SYSTEMIC CHEMICAL EDUCATION REFORM [SCER] IN THE GLOBAL ERA

A.F. M. Fahmy
Faculty of Science, Department of Chemistry Ain Shams University,
Abbassia, Cairo, Egypt
E: Mail: afmfahmy42@gmail.com; Website: www.satlcentral.com

ABSTRACT

Systemic chemical education reform [SCER] has gained a great importance internationally due to the competitive job market and global market economy which create global challenges and stresses on our current educational system. SCER is a dynamic process that requires constant communication, evaluation and has implications for curriculum, instruction, assessment, and professional development. It occurs in all aspects and levels of education process those impacts in all stake holders. The present work presents the systemic view of CER which means the change of our chemistry educational system from linearity to systemic in which we design the chemistry curricula and write the contents systemically. Also the content was taught by using SATL strategy on the light of systemic standards and objectives, which are measured by systemic assessment. In this paper we will shed light on systemic curriculum design [SCD], systemic content [SC], and systemic assessment [SA] in the frame of Systemic Chemical Education Reform. *[AJCE 4(1), January 2014]*

INTRODUCTION

On reaching the 21st century and with the development of communication media and the ease of information flow, the world seemed to be living in a small village full of developed and complicated information. The new century generation has challenges that are difficult and numerous, either to find its place in this universe or the international flood of science and knowledge will take him/her away. So it is a must to make a revolution in our educational systems so that to create a generation that is able to see the whole and not to miss some parts of it. To connect facts and concepts in a global context, we want as we live in 21st century to reach by our educational system from linearity to systemic. So we searched for an educational system growing the systemic way of thinking of our students that is one of the most important characteristics of Global Era.

Here is the systemic education reform which means the change of our educational system from linearity to systemic in which we design the curriculum and write content systemically, which presented by SATL strategy on the light of systemic standards, objectives and assesses by systemic assessment.

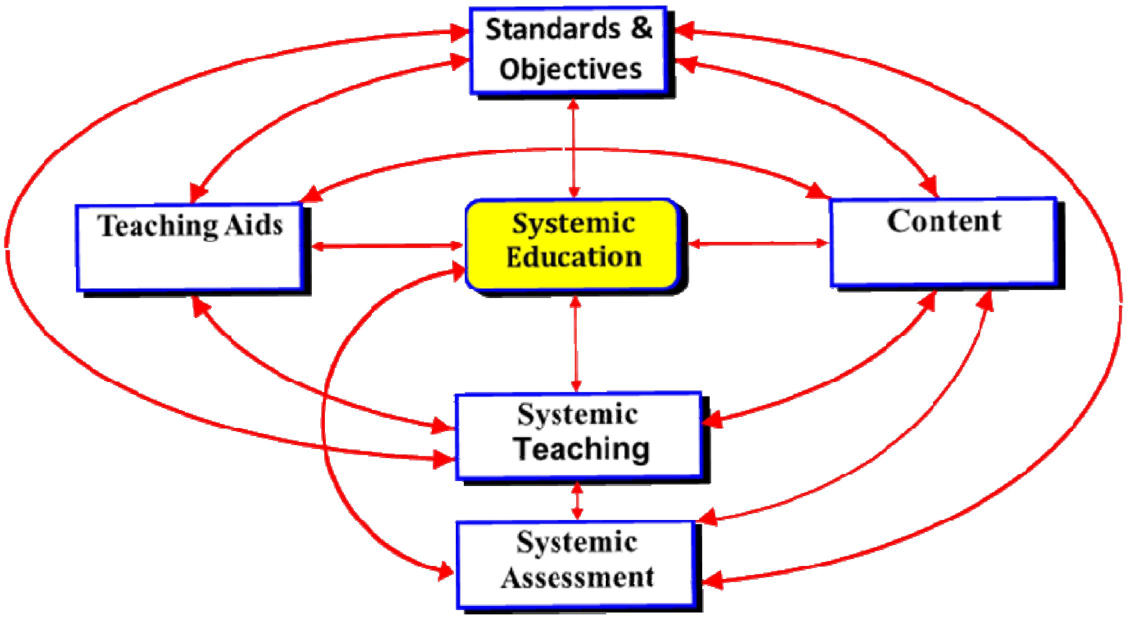


Fig.1: Systemic Education [SE]

Systemic diagram in fig -1 shows the components of systemic education. By Systemic Education [SE] it means (i) education in the higher learning levels [Synthesis-Analysis-Evaluation-then Creativity], (ii) education leads to highly ordered cognitive structure, (iii) education concerned with meta-cognition rather than cognition, (iv) education concerned with systemic thinking which is one of the important learning outcomes of SATL and necessary for preparation of citizen live in the global Era.

