A 25TH ANNIVERSARY WITH SATL IN CHEMISTRY EDUCATION:
Systemic Approach to Teaching and Learning (SATL), Systemic Assessment (SA) and Systemic Thinking (ST)

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ABSTRACT

About 25 years ago, Fahmy & Lagowski, set up **SATLC** to face; globalization has become a reality we live in with its positive and negative impacts on our lives, the world challenges such as Global climate changes, terrorism, world economic crises, environmental pollution and the widespread of systematization in activities such as tourism, commerce, economy, security, education etc.., So, **SATL** became a must and countries are in an urgent call to prepare their citizens to be able to think systemically and creatively. **SATL** provides inter-relationships between concepts, methodologies, and disciplines. It leads to Systemic Thinking **[ST]** and enhances the quality and quantity of chemistry education. During the last twenty-five years, the 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 indicated that a greater fraction of students was exposed to systemic techniques in the experimental group, achieved at a higher level than the control group taught by conventional linear techniques. The same results have been reached in the experimentation of chemistry units in other countries *(e.g.,* Pakistan, Albania, Slovak*)*. Also**,** Fahmy & Lagowsky used SATL techniques to create a new assessment strategy known as Systemic Assessment [SA] that not only reflects the SATL strategy of instruction but, perhaps, also probes other aspects of student knowledge. SA was used to assess students' achievements after being exposed to SATLC. SA is used to enhance Systemic Thinking [ST]. Also, **ST** is one of the important learning outcomes of SATLC & is very important in the preparation of systemic creative thinkers for Systemic Decision-Making [SDM]. *[African Journal of Chemical Education—AJCE 13(4), December 2023]*

INTRODUCTION

About twenty-five years ago Fahmy and Lagowski [1-6] set up SATL after the spread of globalization in a wide range of human activities. SATL methods have been expressed in chemistry 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. They recognized that the basic goal of SATL is the achievement of meaningful understanding by students and suggested that this goal can be attained through the development of systemic thinking, in the context of constructivist and systemic-oriented learning tasks (SATL techniques). Meaningful understanding of chemistry concepts includes the ability of students to link related chemical concepts and construct a chemical representation using chemical information. SATL is also used as a vehicle to engage the students in deep learning which differs from surface learning, which focuses on rote memorization and superficial understanding of concepts and making connections between new and prior knowledge.

The same authors [7] believe that the SATL technique has additional benefits for societies facing globalization issues. As a start, the uses of systemics can help students begin to understand the interrelationships between 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; from learning chemistry subject and learning to see all subjects in a greater context.

Unlike concept maps, systemic diagrams are closed systems of the selected concepts with the arrangement of concepts into interacting systems in which all relationships between them are made definitive in front of the learners. Explaining why this difference is crucial, Fahmy and Lagowski noted that such "concept clusters" permit learners to see the domain, subject, or content holistically without missing its parts [4].

Herin, et al 2023 [8] stated the SATL teaching strategy can be considered as a hybrid methodological approach, which combines and utilizes ideas and features of systemic and constructivism adapting them to concept mapping procedures. The primary objective of SATL is the increase of a student's deep understanding of science concepts. They believe that this objective can be achieved through the development of systemic thinking, in the context of constructive educational processes and appropriate, systemically oriented, teaching/learning activities, as those proposed within the SATL strategy. The systemic approach aims to create a dynamically evolving closed system of concepts in a cyclic form. This visual representation of such a conceptual system is named a "*systemic diagram*" which is the main teaching-learning tool used in the SATL-strategy. These diagrams are powerful explanatory tools that can contribute to learning when used in a constructive manner.

Theodoros Vachliotis et al. 2021 [9] stated that in the systemic diagrams, all the stated concepts are interrelated, directly or indirectly, creating a closed conceptual pattern that emphasizes the mutual interactions between concepts. The introduction of new information is accomplished through connection with relevant prior knowledge. The founders of the SATL strategy suggested a specific way for using systemic diagrams as a teaching-learning tool (Fahmy & Lagowski, 1999, 2003) [3, 4]. First, the new subject matter is taught through a traditional linear approach (**LA**) (lectures and presentations). Then, starting from a given initial linear diagram constructed on the basis of relevant prior knowledge, the students with the help of their teachers are encouraged to complete, through sequential steps, a series of structured systemic diagrams (**SD**) required for the section being studied. A progressive systemic interaction of new concepts and their interrelations with the previously taught concepts in the sequential **SD**, from **SD0** (the starting point of teaching the unit) to **SDf** (the end point of teaching the unit) diagrams are clear in front of the students [7, 9].

In SATLC strategy development of a systemic diagram, based on questions asked by the teacher guiding the teaching-learning process. These questions should be answered by students using their relevant prior knowledge and common sense. This approach allows students to participate more actively in the building of the systemic diagrams. The basic differentiation of the SATL strategy compared with a traditional teaching approach is, first, the integration of concept mapping techniques for teaching as well as for assessment of student achievement, and second, the representation and the study of concepts and their interrelationships as a closed and step-by-step growing system (Lagowski; Fahmy [3,4] and Fahmy [7]). A systemic diagram represents a network of connections between concepts that can be meaningful for the student. Such a conceptual whole consists of smaller, conceptually interrelated, subsystems. The study of such a closed systemic involves the application of analysis and synthesis procedures within the defined system, which may lead to the development of systemic thinking skills and, consequently, to enhance understanding [8]. Golmi [10] stated that SATL strategy is the changes in the way of organization of concepts intended to increase the yield and quality of the teaching process besides the role of the teacher as an organizer and the student as an active part in the learning process. SATL is a new approach contrasted to the common approach of the concept map which involves the creation of a hierarchy of concepts [7].

According to Nazir et al [11] systemic approach contradicts the linear method which is currently used in our educational systems. Also stated that teachers can minimize the difficulties in concept building by providing a better perspective related to the basics of the subject. The recently emerged concept-based teaching methodology (SATLC) is a fascinating route to meet this noble endeavor. The SATL method has been discovered to play an essential role, towards the efforts for a better understanding of chemistry concepts. In addition to that, the results reported from the evaluation of the SATL technique have been very promising as far as the improvements in students' academic achievements are concerned.

According to Cardellini et al [12] through the use of a systemic approach, we believe it is possible to teach people in all areas of human activity; economic, political, ethical, and 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 recognizable Fahmy [7], 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 [13] stated that 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.

Maria Ganajova et al. 2022 [14] stated that (SATL) involves an arrangement of concepts/problems into diagrams, which represent how they are linked. The goal of their work is to present the systemic approach in teaching chemistry and provide examples of systemic tasks in terms of this approach on a selected topic from inorganic chemistry, i.e. s-block elements and their compounds. By SATL, systemic tasks in chemistry aim to verify and develop students' ability to determine the relationships and links between reactants and reaction conditions, as well as their ability to write down chemical reactions in the form of chemical equations. The evaluation of teachers' opinions on the pros and cons of the systemic tasks implementation into teaching is presented. Systemic tasks verify and develop students' ability to determine relationships and contexts between reactants and reaction conditions, and skills, which are related to the recording of chemical equations. Teachers see the potential of systemic tasks in deep understanding and development of critical and systemic students' thinking, as opposed to rote learning]. Gulten Sunders 2023 [15] stated that SATL treats concepts and topics in two dimensions and in a spatial arrangement where the presentation of topics and their relationships have a central role.

The main objective here is to build an interactive system in which learners recognize all the relationships between fundamental concepts and topics [16] The difference is that the structure of systemic diagrams manifests in the form of a closed system of concepts, whereas hierarchical concept maps mostly include more limited relationships. All relationships between concepts can thus be shown in systemic diagrams. For example, while we can show the different addition reactions of alkenes in one part of a systemic diagram related to alkenes, in another part, we can show the synthesis of alkenes from alkyl halides. In summary, when we focus on the reactions between organic molecules in systemic diagrams, the diagrams provide much more detailed information compared to concept maps [17]. Presenting concepts in closed-cluster form in systemic diagrams not only enables learners to find detailed information, but also helps them to develop important thinking skills such as decision-making, multidimensional thinking, and forming relationships so that they can organize a conceptual structure [15]. When learners develop such high-level thinking skills, this plays a facilitating role in reaching meaningful understanding. It can be said then that learners can reach a meaningful understanding with SATL

Objectives of SATLC: (7)

1. To change our educational systems from surface to deep learning that prepares our graduates to meet the needs of the global markets besides high skills that enable them to live and act positively in the global age.
2. To face the global challenges that face the world today such as global terrorism, global climate changes etc. That requires preparation of human calibers ready to think systemically and creatively that required for a better and safer world for all.
3. To change our teaching and learning strategy from linearity to systemic which enhances the interconnectedness between learned concepts to build a correct cognitive structure.
4. To face the Global changes of most human activities. Economics, media, security, politics, education, & and health. Are among the human activities that have achieved a global perspective.

5. To enhance the working memory of our student by grabbing their interest by finding ways to connect information that helps with forming and retrieving long-term memory.
6. To enhance our teaching and learning capacity by converting our students into active, creative learners and teachers to act as good facilitators during the learning process.
7. To appreciate the huge contribution of chemistry to human welfare.

Drawbacks of the Current Educational Systems: (7)

Our educational systems suffer from the following drawbacks:

1- Low Performance of the current Curriculum **s**ystem due to the linearity of each component of the curriculum system. To get maximum performance of the systemic curriculum, it is necessary that each of its components should be written systemically and act as a sub-systemic (Fig.1)

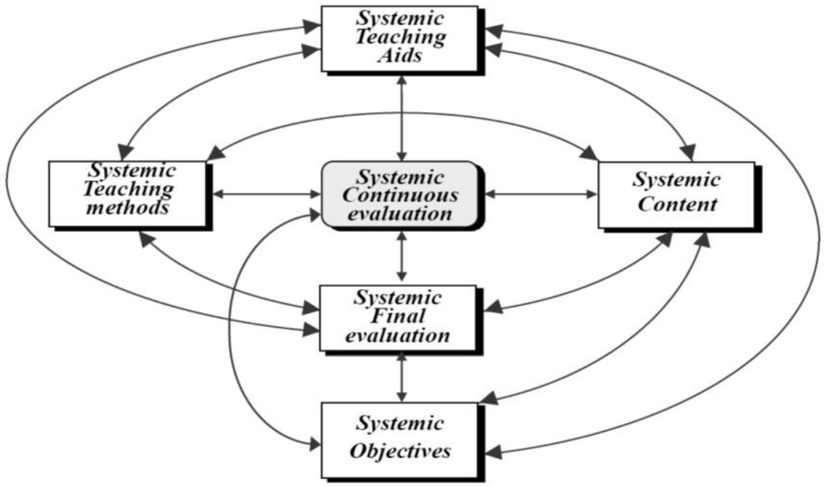


Fig.(1): Systemic curriculum

In the above systemic curriculum diagram, the objectives should be systemic, and each component of the systemic curriculum should be designed systemically.

2. Slight Interaction of the Current Learning Domains:

[Cognitive- Psychomotor, and Affective 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 settle them into the cognitive structure of the learner and enables him to use it systemically in different situations. It also helps learners to deduce new relations that enrich the operation of teaching and learning from its cognitive, psychomotor and emotional sides. The following diagram illustrates the idea of linear (traditional) and systemic illustrations of concepts.Fig.2a, b [7]

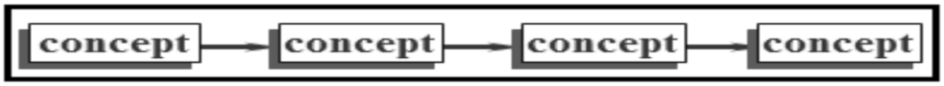


Fig.(2a): Linear (traditional) representation of concepts

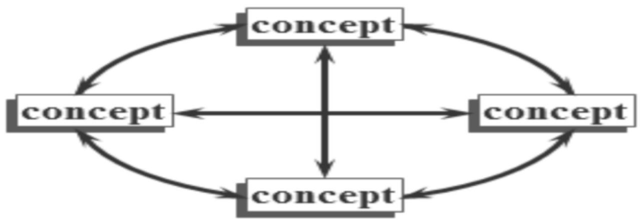


Fig.(2b): Systemic representation of concepts

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 a chemistry concept map **(Systemic**; **SD1-SD5)**.[7]

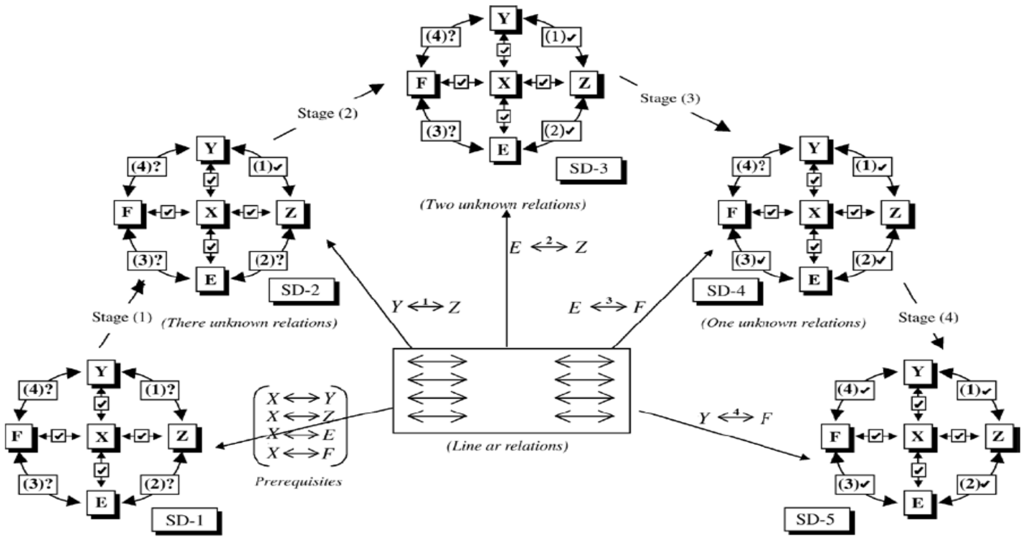


Fig. (3): Systemic teaching strategy.

The above systemic diagrams involved in teaching are similar except that the number of known **(√)** and the unknown relationships **(?)** ones as indicated in Fig.3.

USES OF SATLC- STRATEGY IN REBUILDING UNITS

[SYSTEMIC GENERAL BUILDING STRATEGY]

In the SATL rebuilding strategy of units, we convert the linearly based units in different branches of chemistry to the systemically based units (during teaching) according to the following general strategy [16].

SATL- Strategy for Building Unites in Chemistry:

In continuation to our work on SATL- building strategy of teaching units [16]. We convert the linearly based units in chemistry to systemically based units according to the following general building strategy (Scenario).

<u>Step</u>-1: The systemic aims and the operational objectives for the unit should be defined in the frame of national standards.

<u>Step</u> 2: The prerequisites needed for teaching the unit from previous studies (concepts, facts, reaction types and skills) should be tabulated in a list.

<u>Step</u> 3: Then content analysis of the linearly based unit into concepts, facts, and reaction types, mental and experimental skills.

<u>Step</u> 4: Draw a diagram illustrating linear relations among the concepts of the unit.

<u>Step</u> 5: We modify the linear diagram by putting the sign **(□)** on the already-known relationships between concepts. Then the remaining linear relations are unknown and signed by **(?).**

<u>Step</u> 6: The final linear diagram should be modified to a systemic diagram (**SD0)** by adding unknown relations between the concepts**. SD0** is known as the starting point of teaching the unit.

<u>Step</u> 7: Then the student follows up the scenario of teaching the unit step wisely.

Started by **(SD0)** which has determined the starting point of the unit. The unit ends with a terminal systemic **(SDf)** in which all the relationships between concepts are identified. In going **from SD0 through SDf** he/she will crossover several systemics with known and unknown relationships like **SD1, SD2**, …..etc.

At the end of the teaching scenario of the unit, we can ask the students to build systemics showing the relations between any three, four and/or five concepts (from the **SDf**) via systemic assessment SAQs,s [17-21].

So, the scenario of teaching any course systemically involves the development of a systemic diagram **(SD0)** that has determined the starting point of the course; it incorporates the prerequisite materials. The course ends with a terminal systemic **(SDf)** in which all the relationships between concepts are known. In going from **SD0 through SDf** we crossover several systemics with known and unknown relationships like (**SD1, SD2, etc.)**

I-SATLC-Applications in Egypt

A list of SATLC materials was produced in Egypt, for instance, SATL General Chemistry for secondary schools; SATL Aliphatic, Aromatic, Green Chemistry, Heterocyclic Chemistry, Inorganic Chemistry, and Physical Chemistry for university-level.

SATLC-Secondary Schools I-A:

- Our experiments about the usefulness of SATL to learning Chemistry at the secondary school level were conducted in the Cairo and Giza school districts (2, 6).

I-A-1: SATL-Classification of Elements

- Fifteen SATL-based lessons in inorganic chemistry taught over three weeks were presented to a total of 130 students **(6).** The achievement of these students was then compared with 79 students taught the same material using the standard (linear) method.
- The details of the transformation of the linear approach to the corresponding systemic closed concept cluster were presented.

I-A-1-1: Periodicity of Physical and Chemical Properties of Elements in the Periodic Table (6.7, 22):

1-A-I-1-a: Periodicity of the properties of the elements within the Periods:

Teaching Scenario:

Steps 1-3: Follow the general building strategy from the **first step to third step**. Then move to the following steps.

Step 4: After the students studied the periodicity of physical and chemical properties of elements in periods. They can draw (with the help of their teachers) the following diagram that summarizes the periodicity of the properties **within the horizontal periods** of the periodic table as illustrated in the diagram in (**Figure 4**).

