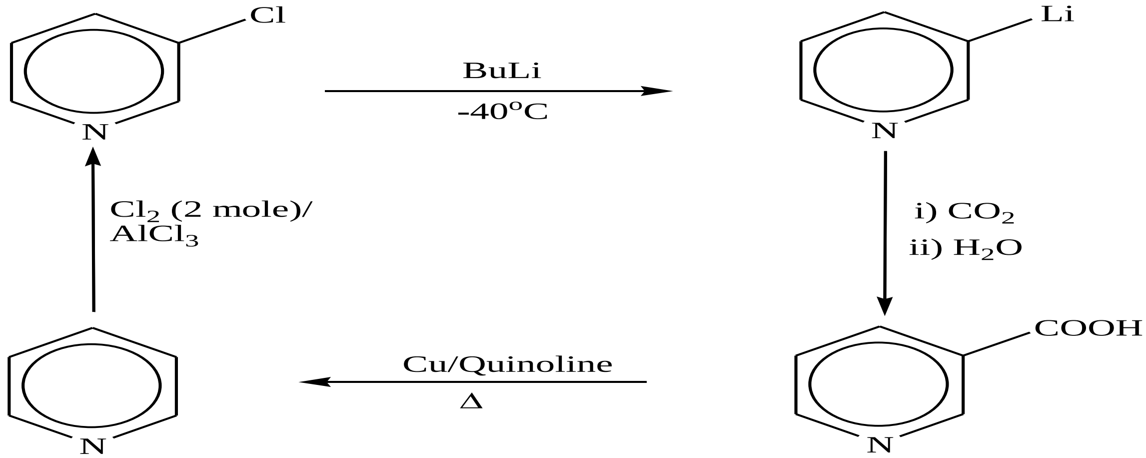


Form II: Synthesis of Quadrelatral Systemic Chemical Relations:

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

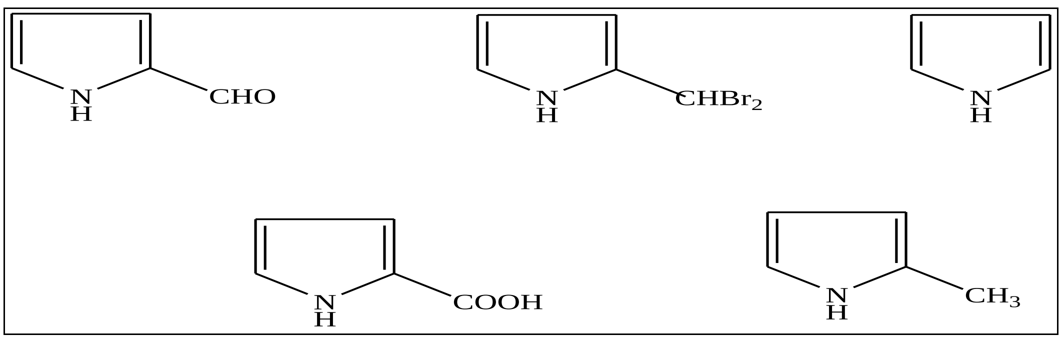


Answer:

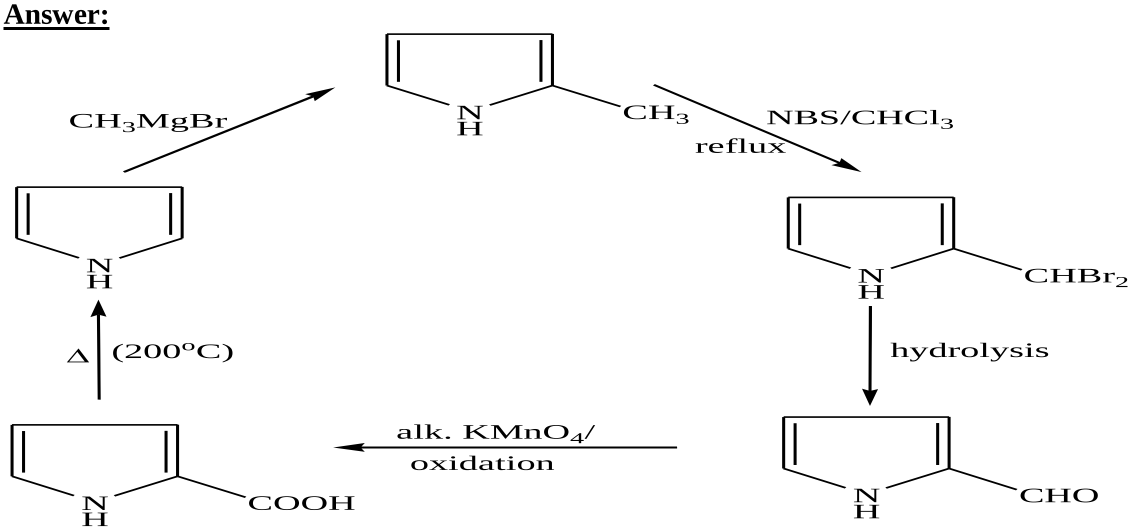


Form III: Synthesis of Pentagonal Systemic Chemical Relations:

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



Answer:



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

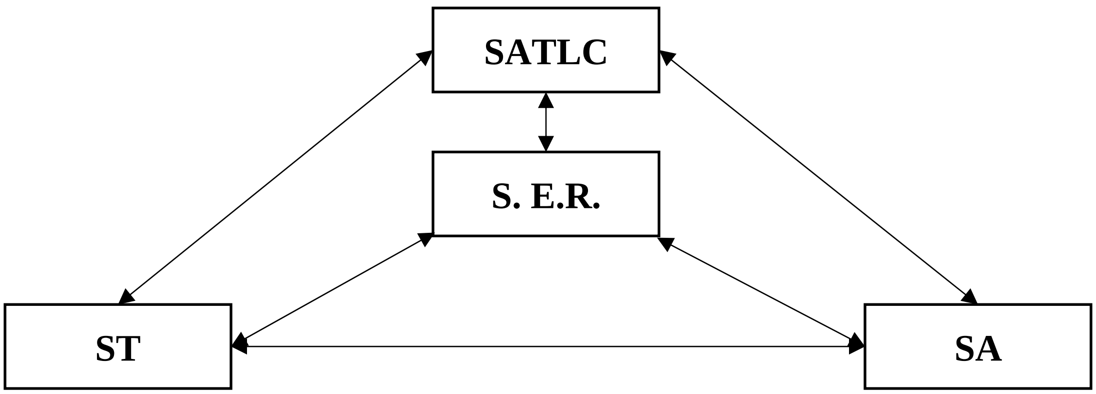
1. Enables us to deal with the elements of any situation in harmony rather than in isolation.
2. It offers the potential to find systemic focus in any situation.
3. Enables anyone can use it to gain deeper insight about anything**.**

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 diagram illustrating the Systemic Education Reform.

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.

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