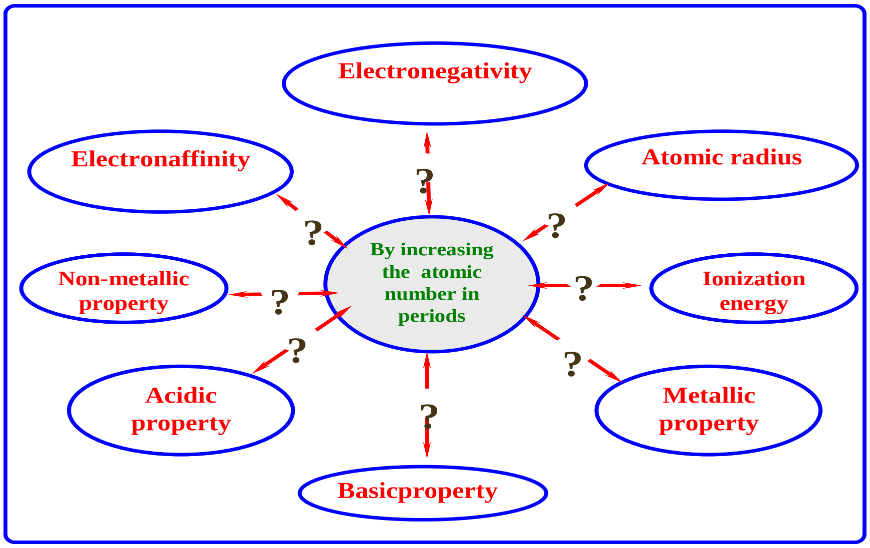


Fig.(4): periodicity of properties of the elements within the periods.

The previous diagram of periods represents linear separated chemical relations between the Atomic number and Atomic radius – Ionization energy - Electron affinity - Electronegativity - Metallic and non-Metallic properties - Basic and Acidic properties.

<u>Step</u> 5: Then the linear Diagram **(Fig.4)** can be transformed by students with the help of their teachers into a systemic diagram **(SD1- P**) which illustrates the periodicity of the properties through the periods systemically **Figure (5).**

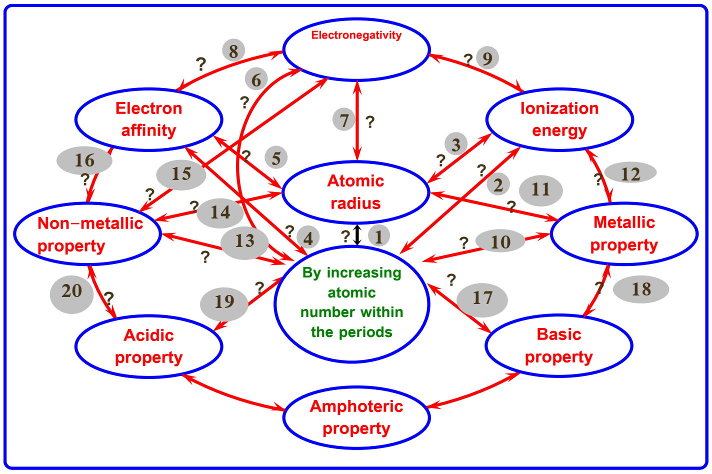


Fig.(5): Systemic diagram (**SD1-P**) for the periodicity of properties of elements in periods

<u>**Step**</u> **6:** The students with the help of their teachers can identify all the unknown relations **(?)** and then modify systemic diagrams **(SD1-P) Figure (5)** to (**SD2-P**) with all known relations for periods **Figure (6)**.

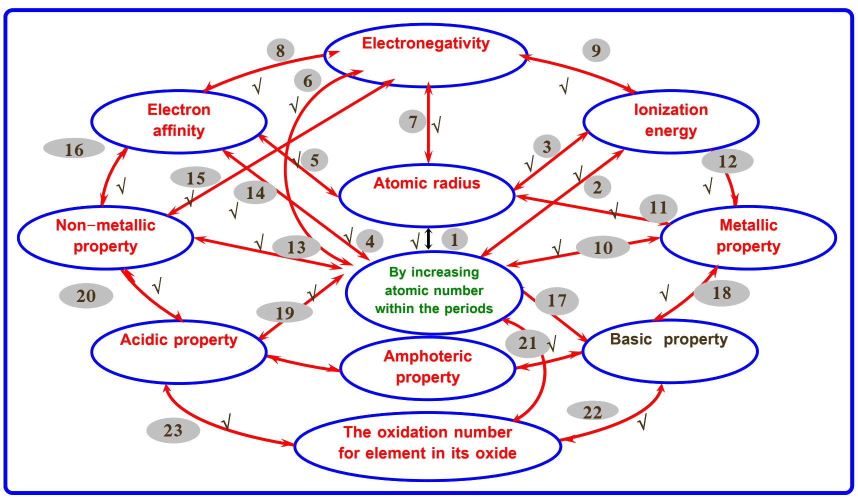


Fig.(6): Systemic Diagram (**SD2-P**) for the periodicity of the Properties for the elements within periods.

<u>1-A-I-1-b: Periodicity of the properties of the elements within the Groups</u>:

<u>Step</u> 7: After the students studied the periodicity of physical and chemical properties. They can draw (with the help of their teachers) the following diagram that summarizes the linear periodicity of the properties **within the vertical groups** as illustrated in the linear diagram (**Figure 7).**

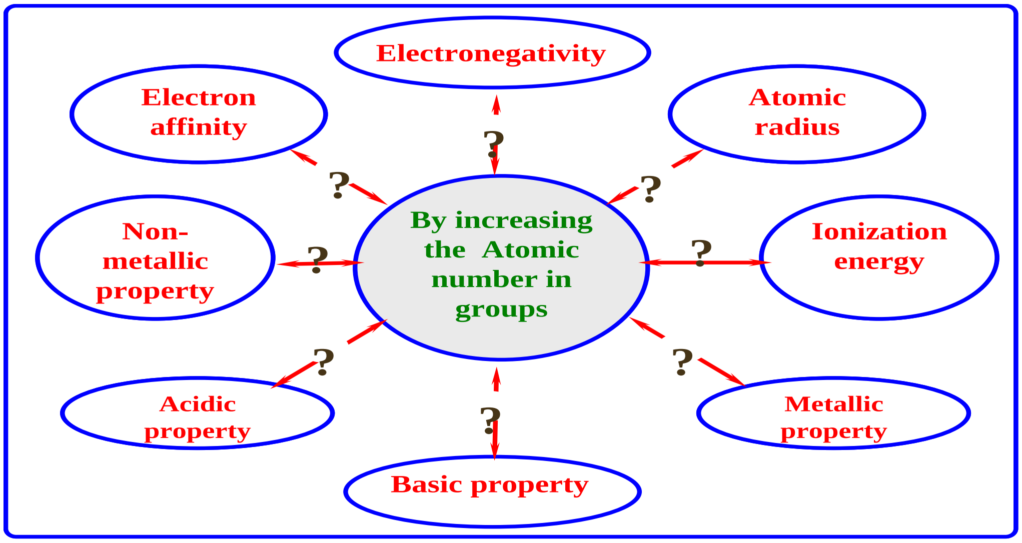


Fig.(7): Periodicity of the properties of the elements within the groups represented in linear separate relations

<u>Step</u> 8: Then the linear Diagram **(Fig. 7)** can be transformed by students with the help of their teachers into a systemic diagram **(SD1-G) Figure (8).**

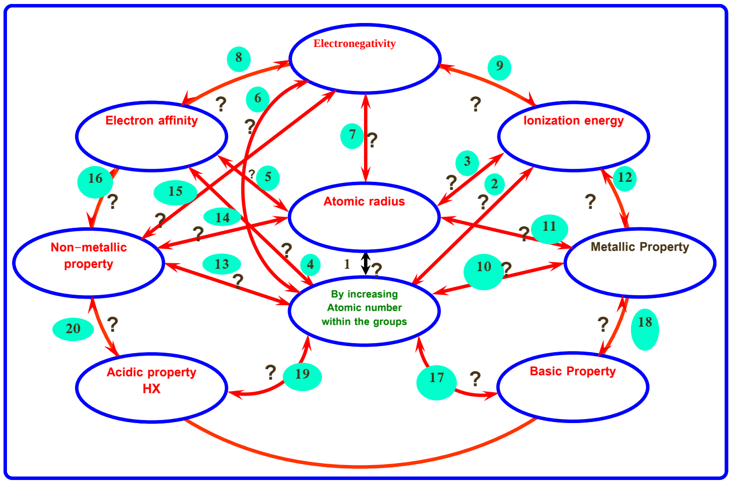


Fig.(8): Systemic Diagram (SD - G) for the periodicity of properties

<u>**Step**</u> **9:** The students with the help of their teachers can identify all the unknown relations **(?)** and then modify systemic diagrams **(SD1-G) Figure (8)** to **(SD2-G)** with all known relations for groups **Figure (9)**,

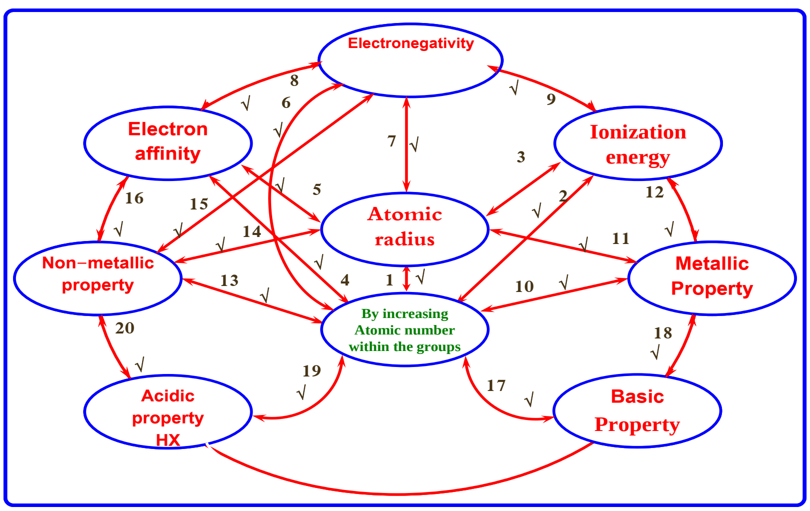


Fig.(9): Systemic Diagram (**SD2 G)** for the periodicity of the properties within groups

I-A-1-2: Systemic Periods and Groups in the periodic Table

I-A-1-2a: Linear and Systemic Periods:

Teaching Scenario:

Step-1: The students by the help of their teachers studied the graduation of the element properties in linear periods of the periodic table from left to right increasing or decreasing. They apply this on the period (2). The linear graduation of the elements properties in the second period starting from Lithium to Neon increasing or decreasing where examined.

Li	**Be**	**B**	**C**	**N**	**O**	**F**	**Ne**

Step-2: Teacher started to explain the meaning of a systemic period as closed system in which each element can be interrelated to the others and the graduation in the properties are studied systemically starting from any element in the period to any other element.

Step-3: Teacher asks the students to transfer the linear period-2 to a systemic period as shown in the **Figure (10).**

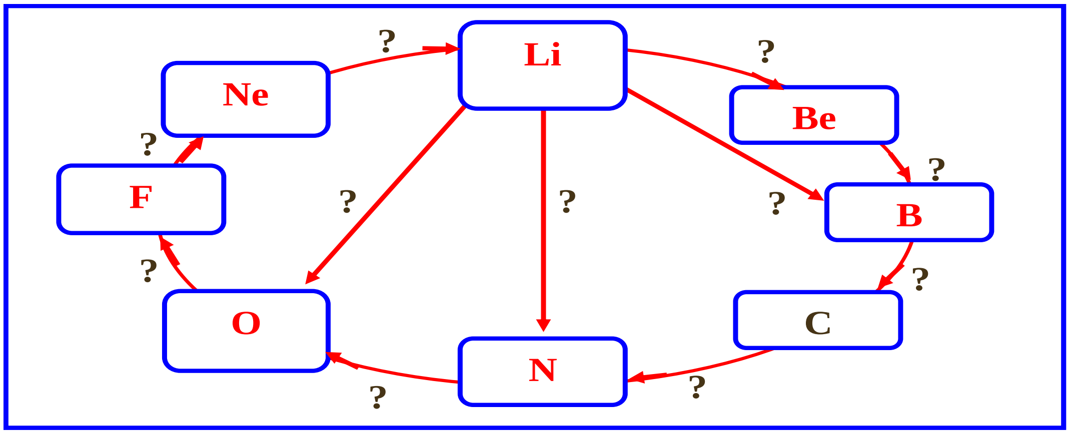


Fig.(10): Systemic period (2)**[SD-P2**]

SD-P2 shows increasing or decreasing in the given property on moving from one element to another through the systemic period.

<u>Step-4</u>: Teacher raises the attention of the students about the main characteristics of the systemic period which differs from the linear period characteristics in the following:

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

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

<u>Step-</u>5: The students' by the help of their teachers indicated the change in the electron affinity in period -2 increases by increasing atomic number with the exception of Beryllium , Nitrogen and Neon as shown in the following table:

Li	Be	B	C	**N**	**O**	**F**	**Ne**
58.5	**+66**	**-29**	**121**	**+31**	**-142**	**-332**	**+99**
	□			□			□
	(abnormal)			**(abnormal)**			**(abnormal)**

Step-6: Teacher ask students to transfer the electron affinities from the table to the systemic period [**SD-P1] Fig.10**, then put the type of changes in electron affinity between elements (increasing or decreasing) as represented **in Fig 11 –[SD P-2].**

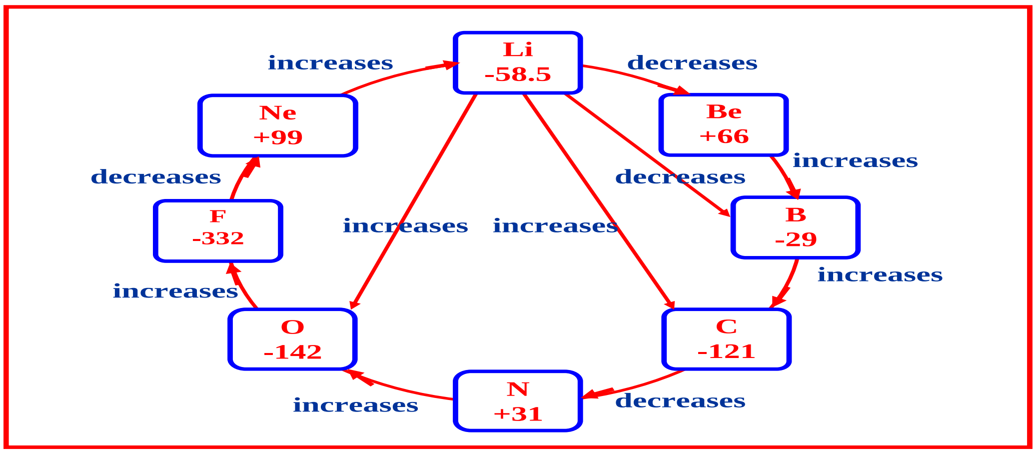


Fig.(11): Periodicity of electron affinity in systemic period (2)[SD-SP2]

-Notice: As the (-ve) value increases the amount of energy released increases.

So, the electron affinity increases**.**

Step-7: Then teacher illustrates the general systemic period **(GS-P)** as shown in **Figure 12.**

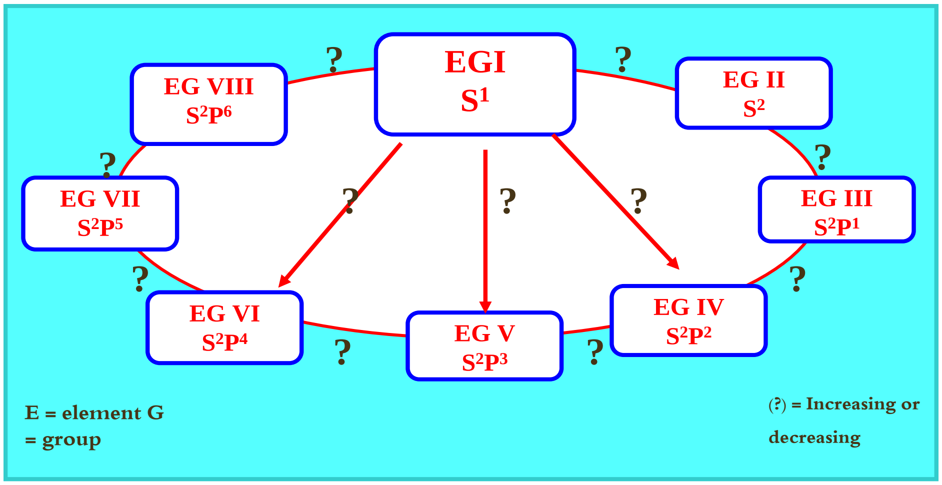


Fig.(12): G-systemic period [GS-P]

Then ask students to use the **(GSP**) to convert other linear periods of the periodic table. By converting those to systemic periods then examine the systemic relations between any two elements in periods.

I-A-1-2b: Linear and Systemic Groups (6, 7, 22)

Step-1: The teacher raises the attention of the students about the main characteristics of the general linear groups includes the graduation of the properties linearity from top to bottom as shown in the following **Figure (13).**

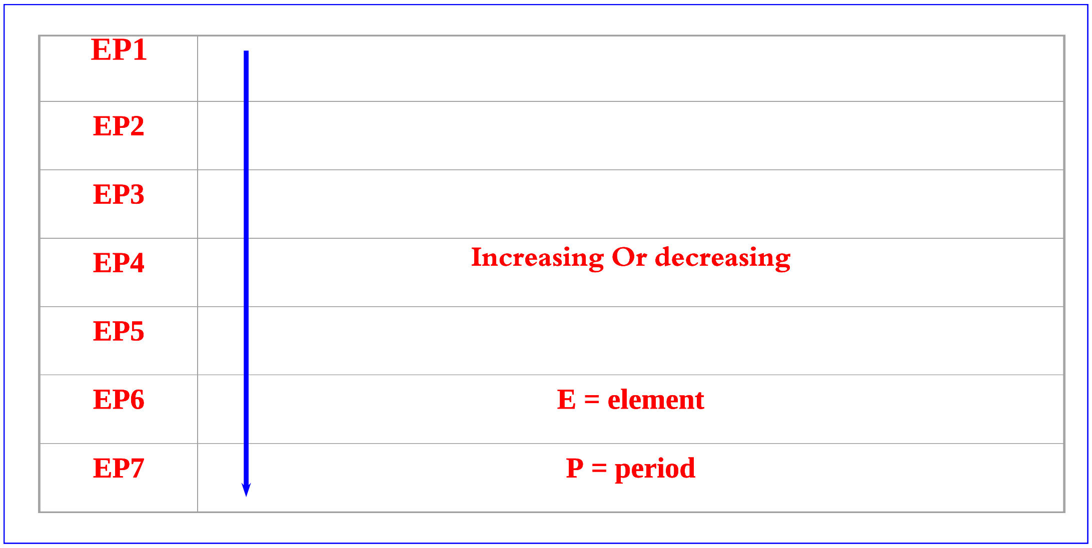


Fig.(13): General Linear Group

<u>Step</u>-2: Teacher started to explain the meaning of a systemic group as closed system in which each element can be interrelated to another and the graduation in the properties are studied systemically starting from any element in the period to any other element.

<u>Step</u>-3: Teacher asks the students to transfer the general linear group figure. **(13)** To systemic general group **[SG-G]** as illustrated in **figure (14).**

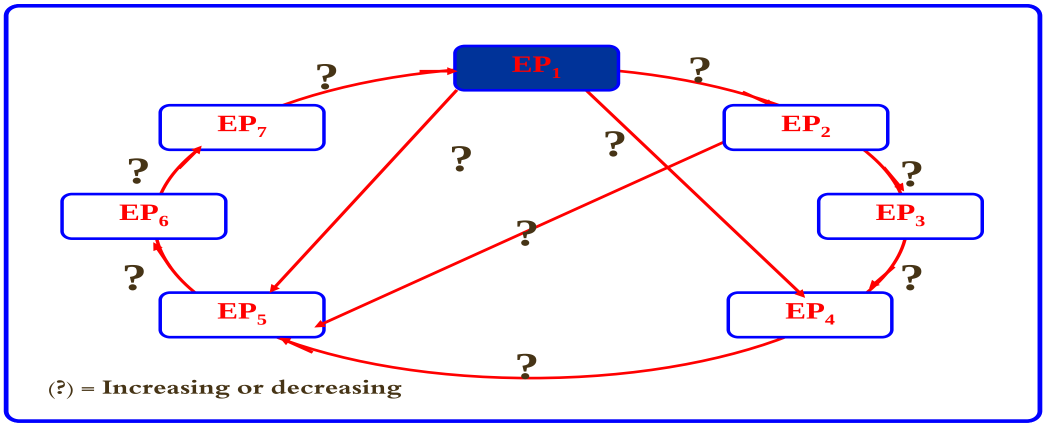


Fig.(14):General Systemic Group [GS-G]

<u>Step</u>-4: The teacher raises the attention of students that in systemic group the graduation in the properties are to be studied systematically. Starting from any element to another. It can be represented by the following systemic (**GS-G) Fig (14).**

<u>Step</u>-5: Teacher asked their students (as an assignment) to transfer the linear groups in the periodic table into Systemic groups by making use of **(SG-G) Fig.(14).**

<u>I-A-1-3: The results of experimentation</u>:

The results of a study of the achievement of a control group, taught linearly vs an experimental group taught by SATL techniques indicate that a greater proportion of students exposed to systemic techniques achieved at a higher level than did the control group. The overall results are summarized in **Figures 15, and 16**

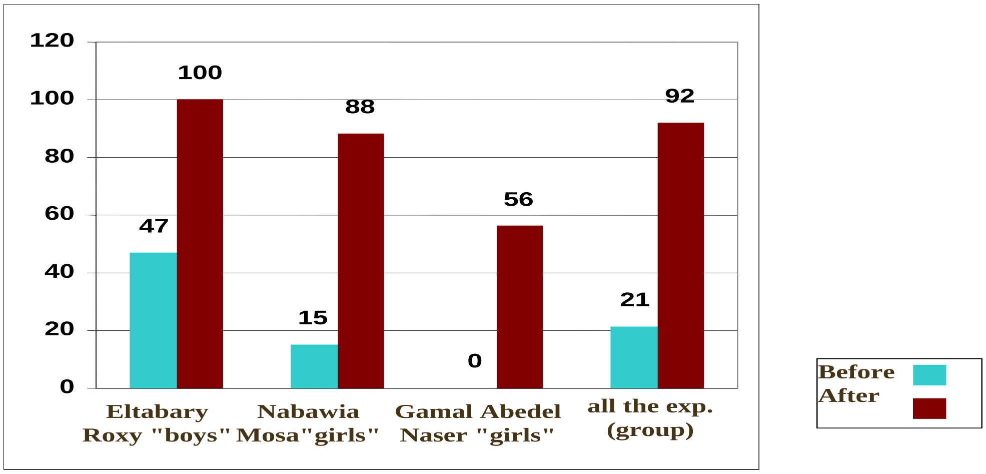


Fig.(15): Percent of students in the experimental groups who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the systemic intervention period.

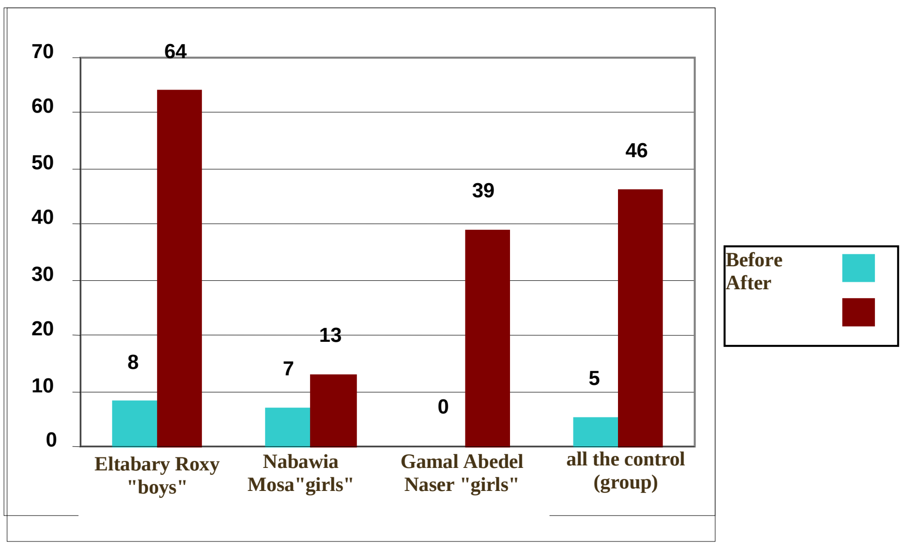


Fig. (16): Percent of students in the control groups who succeeded (achieved at a 50% or higher level).

The results from the pre-university experiments lead to the following conclusions that stem from the qualitative data and from surveys of teachers and students, and anecdotal evidence (**2, 6, and 20**)

a. Implementing the systemic approach for teaching and learning using this unit of general chemistry within the course has no negative effects on the ability of the students to continue their linear study of the remainder of the course by linear approach.

b. Teacher's 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.

I-B: SATLC – In University Level:

I-B: The Systemic Approach to Teaching and Learning Organic Chemistry (SATLOC): Systemic Strategy for Building Organic Chemistry Units:

I-B-1: [Benzene and Related Compounds] Scenario of Teaching]

In continuation of our work on the uses of SATL- strategy in building chemistry units, especially in aromatic chemistry, herein we will present our work on systemic aromatic chemistry **[17**] via the following scenario of building the above-mentioned unit.

<u>Step</u> 1-3: Follow the general building strategy from **first step to third stip**. Then move to the following steps.

Step 4: After the student studies the synthesis and reactions of benzene. He can draw the following diagram **Fig.1**7 that summarizes synthesis and reactions of benzene.

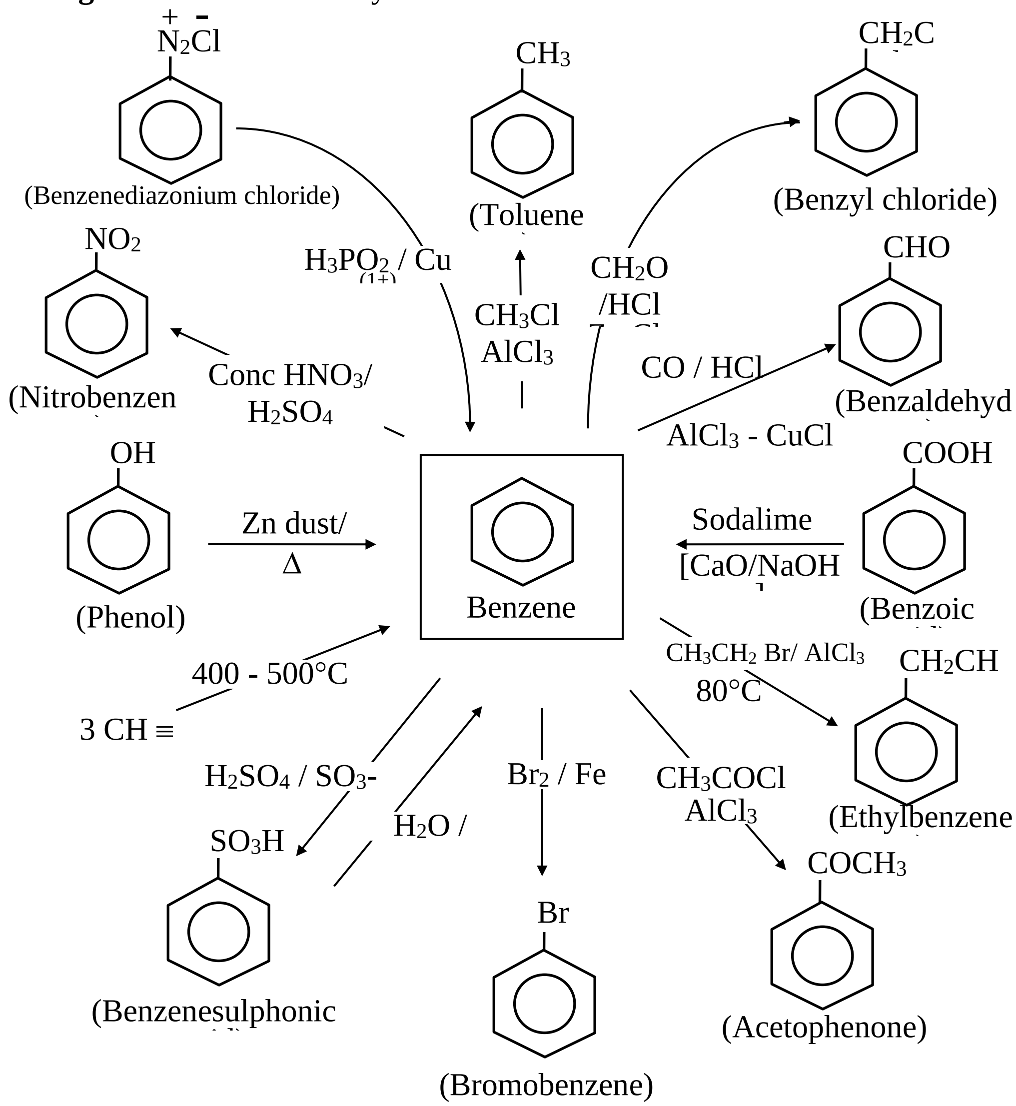


Fig.(17): Linear chemical relationships between benzene and related compounds.

The above diagram shows that all the chemical relations are linear and separated relations.

Step 5: The linear diagram (**Fig. 17**) can be transformed by students via the help of their teachers into a systemic diagram **SDo, Fg.18.** This diagram shows that the individual relationships of the compounds suggested to be synthesized from benzene (alkyl benzenes, nitrobenzene, halo benzenes, phenol, aromatic alcohols benzaldehyde, Acetophenone……….). **Fig. 18** can be systemically interconnected. By adding the unknown chemical relations between them. **SD0** is known as the starting point of teaching the unit (16)

We can illustrate the above chemical relations systemically in the following systemic diagram (**SD0**), **Fig.18**.

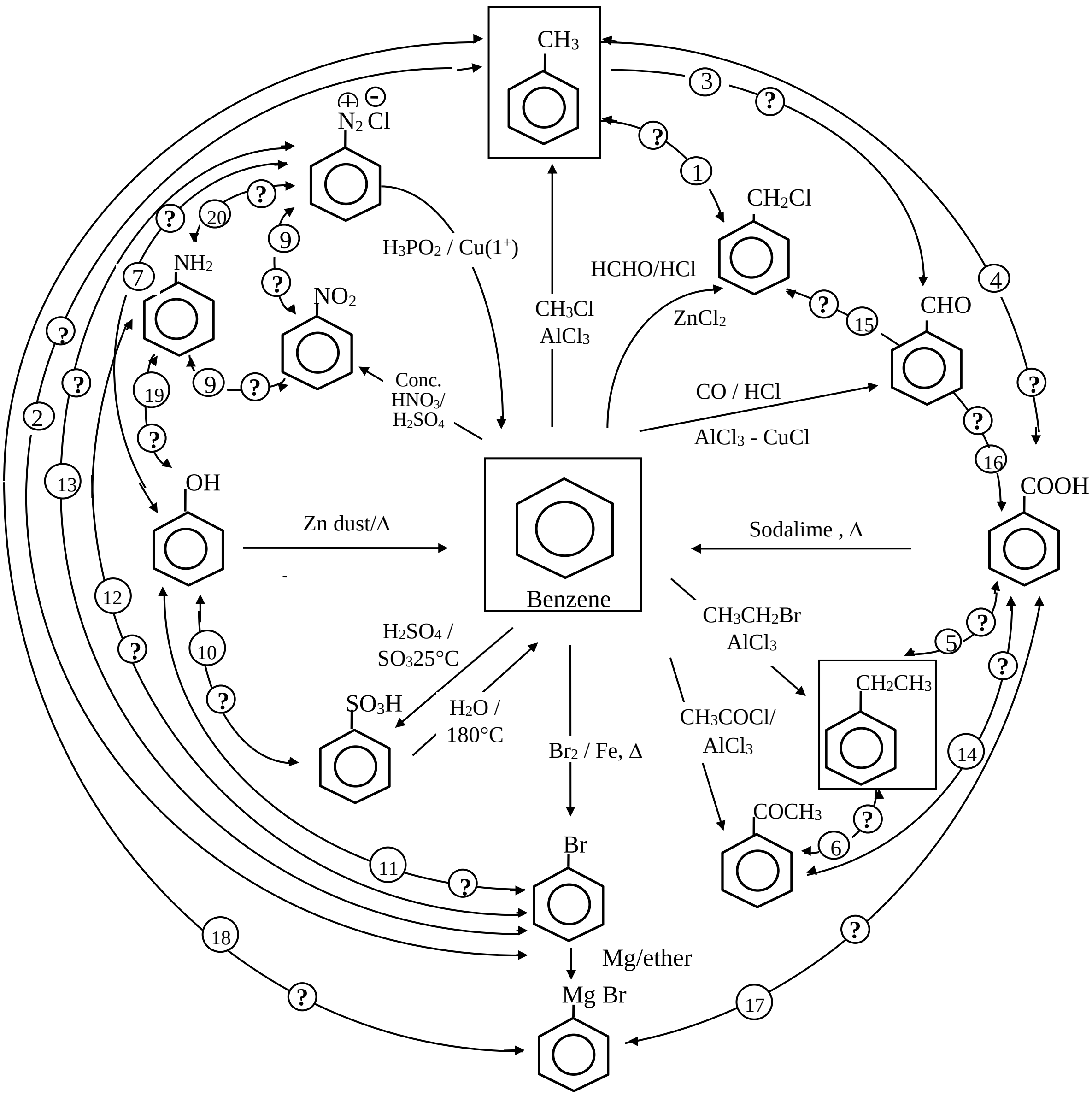

CH3
N2 Cl
CH2Cl
NH2
NO2
H3PO2 / Cu(1+)
HCHO/HCl
ZnCl2
CH3Cl
AlCl3
CHO
Conc.
HNO3/
H2SO4
CO / HCl
AlCl3 - CuCl
OH
COOH
Zn dust/Δ
Sodalime , Δ
Benzene
CH3CH2Br
AlCl3
H2SO4 /
SO325°C
SO3H
H2O /
180°C
CH2CH3
CH3COCl/
AlCl3
Br2 / Fe, Δ
COCH3
Br
Mg/ether
Mg Br

Fig. (18): SD0 - represents some of the major reactions of benzene and benzene derivatives.

The systemic diagram **SD0** shows the unknown chemical relations **1 through to 20** between the aromatic compounds Table 1. These relations will be clarified later during the study of the unit,

Table (1):

No.	**Chemical Relations**		**No.**	**Chemical Relations**	
1	Toluene and benzyl chloride	?	12	Bromobenzene and aniline	?
2	Toluene and bromobenzene	?	13	Bromobenzene and benzene-	?
3	Toluene and benzaldehyde	?		diazonium chloride	
4	Toluene and benzoic acid	?	14	Acetophenone and benzoic acid	?
5	Ethylbenzene and benzoic acid	?	15	Benzyl chloride and benzaldehyde	?
6	Acetophenone and ethyl benzene	?	16	Benzaldehyde and benzoic acid	?
7	Phenol and benzenediazonium	?	17	Phenyl magnesium bromide and	?
	Chloride.	?		benzoic acid	
8	Nitrobenzene and benzene-		18	Phenyl magnesium bromide and	?
	diazonium chloride.	?		toluene	
9	Nitrobenzene and aniline.	?	19	Phenol and aniline	?
10	Phenol and benzenesulphonic.		20	Aniline and benzenediazonium	
	Acid.	?		chloride	
11	Bromobenzene and phenol.				?
					?

Step 6: [Change of SD0 to SD1] After all possible synthetic routes and reactions of Alkyl benzenes are discussed in the classroom and after the recognition of various chemical relations the systemic diagram **SD0** can be improved by students into another systemic diagram **SD1-Fig.19** by adding chemical relations (**1 through 6, and 18)**.

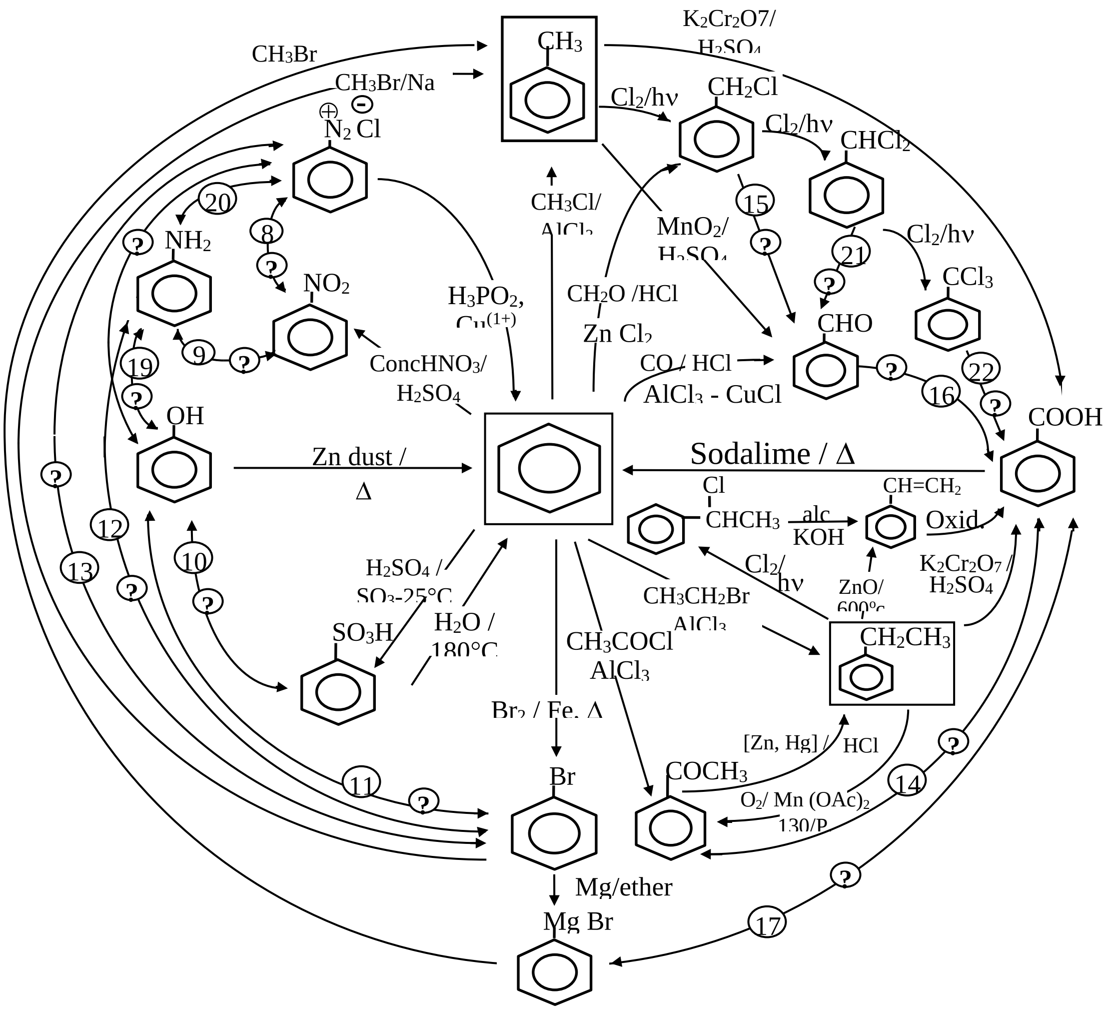


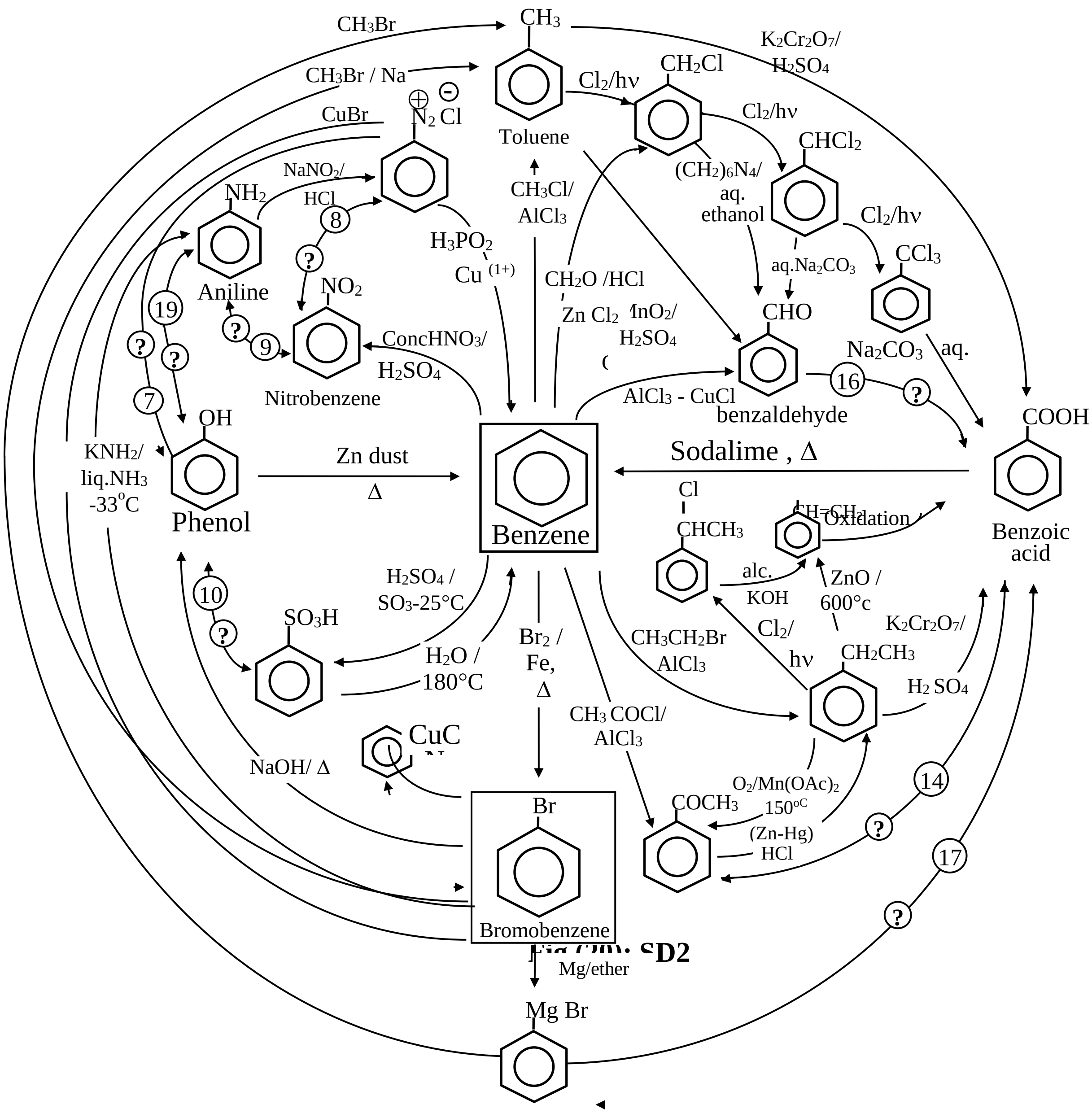
Fig.(19): SD1

Step7: **[Change of SD1 to SD2]**: After progress in teaching the unit via the gilded classroom discussions about the synthesis and reactions of halogen derivatives of aromatic hydrocarbons the systemic diagram **SD1** can be improved by students into systemic diagram **(SD2, Fig.20)** by adding the following defined chemical relations **(cf. Table 2).**

Table (2):

No.	Chemical relations	
11	Bromobenzene to phenol [NaOH, heat]	✓
12	Bromobenzene to aniline [KNH_2/liq. NH_3]	✓
13	Benzenediazonium chloride to bromobenzene [CuBr]	✓
15	Benzyl chloride to benzaldehyde [$(CH_2)_6N_4$/aq.alc.]	✓
20	Aniline to benzenediazonium chloride ($NaNO_2$/HCl)	✓
21	Benzal chloride to benzaldehyde [aq. Na_2CO_3]	✓
22	Benzotrichloride to benzoic acid [i)aq.Na_2CO_3, ii)HCl]	

But we still have unknown chemical relations (**7-10, 14, 16, 17, and 19).** These relations will be defined during our study of the rest of the aromatic chemistry unit.


CH3Br
CH3
CH3Br / Na
Toluene
Cl2/hν
CH2Cl
K2Cr2O7/
H2SO4
CuBr
N2 Cl
Cl2/hν
CHCl2
NaNO2/
HCl
8
NH2
Aniline
CH3Cl/
AlCl3
(CH2)6N4/
aq.
ethanol
Cl2/hν
CCl3
H3PO2
Cu (1+)
CH2O /HCl
Zn Cl2
aq.Na2CO3
NO2
19
Nitrobenzene
ConcHNO3/
H2SO4
9
7
CHO
Na2CO3
aq.
16
AlCl3 - CuCl
benzaldehyde
OH
KNH2/
liq.NH3
-33°C
Phenol
Zn dust
Δ
Benzene
Sodalime , Δ
COOH
Benzoic
acid
Cl
CHCH3
Oxidation
alc.
KOH
ZnO /
600°c
K2Cr2O7/
H2 SO4
10
SO3H
H2SO4 /
SO3-25°C
H2O /
180°C
Br2 /
Fe,
Δ
CH3CH2Br
AlCl3
Cl2/
hν
CH2CH3
CH3 COCl/
AlCl3
NaOH/ Δ
Br
Bromobenzene
COCH3
O2/Mn(OAc)2
150°C
(Zn-Hg)
HCl
14
17
Mg/ether
Mg Br

<u>Step.8</u>: <u>[Change of SD2 to SD3]</u>: After studying the **<u>synthesis and reactions of benzenesulphonic acids</u>** the student can improve **(SD2 to (SD3**, **Fig.21**) by adding the reactions of sulphonic acids with NaOH **(relation 10),** and KSH, KCN, $NaNH_2$.But we still have unknown chemical relations **<u>(7-9, 14, 16, 17, and 19).</u>**

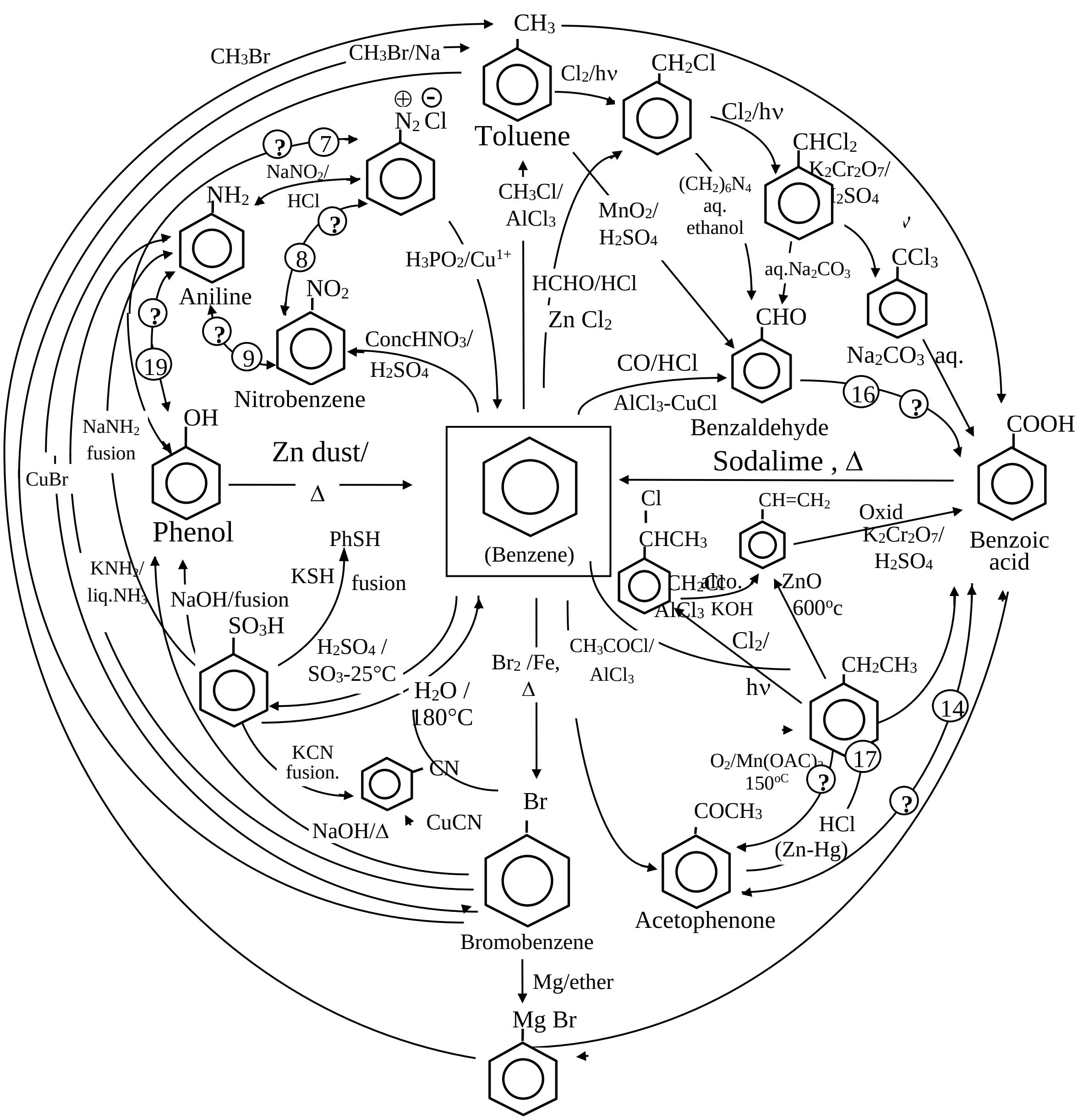


Fig.(21): SD3

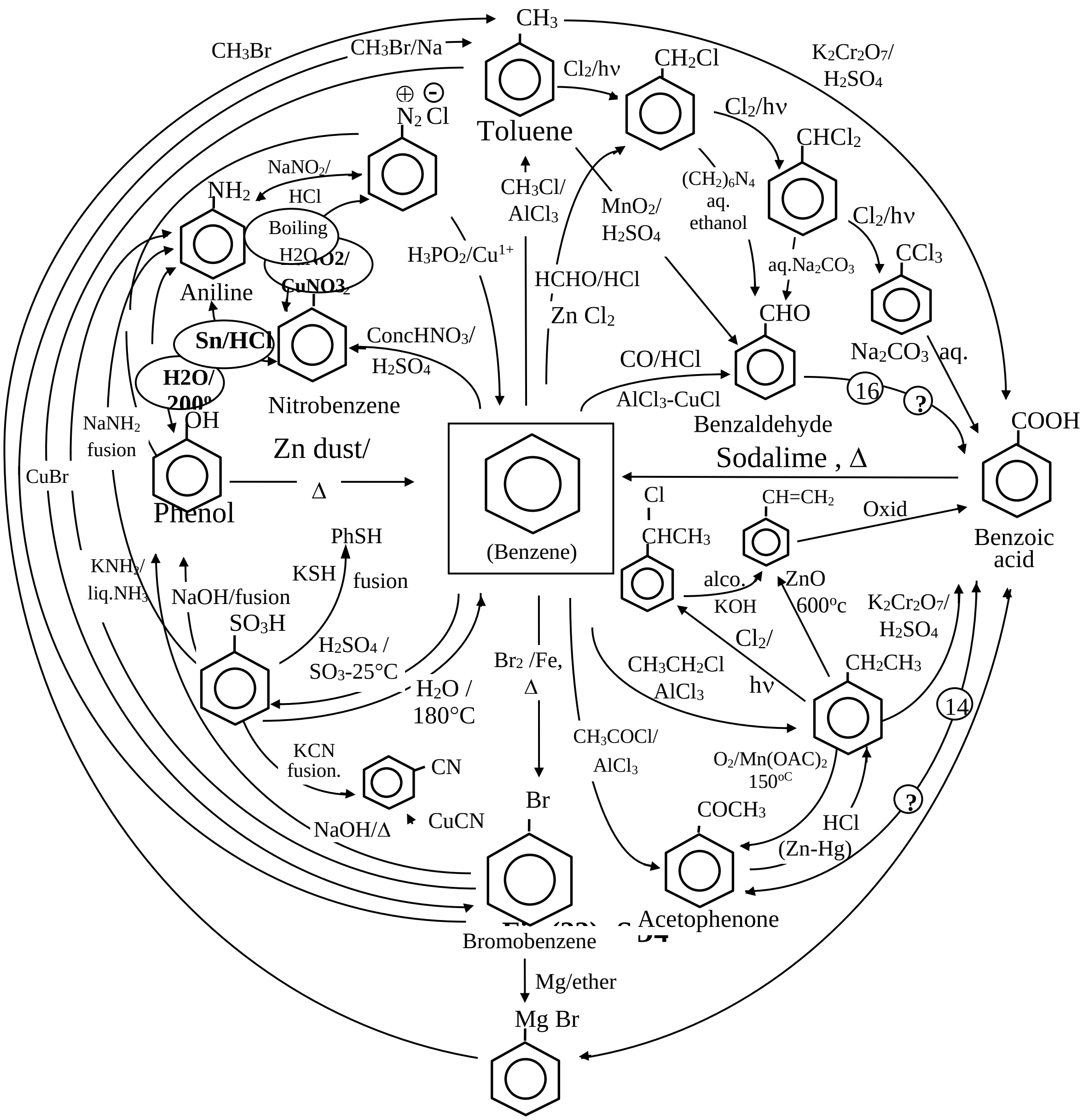
Step 9: [Change of SD3 to SD4]:

After studying the **synthesis and chemical reactions of aromatic nitro - compounds, diazonium salts and aniline** the student can change the systemic diagram **(SD3) to (SD4**, **Fig.22**) by adding the following chemical relations **Table (3):**

Table (3)

NO.	Chemical relations	
8	Benzenediazonium chloride to nitrobenzene ($NaNO_2$ / Cu NO_2)	✓
7	Benzenediazonium chloride to phenol (Boiling water)	✓
9	Nitrobenzene to aniline (reduction Sn / HCl)	✓
19	Aniline to phenol (H_2O, 200^o).	✓

But we still have the following unknown chemical relations. **[14, 16, 17].** These relations will be defined later during our study of the rest of the Aromatic chemistry unit.



CH_3
CH_3Br
CH_3Br/Na
$Cl_2/h\nu$
CH_2Cl
$K_2Cr_2O_7/$
H_2SO_4
$\overset{\oplus}{N_2}\overset{\ominus}{Cl}$
Toluene
$Cl_2/h\nu$
$CHCl_2$
$NaNO_2/$
HCl
NH_2
$CH_3Cl/$
$AlCl_3$
$MnO_2/$
H_2SO_4
$(CH_2)_6N_4$
aq.
ethanol
$Cl_2/h\nu$
Boiling
H_2O
H_3PO_2/Cu^{1+}
CCl_3
Aniline
HCHO/HCl
aq.Na_2CO_3
$Zn\ Cl_2$
CHO
Sn/HCl
$ConcHNO_3/$
H_2SO_4
CO/HCl
Na_2CO_3 aq.
$H_2O/$
$AlCl_3$-CuCl
16
?
Nitrobenzene
Benzaldehyde
COOH
$NaNH_2$
fusion
OH
Zn dust/
Δ
Sodalime , Δ
CuBr
Phenol
Cl
CH=CH_2
Oxid
PhSH
CHCH$_3$
Benzoic
acid
$KNH_2/$
liq.NH_3
KSH
fusion
(Benzene)
alco.
KOH
ZnO
600ºc
$K_2Cr_2O_7/$
H_2SO_4
NaOH/fusion
SO_3H
H_2SO_4 /
SO_3-25°C
Br_2 /Fe,
Δ
$Cl_2/$
hν
CH_3CH_2Cl
$AlCl_3$
CH_2CH_3
H_2O /
180°C
14
KCN
fusion.
CN
$CH_3COCl/$
$AlCl_3$
$O_2/Mn(OAC)_2$
150ºC
Br
COCH$_3$
?
NaOH/Δ
CuCN
HCl
(Zn-Hg)
Acetophenone
Bromobenzene
Mg/ether
Mg Br

<u>Step10</u>: **<u>[Change of SD4 to SDf]</u>** After studying of **<u>synthesis and chemical reactions of aromatic aldehydes, ketones and acids</u>** the student can modify the systemic diagram **(SD4) to (SDF, Fig.23)** by adding the following chemical relations.

No	Chemical relation	
14	Acetophenone to benzoic acid ($KMnO_4$)	√
16	Benzaldehyde to benzoic acid ($KMnO_4$)	√
17	Phenyl magnesium bromide to benzoic acid (CO_2, H_2O)	√

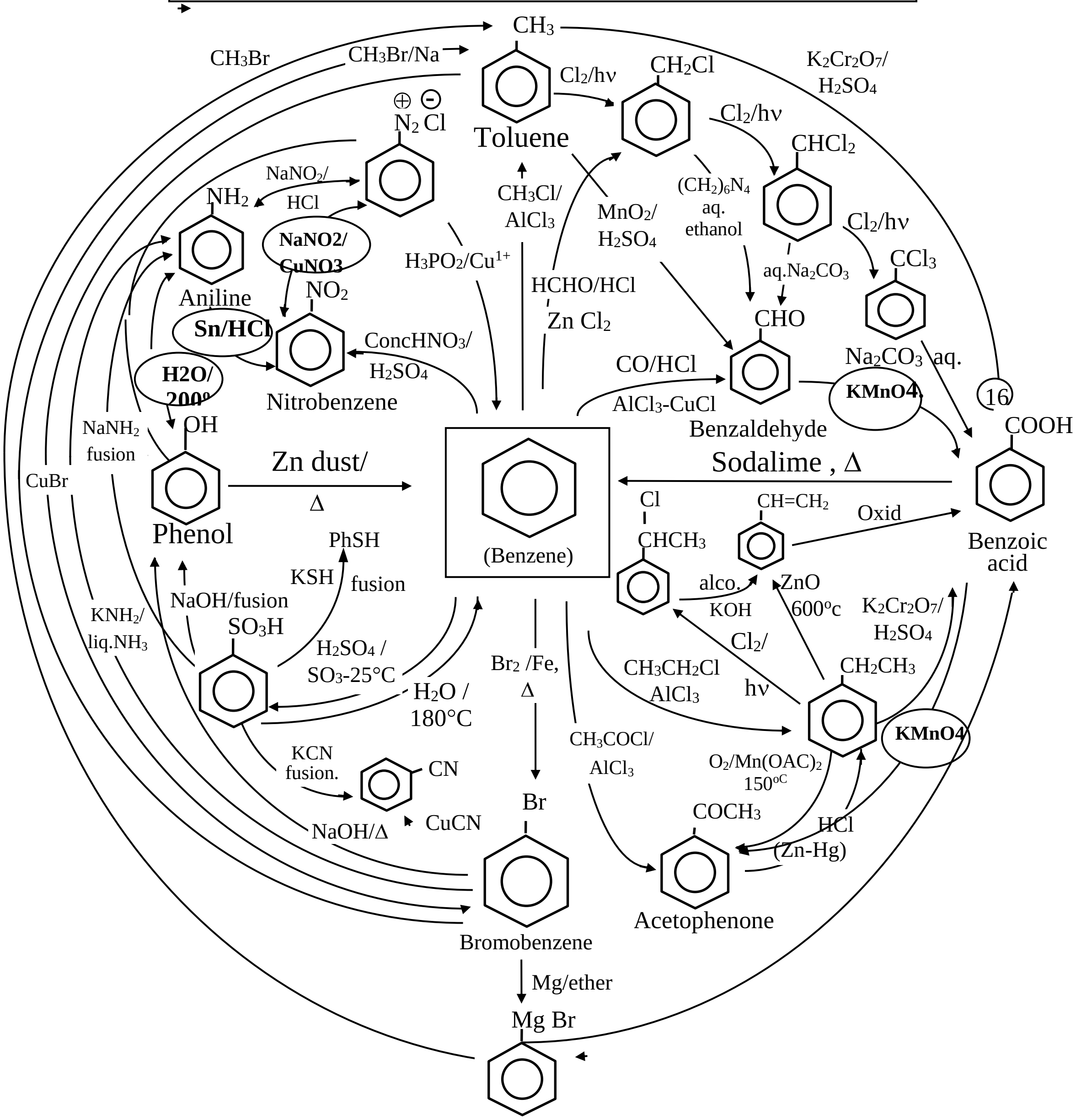


Fig.23: SDf

In the **(SDF)** all chemical relations between benzene and its related compounds were clarified and we reach the end point of teaching the unit. At this point, new ideas and connections begin to arise in students' minds in a systemic pattern. This will open the door for new approaches towards synthetic organic chemistry. Also; we can assess the student achievements in aromatic chemistry after each stage of learning the unit via Systemic Assessment Questions **[SAQ, s]** on the systemic diagrams from **SD0** to **SDF** (**18-23-**).

I-B-2: Aliphatic Chemistry [Aliphatic Hydrocarbons]

We present here the results of a study of the efficacy of systemic methods applied to the usual first-semester content of the second-year organic chemistry course (16 lectures, 32 hours) at Zagazeg University [6,7]

Scenario of Teaching:

In continuation of our work on the uses of SATL- strategy in building chemistry units, especially in aromatic chemistry, herein we will present our work on systemic aliphatic hydrocarbons via the following scenario of building the above-mentioned unit.

Steps 1-3: Follow the general building strategy from the **first step to the third step**. Then move to the following steps.

<u>Step</u> 4: After the student studied the synthesis and reactions of Alkanes. He can draw the following diagram **Fig.24** which summarizes the synthesis and reactions of Alkanes.

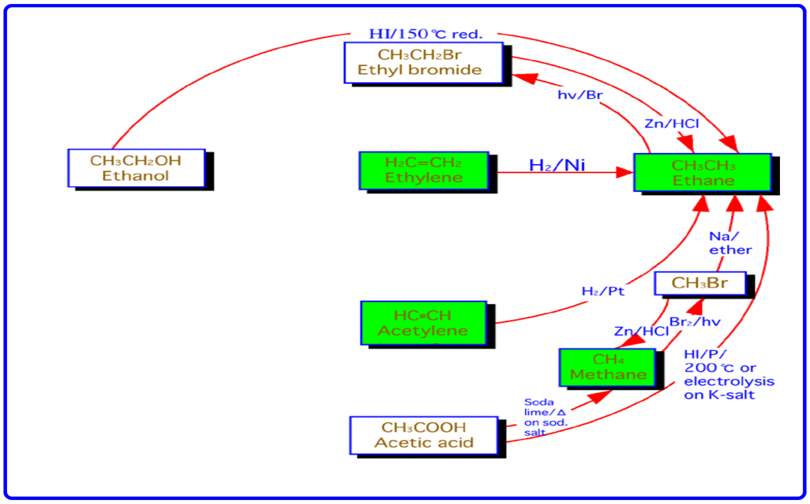


Fig. (24): Linear diagram that represents summarizes the synthesis and reactions of Alkanes.

The linear version of teaching this material was presented to a group of students that were the control group in our study. The systemic version was taught to another group of students defined as the experimental group.

<u>Step</u>-5: The linear diagram (**Fig.24**) can be transformed by students via the help of their teachers into a systemic diagram **SDo, Fig.25.** This diagram shows that the individual relationships of the compounds suggested to be synthesized from Methane which are (Ethane- Ethylene-Acetylene Methyl bromide -Ethyl bromide-Ethanol-Acetic acid).

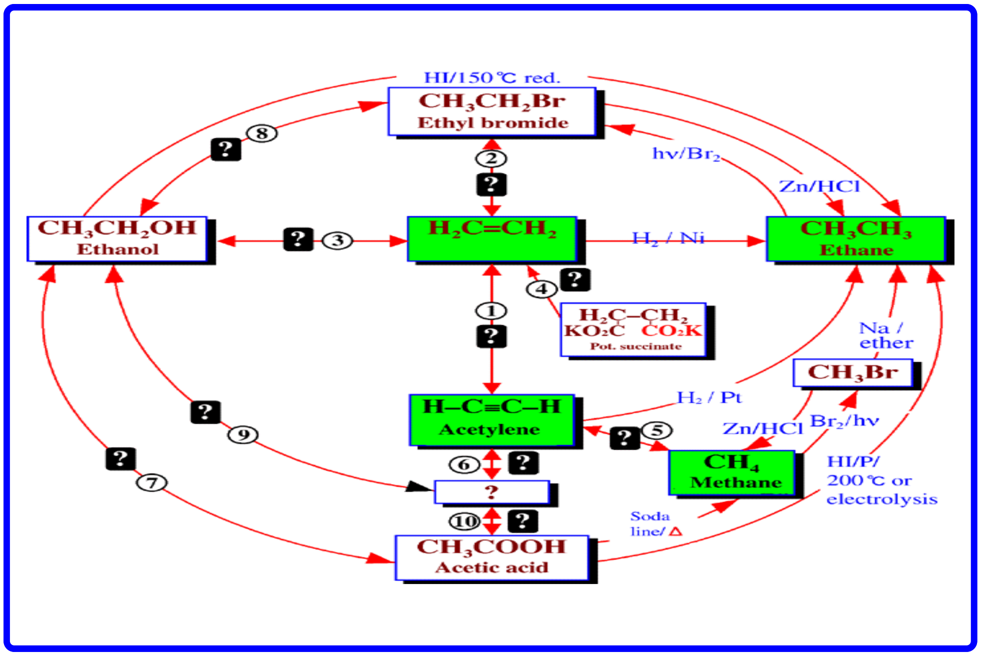


Fig.(25): Systemic diagram (SD0) that represents some of the major chemistries of alkanes.

In the systemic diagram **SD0** some chemical relationships are defined whereas others are undefined (to be learned). These undefined relationships are developed systematically.

Step-6: After using the diagram **SD0** shown in **Fig. 25** as the basis for the study of the synthesis and reactions of alkenes, and alkynes, the students can modify this systemic diagram **(SD0 in Fig. 25)** to accommodate other chemistries of hydrocarbons as shown in **(SD1), Fig. 26.**

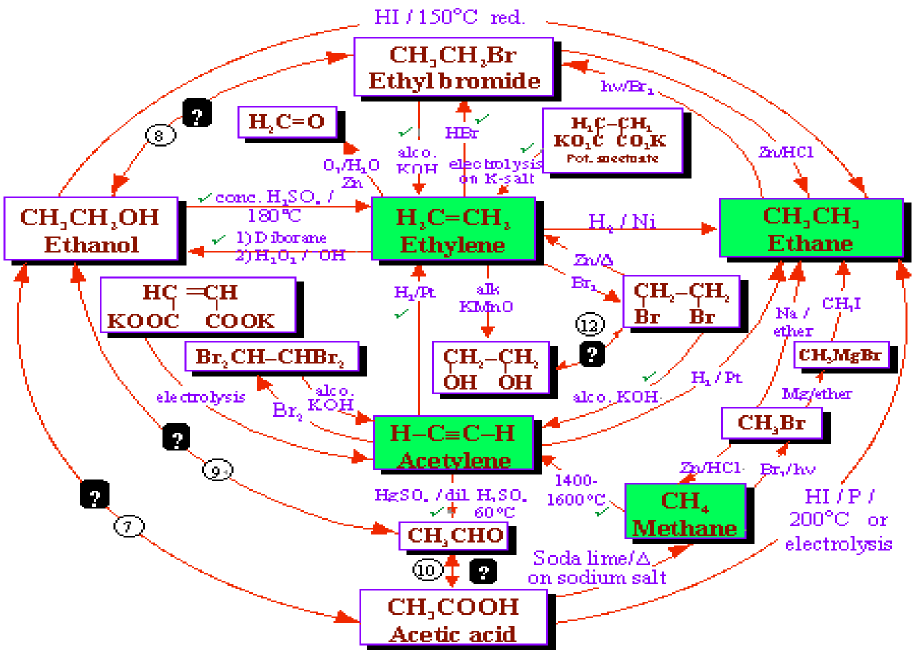
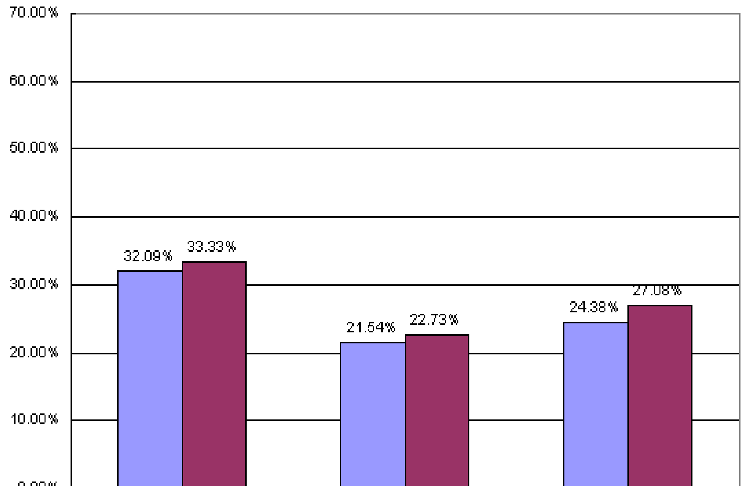


Fig. (26): The systemic Diagram (SD 1) illustrates the relationship between the hydrocarbons and derived compounds.

The systemic diagram (SD-1) shown in Figure (25) can be used to accommodate the chemistries of ethyl bromide and ethanol yielding a new systemic diagrams **(SD27, SD28).**

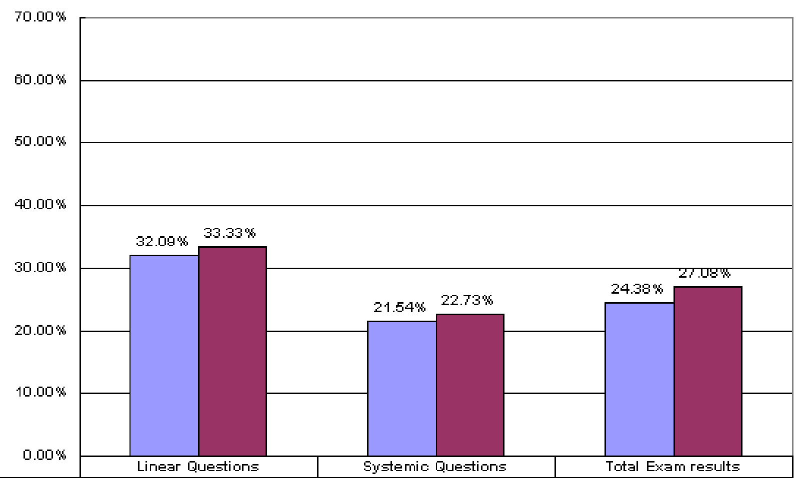
The systemic diagrams developed were used as the basis for teaching organic chemistry courses to the experimental group at (Zagazeg University Egypt). The experiment was conducted within the Banha branch, Faculty of Science, Department of Chemistry with second-year students. The experiment involved (41) students in the control group, which was taught using the classical (linear) approach; (122) students formed the experimental group, which was taught using SATL methods illustrated in the systemic diagrams shown in Figures (SD0) through (SD3).- 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.

- **Figures (29) and (30)** 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. (29): Average scores for control groups before and after intervention.



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

Fig.(30): Average scores for the experimental group before and after the intervention.

-SATLOC improves the students' ability to view OC from a more global perspective.

-SATLOC increases students' ability to learn subject matter in a greater context.

- SATLOC helps the students to develop their mental framework at higher-level Cognitive processes (application, analysis, and synthesis).

II-SYSTEMIC ASSESSMENT [SA

Systemic assessment [SA] in chemistry is a new innovative way of evaluating students' understanding of chemistry concepts and their interrelationships. It is based on the systemic approach to teaching and learning (SATL), which uses systemic diagrams and systemic assessment questions (SAQ,s) to help students learn chemistry in a meaningful and holistic way. SAQs,s are different from traditional linear questions, as they require students to analyze, synthesize, evaluate, and correlate between concepts in a systemic way Fahmy [21]. According to Fahmy & Laowski [18-21] SAQ,s can be of various types, Systemic multiple choice[SMCQs,s].Systemic true false [STFQ,s], Systemic Maching questions [SMQ,s], Systemic synthesis questions[SSynQ,s], Systemic analysis questions[SAnQ,s] and Systemic sequencing questions [SCQs].

These types of questions can be used to assess students' learning outcomes in different domains of chemistry, such as organic chemistry, inorganic chemistry, physical chemistry, and general chemistry, at secondary and tertiary levels [18-21]. Systemic assessment has been shown to be an effective tool for improving students' academic achievements, increasing equity of learning outcomes, and enhancing students' higher-order thinking skills. The SAQ scheme was found to be a valuable strategy for assessing meaningful understanding, as well as systems thinking in organic chemistry. A significant association was observed between students' performance on SAQs and on objective items designed for assessing meaningful understanding of organic chemistry concepts. This association indicates that the students' systems thinking level developed in organic chemistry is strongly related to a deeper understanding of the relevant science concepts [22,23]. To solve SAQs students should consider several concepts at once, as well as their relationships with one another. So that they can apply them to a new problematic situation.SAQs access students' ability to correlate between different concepts, and also to discover the new relationships between them.[24] A single question covers a wide range of concepts in the selected course topic, *e.g.*, several classes of organic compounds: alkanes, alkenes, alkynes, alkyl halides, alcohols, aldehydes and carboxylic acids [20,24]. 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 [23].

II-1.1. Why Systemic Assessment? (7)

Systemic assessment (SA) has the following advantages: (i.) measures the cognitive structure from the quantitative through the qualitative (domains); (ii). assesses student's higher-order thinking skills where they are required to analyze, synthesize, and evaluate; (iii). it measures the student's ability to correlate between concepts; (iv). enables the students to discover new relationships among concepts; (v). gives the students rapid feedback during the term about how well they understand the course material; (vi). assesses the students in a wide range of concepts in the course units (learning outcomes, ILOs); (vii) develops the ability of students to think systemically, critically, and creatively, and to solve problems; (viii). very easily scored.

II-1-2: The Role of Systemic Assessment in the Systemic Curriculum: (7)

To have a systemic curriculum the following should be done:

1- The objectives should be systemic.

2- The content should be arranged systemically as shown in the **(SD0)**.

3- The teaching method should be systemic and start by systemic **(SD0)** and end by terminal systemic **(SDf),** passing by Intermediate systemics **(SD1 and SD2), (Fig. 2).**

4- The multimedia should be systemic, helping the teacher to teach the unit systemically.

5- All the above curriculum components should interact and be in harmony, affecting one another into one systemic unit, then the assessment comes stepwise from the beginning of the unit teaching till to the end.

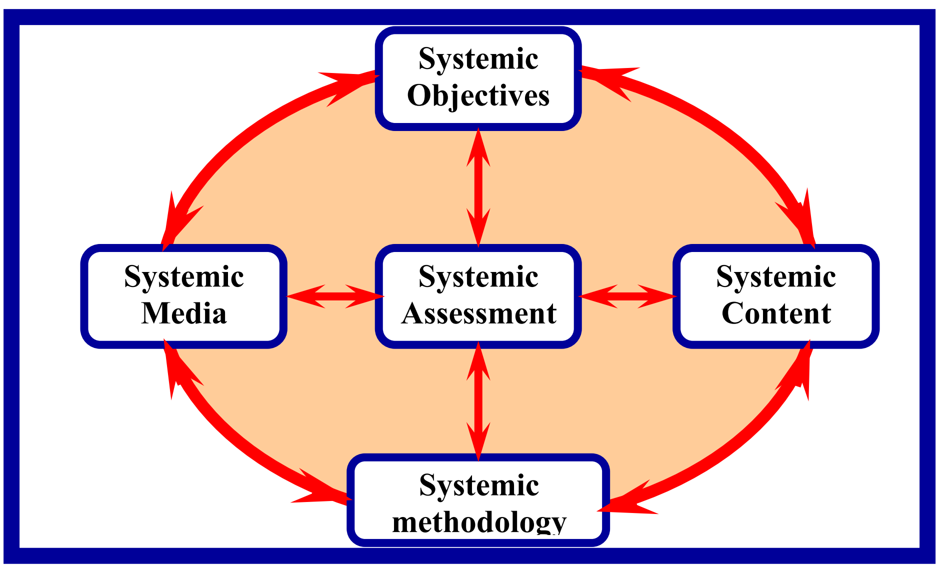


Fig. (31): Systemic curriculum:

Systemic assessment is the key component of the systemic curriculum. As shown in **Fig. 31.** It is used during the course to monitor the student's progress **(formative)** and at the end of the course to monitor the progress student's Cognitive Structure (**summative**).

II-1-3: Purpose of Systemic Assessment:

The main aim of SA is to enhance, support and improve both teaching and learning processes via:

1. Help teachers use evidence of student learning to assess student achievement against the goals and standards of the courses and programs.
2. Help teachers to improve their teaching performance.
3. Enable students to give feedback during their study of any course materials.
4. Help students make maximum connections between Chemistry concepts, compounds, and reactions.
5. Enable students to achieve the highest standards they are able.

II-1-4: Types of Systemic assessment Questions :

SAQs,s could have several chaps, depending on what type of SAQ you need. Fahmy and Lagowski (18-21) have presented the following types of SAQs: systemic multiple-choice questions

(SMCQs), systemic true/false questions (STFQs), systemic sequencing questions (SCQs), systemic matching questions (SMQs), systemic analysis questions (SAnQs), and systemic synthesis questions (SsynQs). Tamara et al [23,24] stated that their empirical research dates since 2016 and includes one specific type of SAQs—systemic synthesis questions, SSynQs. In the very first studies, SSynQs had a constrained fill-in-the-blank format in which students were required to identify elements (*i.e.*, concepts or relationships) that were missing by filling in the empty fields in the provided diagrams. SAQs with similar structures have been applied in the study conducted by Vachliotis and colleagues [22] who have investigated whether specific forms of SAQs could be effective tools for assessing Greek high school students' meaningful understanding of organic reactions.

Tmara et al [24] highlighted that SSynQs were loaded on the "meaningful factor" within exploratory factor analysis. Also, the constrained fill-in-the-blank form of SSynQs proved to be effective as a qualitative model (*i.e.*, instructional or teaching tools) for facilitating the learning process and overcoming students learning difficulties in organic chemistry. It has been found that instruction *via* SSynQs enabled the experimental group to master educational material at a higher level when compared with the control group who received the same traditional instruction. In conclusion, the importance of this study was that the process of solving SSynQs required complex cognitive schemas developed by students.[24] In addition to this, the fill-in-the-blank form one type of higher-order thinking skill—systems thinking skills, within secondary school students. [8, 23,24].

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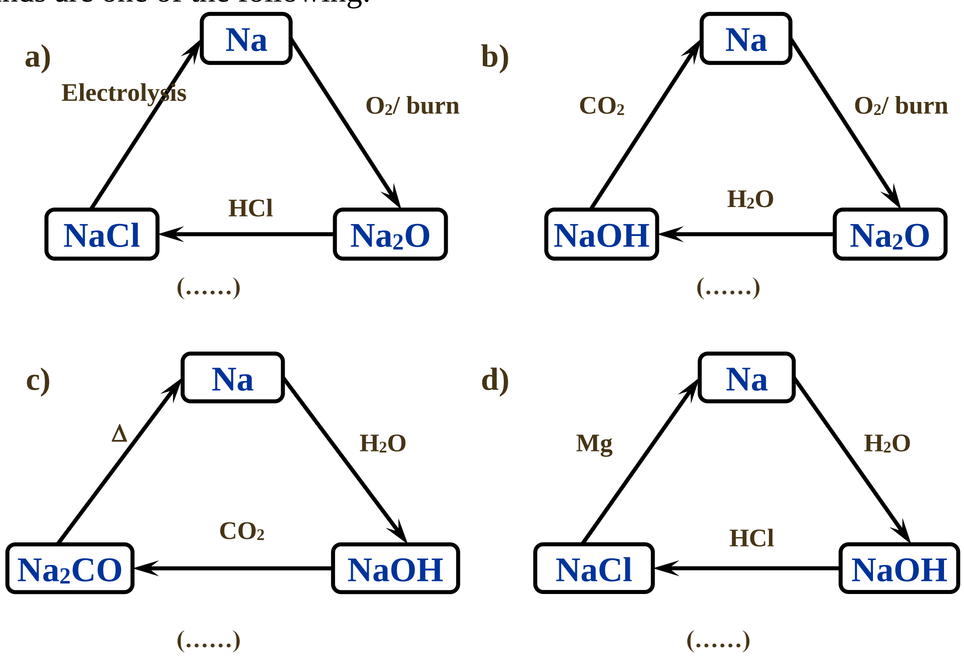
II-1-4-1: <u>Type-1: Systemic Multiple-Choice Questions (SMCQs)</u>

MCQs are the traditional choose one from a list of possible answers. However, **(SMCQs)** choose one systemic from a list of possible systemics. Each systemic represents at least three to five physical or chemical relations, between concepts, atoms, or molecules. Various examples of systemic multiple-choice questions from the fields of general, inorganic, heterocyclic, and physical chemistry are published by Fahmy & Lagowski (7, 17-20).

<u>Form-1: Choose from Triangular Systemics</u>:

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

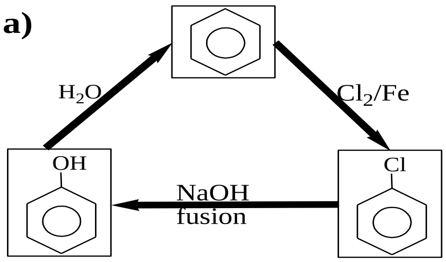
Q1. The systemic diagram represents the correct chemical relations between Sodium and its related compounds are one of the following:



➢ **<u>Answer: (a) √</u>**

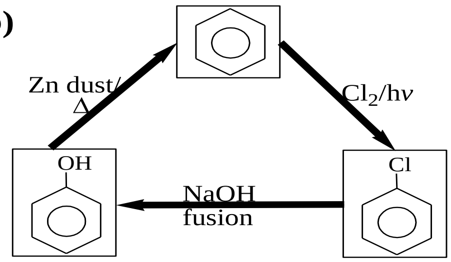
Q2: The systemic diagram represents the correct chemical relations between benzene, chlorobenzene, and phenol is one of the following:

a)



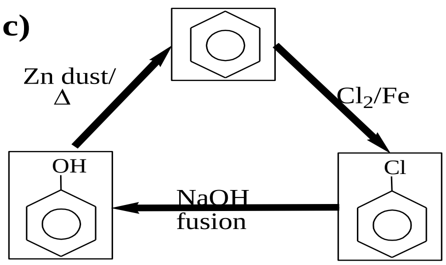
(......................)

b)



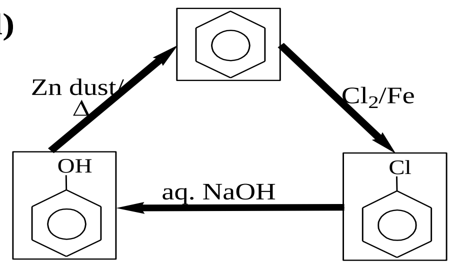
(......................)

c)



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

d)



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

Answer: (c) √

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

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

Q3) The systemic diagram represents the correct chemical relations between (Fe) and its related compounds are one of the following:

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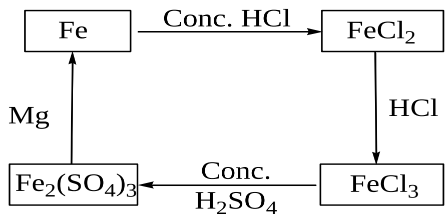
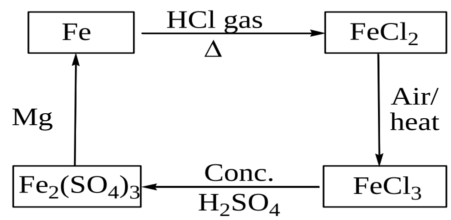
(a)



( )

(b)



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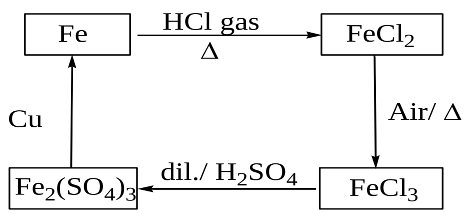
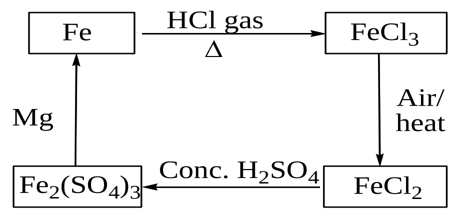
(c)



( )

(d)



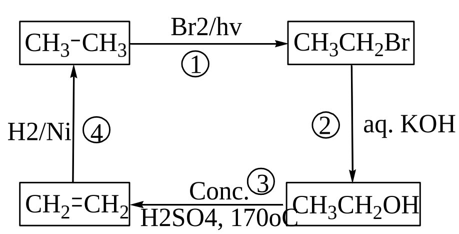
( )

Answer: (b) √

Q4: The systemic diagram represents the following reactions sequence.

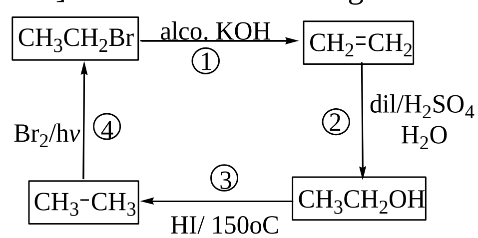
[Substitution –Substitution –Elimination – Addition] is one of the following:

(a)



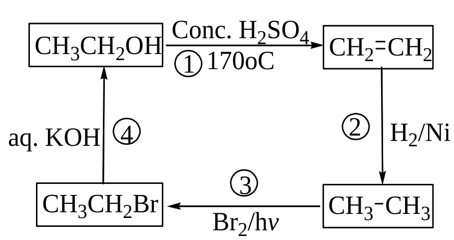
( )

(b)



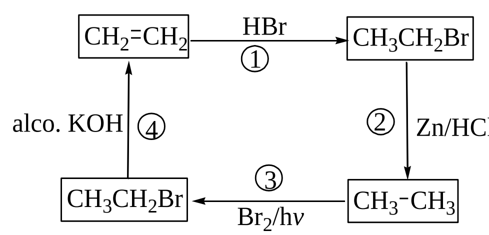
( )

(c)



( )

(d)



( )

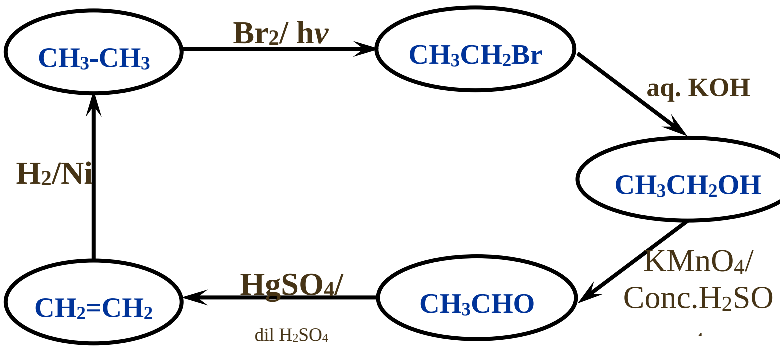
Answer: (a) √

Form (III): Choose between pentagonal systemics:

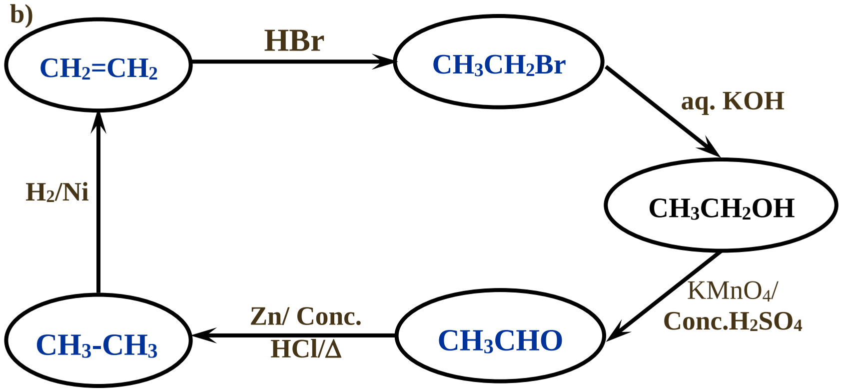
Put (√) in front of the correct systemic diagram:

Q5. The systemic diagram represents the correct chemical relations between Ethylene, Ethane, Acetaldehyde, ethyl bromide and ethanol is one of the following:

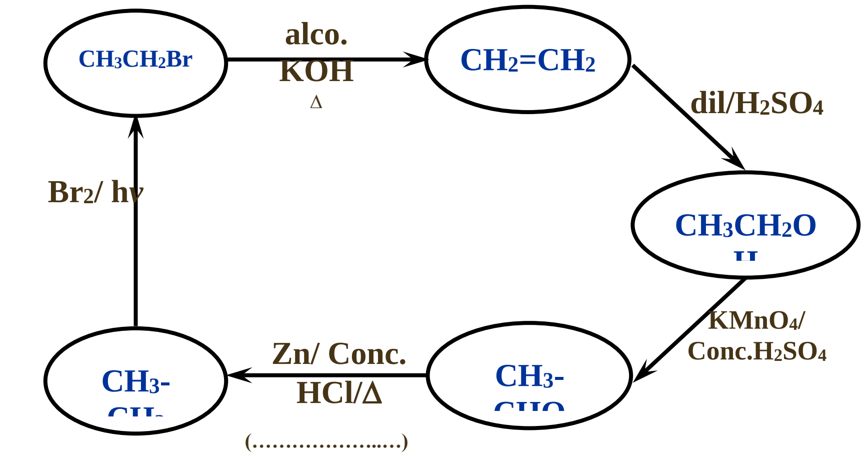
a)



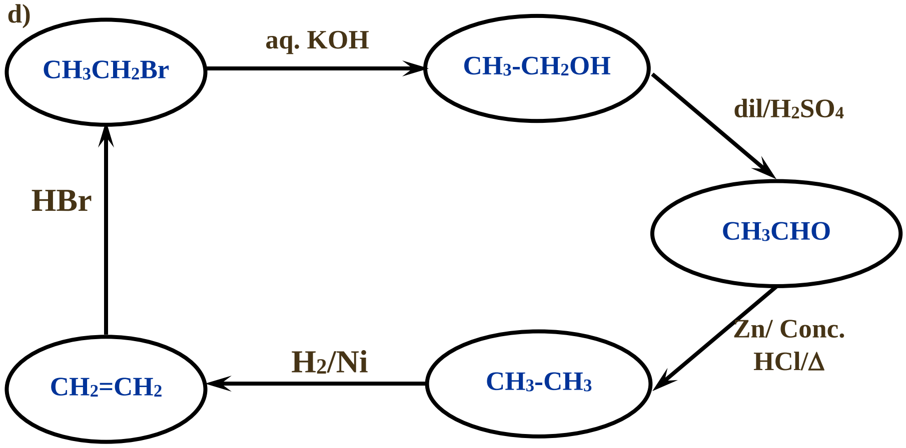
b)



c)



d)



II-4-2.: TYPE-2: Systemic True False Questions [STFQ, s]:

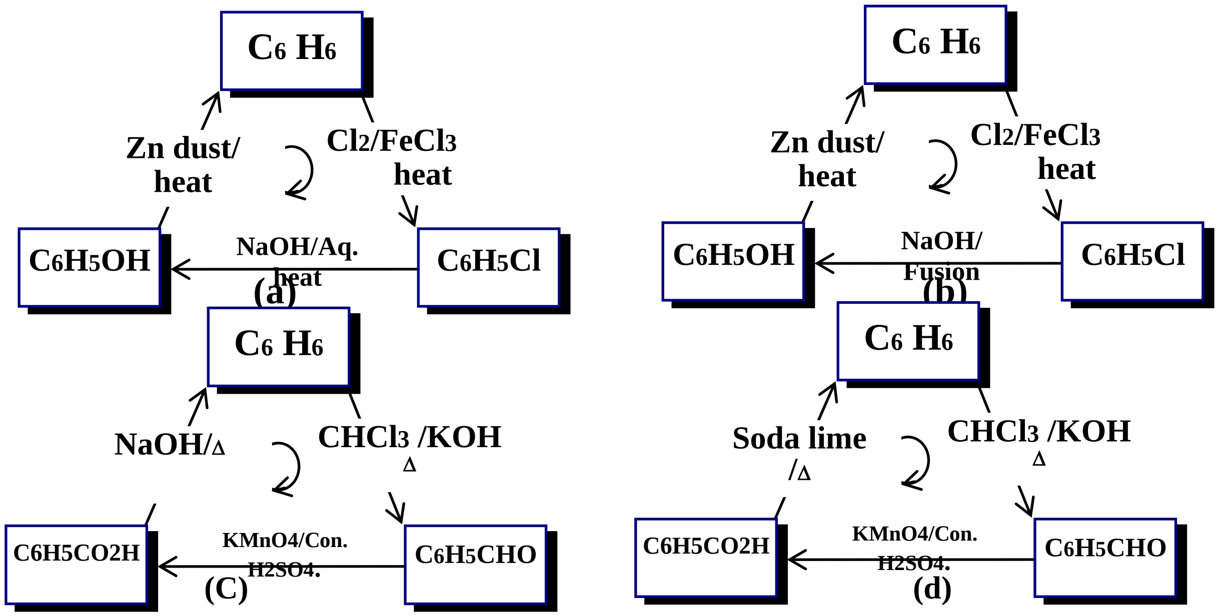
STFQs, s are well suited for testing student comprehension, synthesis and analysis, and require a student to assess whether a systemic is true or false. The advantages of [STFQ, S] are students can respond to many **STFQs,** covering a lot of concepts & facts and their relations in a short time. Student can assess higher-order thinking skills in which students can analyze, synthesize, and evaluate, and teachers can easily score **STFQs, s** [7,19].

<u>Put (√) in front of the correct systemics:</u>

Examples:

Form-1: Choose from triangular systemics:

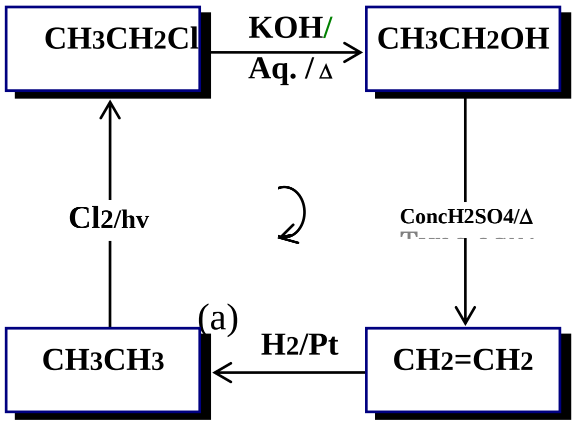
Q 1- Which of the following systemics are true and which are False:

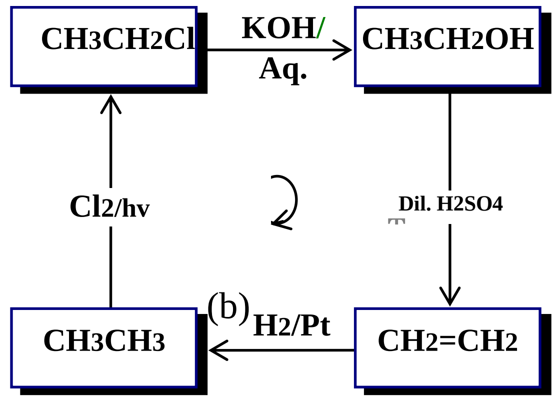


<u>Answer (1) </u>: <u>True systemics (b, d) (√); False Systemics (a, c) (X).</u>

Form-2: Choose from quadrilateral systemics:

Q2: Which of the following systemics are true and which are false:





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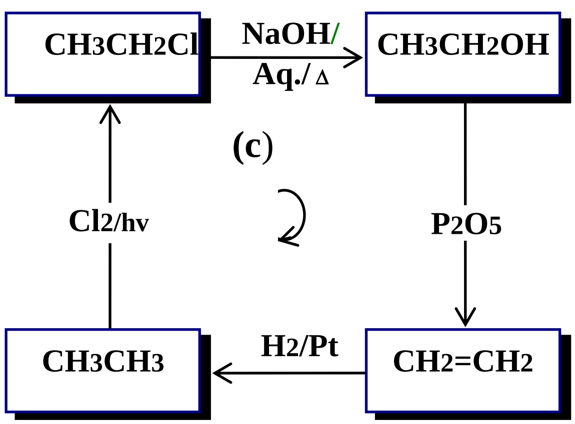
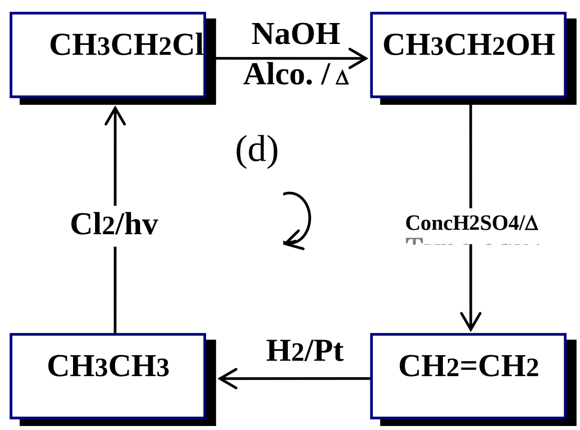
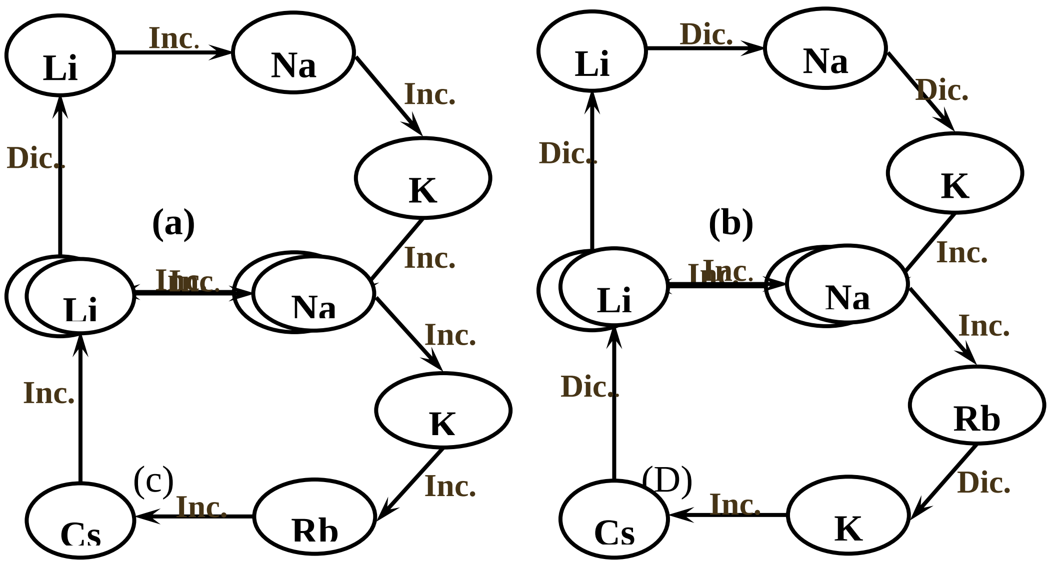




Answer (2): True systemics (a, c) (√); False Systemics (b, d) (X)

Form-3: Choose from pentagonal systemics.

Q3: Which of the following systemics are true and which are false according to the basicity:



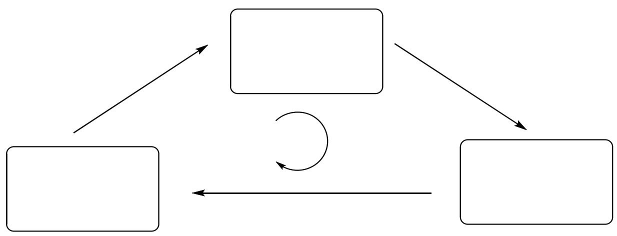
Answer (3) True systemics (a, d) (√); False Systemics (b, c) (X)

II-4-2.:TYPE3: -Systemic Matching Questions: [SMQ,s] (7,20)

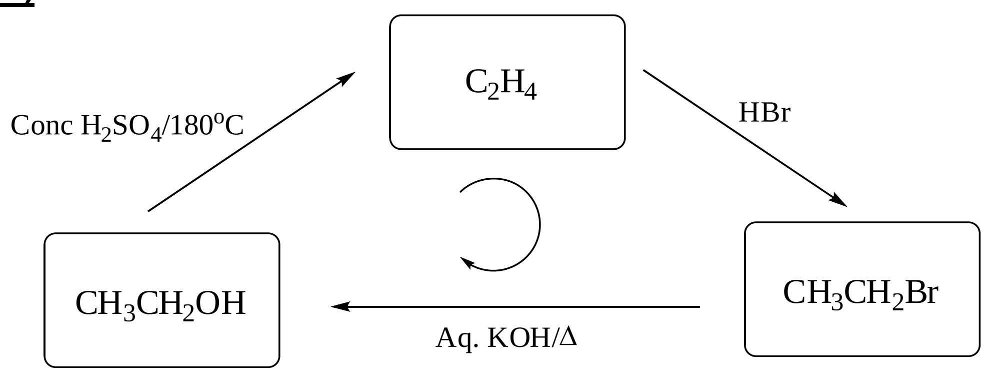
Measure the student's ability to find the relationship between a set of similar items, each of which has two components, Measure the student's ability to find the relationship between a set of similar items, each of which has two components.

<u>Form I</u>: <u>Matching on Trigonal Systemics</u>

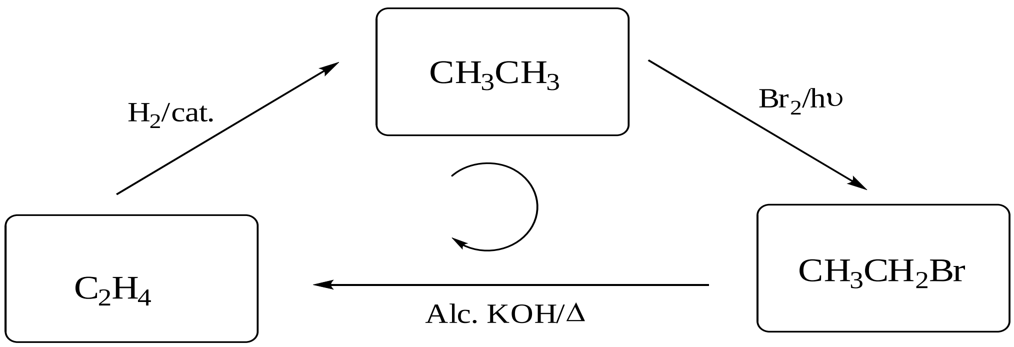
Q_1) Choose aliphatic compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C):

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

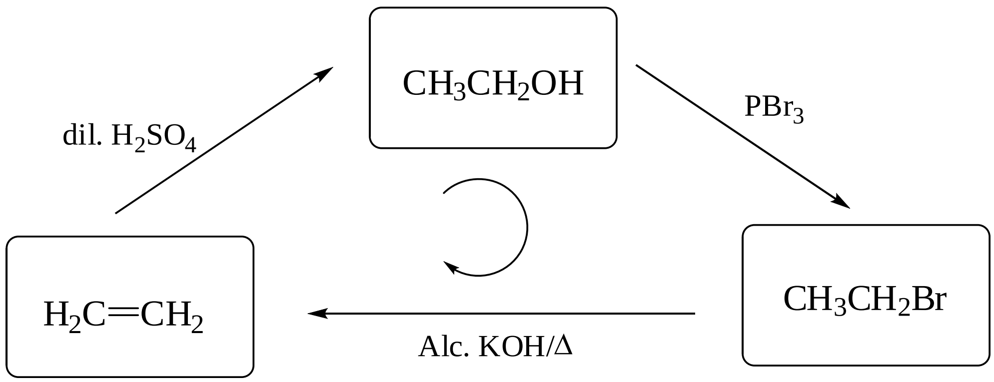
<u>Answer (1)</u>



<u>Answer (2)</u>

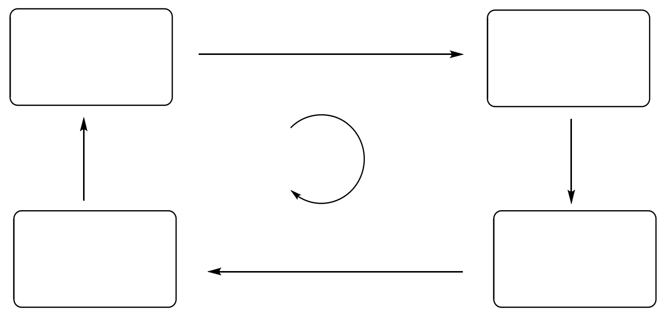


Answer (3)

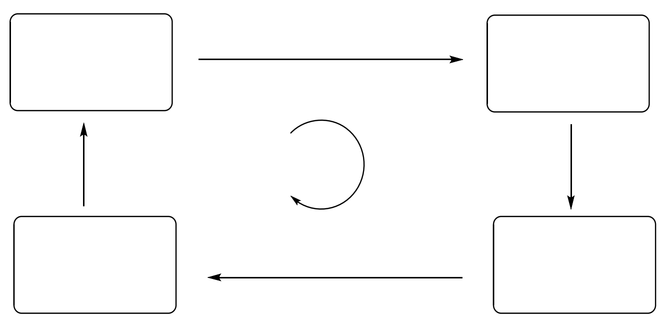


Form II: Matching on Quadrilateral Systemics

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

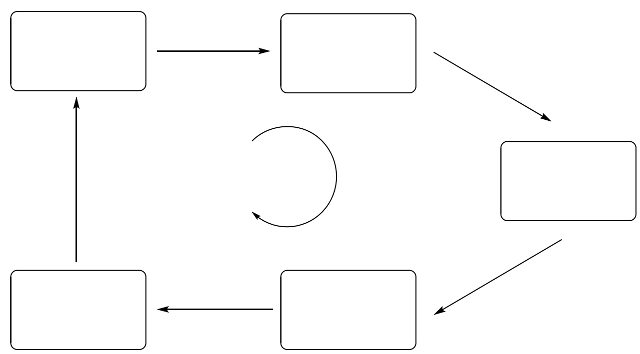
(A)	(C)	(B)
CH_4 CH_3COOH CH_3CHO CH_3CH_2Cl CH_3Cl CH_3CH_2OH CH_3-CH_3 CH_3CN		Soda lime/heat $KMnO_4$/ H_2SO_4 Cl_2/hν Aq. KCN/heat HI/P-200°C Dil. HCl/heat

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

(A)	(C)	(B)
FCH_2COOH **ICH_2COOH** **$ClCH_2COOH$** **$BrCH_2COOH$**	 (according to their acidity)	**Increases** **Decreases**

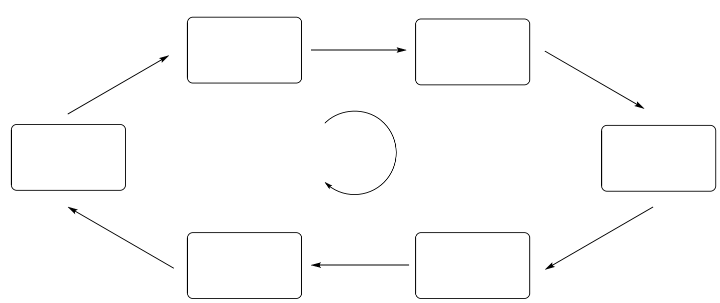
Form III: Matching on Pentagonal Systemics:

Q_4) Choose aliphatic compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C):

(A)	(C)	(B)
CH_3CH_2Br CH_3CHO CH_3CH_2OH CH_3CH_3 $CH_2=CH_2$ $CH\equiv CH$		Alc. KOH Dil. H_2SO_4 $KMnO_4$/conc. H_2SO_4 $Br_2/h\nu$ Zn/conc. HCl aq. KOH

Form IV: Matching on Hexagonal Systemics

Q_5) Choose elements from column (A) and relations from column (B) to build the systemic diagram in column (C):

(A)	(C)	(B)
Sulphur Aluminium Phosphorous Silicon Aluminium Magnesium Lithium potassium	 (Electronegativity)	Increase Decrease

II-4-2.:TYPE4: -Systemic Synthesis Questions: [SSnQ,s] [7,20,22,23]

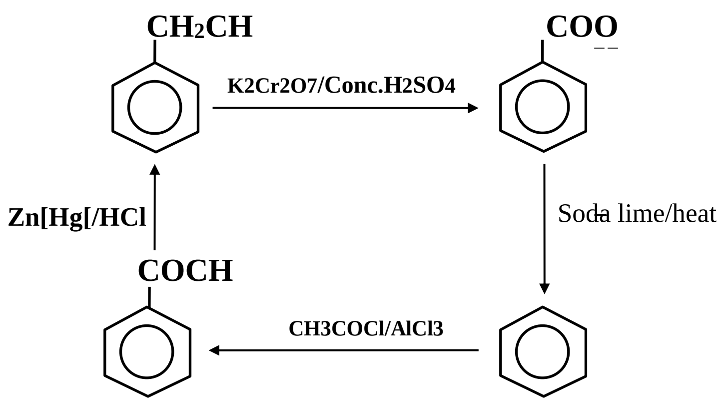
Requires student to synthesize systemic relations between concepts, facts, atoms or formulas, and their relations.

Form-1: Synthesize Quadrilateral Systemics:

Q 1: Draw systemic diagram illustrating the systemic chemical relations between the following aromatic compounds:

[Benzoic acid, Benzene, Ethylbenzene, Acetophenone]

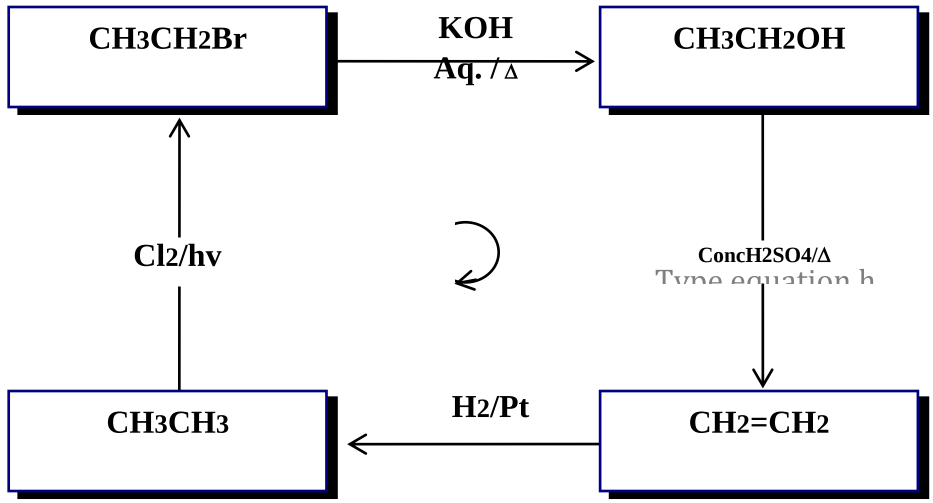
Answer (1):



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

[Ethanol, Ethane, Ethylene, Ethyl bromide]

Answer (2):

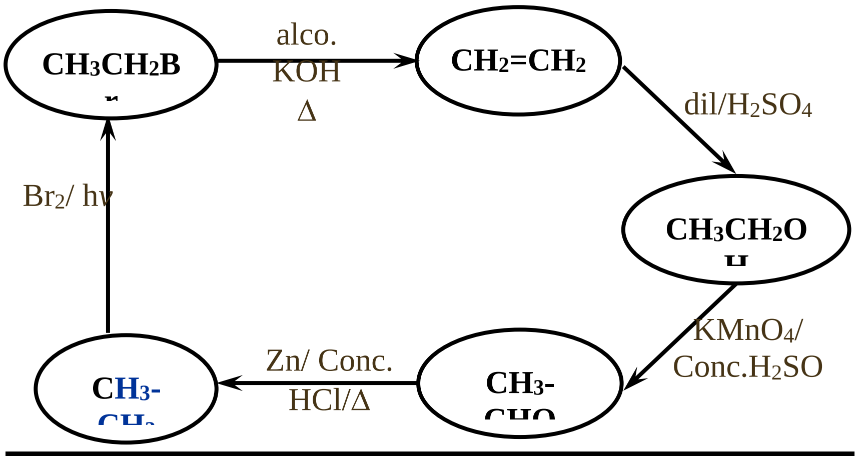


Form-2: Synthesize Pentagonal Systemics:

Q3: Draw systemic diagram illustrating the systemic relations between the following aliphatic compounds:

[C_2H_5Br, C_2H_4, C_2H_6, CH_3CHO, C_2H_5OH]

Answer (3):

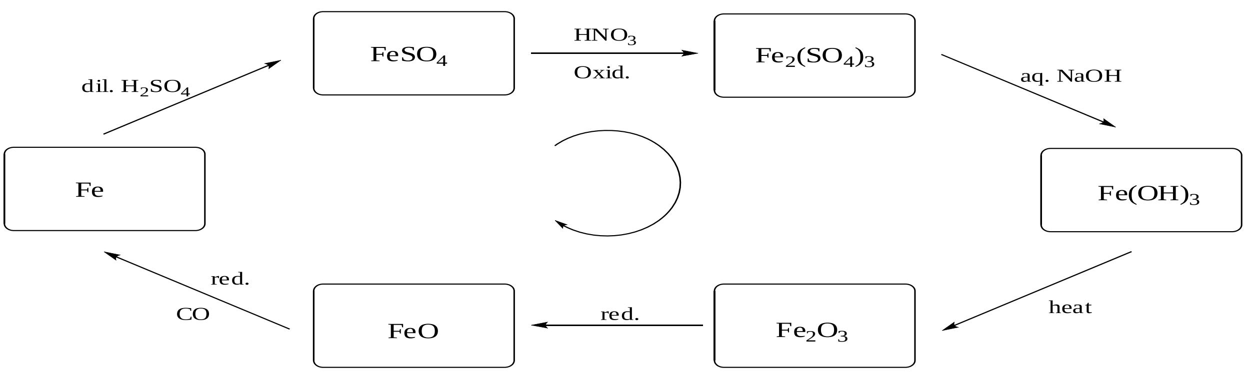


Form (3) : Synthesize Hexagonal Systemics:

Q5) Draw systemic diagram illustrating the systemic chemical relations between Iron and the following related compounds.

[$Fe_2(SO_4)_3$, $FeSO_4$, Fe, FeO, Fe_2O_3, $Fe(OH)_3$

Answer (5):



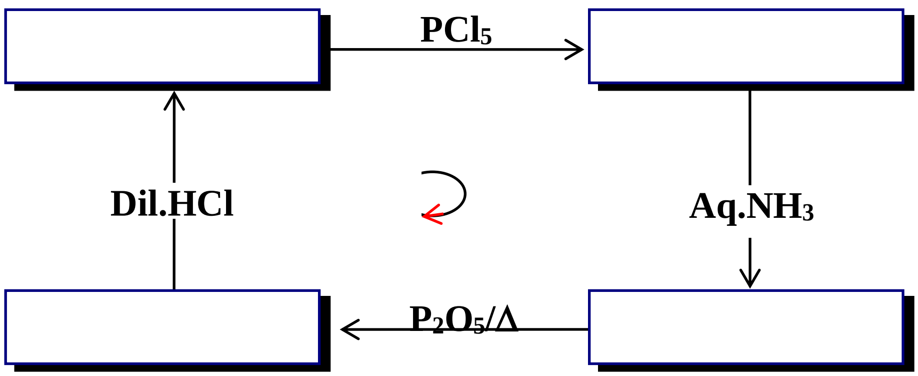
IV.2.2. Type-5: -Systemic Sequencing Questions: [SSQs](19)

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

Examples:

Q1: Arrange the given compounds in the right places of the Systemic diagram:]

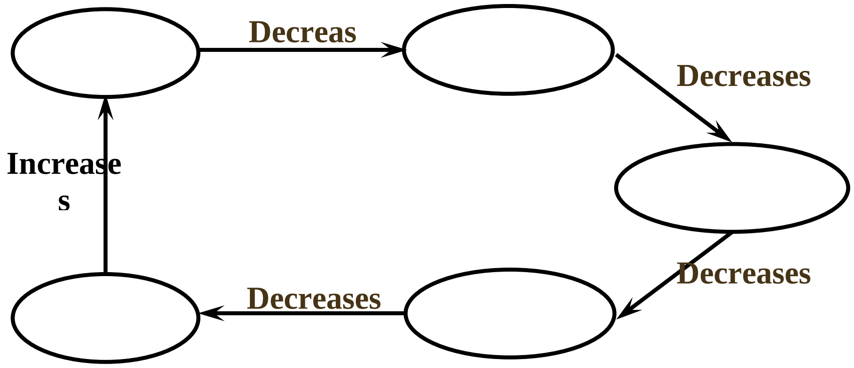
[C_6H_5COCl, C_6H_5CN, $C_6H_5CONH_2$, C_6H_5COOH]



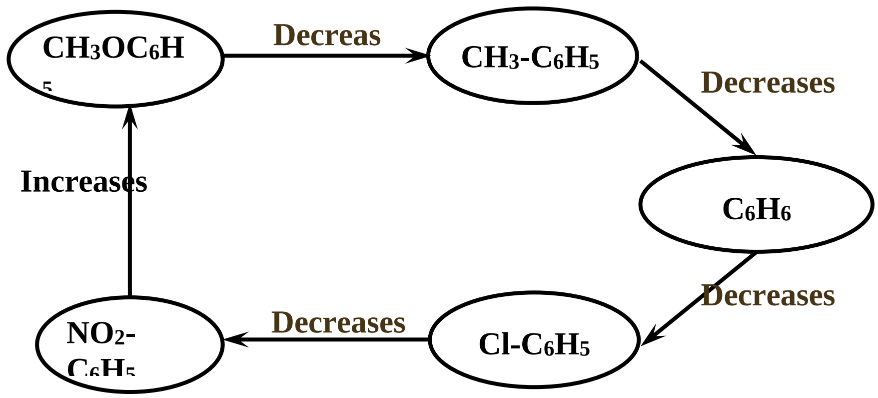
Form-2: Sequencing on Pentagonal Systemic:

Q2: Arrange the given aromatic compounds in the right places of the following systemic diagram according to the ease of Nitration.

[$CH_3C_6H_5$, Cl-C_6H_5, CH_3O-C_6H_5, NO_2-C_6H_5, C_6H_6]



<u>Answer (2):</u>



III-<u>SYSTEMIC THINKING [ST]</u>

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 fact that everything is Systemic & interacts with everything around it (Fahmy, 7). Systemic thinking is a powerful problem-solving approach that includes a variety of tools and methods. Generally used as a way to diagnose complex and cross-functional issues in business operations and technical workflows, systemic thinking focuses on the 'system' as a whole (*UK Indeed Team Dec.2022*) (25).

III-1: What is The Systemic Thinking ?(25)

-Systemic thinking, or systems thinking, is a comprehensive analytical approach to understanding how different elements interact within a system or structure. Commonly used for research and development purposes in scientific, human resources, medical, economic and environmental studies. Systemic thinking is a holistic approach that helps contextualize information. Systemic thinking includes studying all components and their influence on each other. Systemic thinking combines analytical thinking with synthetical thinking to find a system-wide focus to gain systemic deep insights into complex situations and problems.

III-2: Advantages of Systemic Thinking:(25)

- It offers the potential to find systemic focus in any situation.
- Helps identify interconnectedness rather than exclusively studying the elements individually and how these elements interact with one another &what is the result.

- Improves the entire system instead of improving the performance or efficiency of one part of the system and leaving the rest of the structures**.**
- Enables us to deal with the elements of any situation in harmony rather than in isolation.
- Enables anyone can use it to gain deeper insight about anything**.**
- Takes feedback into account by incorporating feedback at each stage. This leads to limiting the Margin of Error and improves efficiency.

III-3: <u>How do we enhance systemic thinking</u>?

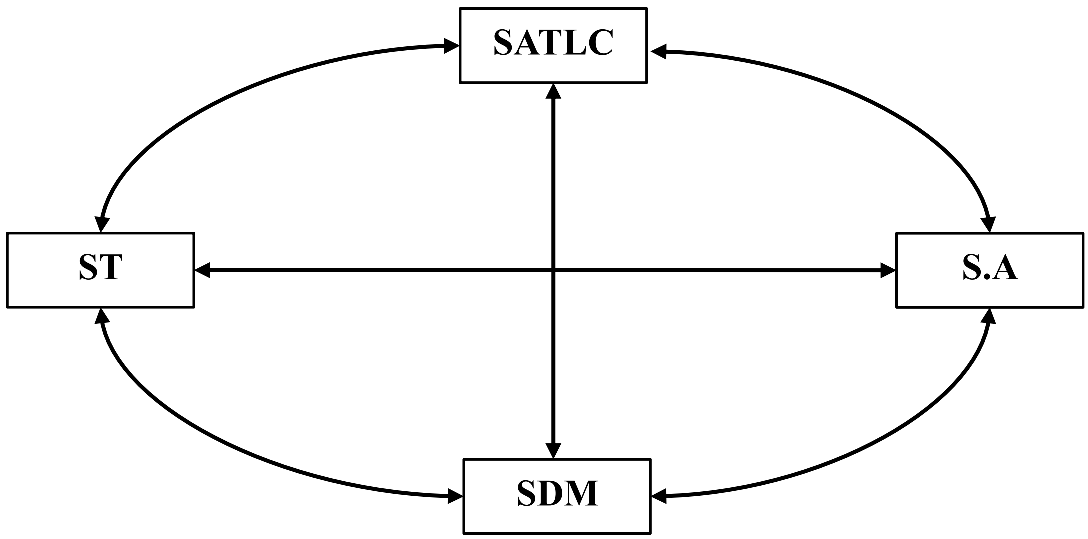
Vachliotis et.al [9,22] stated that systemic assessment questions [SAQs] were designed to be used effectively to assess meaningful understanding and systems thinking after students become familiar with a particular teaching theme. They examined secondary school students' systems thinking skills in an organic chemistry domain. For this purpose, they constructed and evaluated fill-in-the-blank systemic assessment questions [SAQs]. Herin et al (8.23,24) 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 valuable for future research, in which other types of [SAQs] (Fahmy [7,18-21] should be constructed and examined as tools for assessing different aspects of systems thinking construct.

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. (7)

Systemic diagram illustrating the Systemic Education Reform.

Each systemic component interacts with the other components systemically.SA was used to assess students' achievements after being exposed to SATLC. However, SA is used to enhance ST. Also, ST is one of the important learning outcomes of SATLC & very important in the preparation of systemic creative thinkers which is one of the important demands for Systemic Decision-Making [SDM].



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