It was stated previously that systemic education reform was based on changes in content, pedagogy and assessment. However, we present here a new looking for SER which means reform of all the above components of the SE. This means systemic reform of standards, objective, Systemic Curriculum Design [SCD], Systemic Content [SC], Systemic teaching strategy [SATL] (1-3) and Systemic Assessment [SA] (4-7).

In this paper we will shed light on *SCD* - *SC*- *SA* in the frame of Systemic Chemical Education Reform [SCER].

I- SYSTEMIC CURRICULUM DESIGN [SCD]

The first part of our study on systemic chemical education reform [SCER] is the systemic curriculum design. SCD can be illustrated in the following systemic diagram Fig.2.

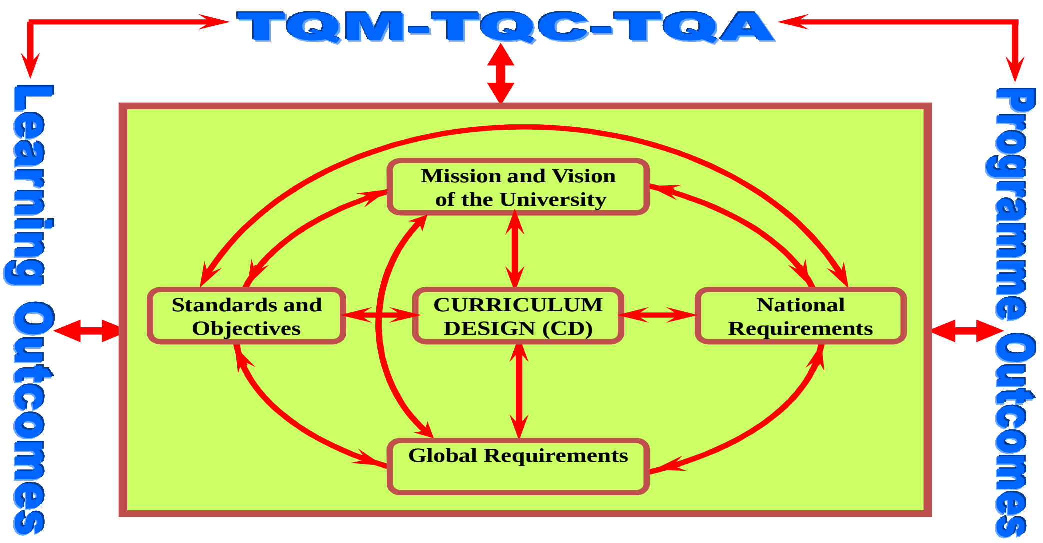


Fig.2: Systemic curriculum design

The above diagram shows the interacted components of systemic curriculum. Curriculum should be designed on the light of the university mission and vision, standards and objectives which should be addressed on the light of local and global requirements. SCD will leads to program, and learning outcomes which fulfill total quality management (TQM), total quality control (TQC) and total quality assurance (TQA) of the educational systems (8).

National requirements were determined by the university, cultural, social, economic and competitive job market requirements which fulfill TQA. All these factors affect each other and affected by other components of SC. Global requirements were determined by global economy market requirement and competitive global job requirements beside the needs for preparation of global citizens.

Learning outcome is a clear statement of that which a learner is expected to be able to do or to know at the end of his/her program/course study in chemistry. It provides easier access to the chemistry curriculum by those wishing to accredit their knowledge and experience gained outside the university. Also help to ensure that appropriate assessment methods are adopted, and thereby increase the potential for diagnostic assessment. Program outcome is a statement of that which a student is expected to be able to do or know at the end of his/her chemistry program / course of study. Program outcome includes statements of personal transferable skills, or key skills in chemistry.

The following are the chemistry curriculum design procedures (8):

1. Instructional Strategies: Make chemistry courses effective, popular, and keep the course materials at the best reading level. How to design chemistry exercises?
2. Work Plans: Where to start? How to reduce chemistry course costs? How to reduce chemistry course length? How to estimate design time?
3. Learner Analysis**:** What you need to know about chemistry learners? Where to get this information?
4. Task Analysis: What are the chemistry sources of data? How to build the chemistry course at the learners' level? What is the best way of sequencing chemistry course content? How to link chemistry learning to job market requirements?
5. Principles of Learning**:** How much theory/background material to include in the chemistry course? What is the best approach(s) used to motivate learners in the chemistry courses? What types of indoor and outdoor activities to schedule based on time?

6. Objectives and Tests: What Types of objectives? How to write objectives quickly and easily on the light of standards? How to design performance checklists for chemistry Labs?
7. Validation and Assessment: What to include in a course assessment? What assessment forms you can use in chemistry? How to measure learning outcomes?

All the above mentioned questions should be clarified by curriculum designer team and constitute the guidelines for the curriculum designer. Chemistry Curriculum Design Procedure works systemically, i.e. each component strongly interrelated to the other components as s illustrated in the systemic diagram Fig.3

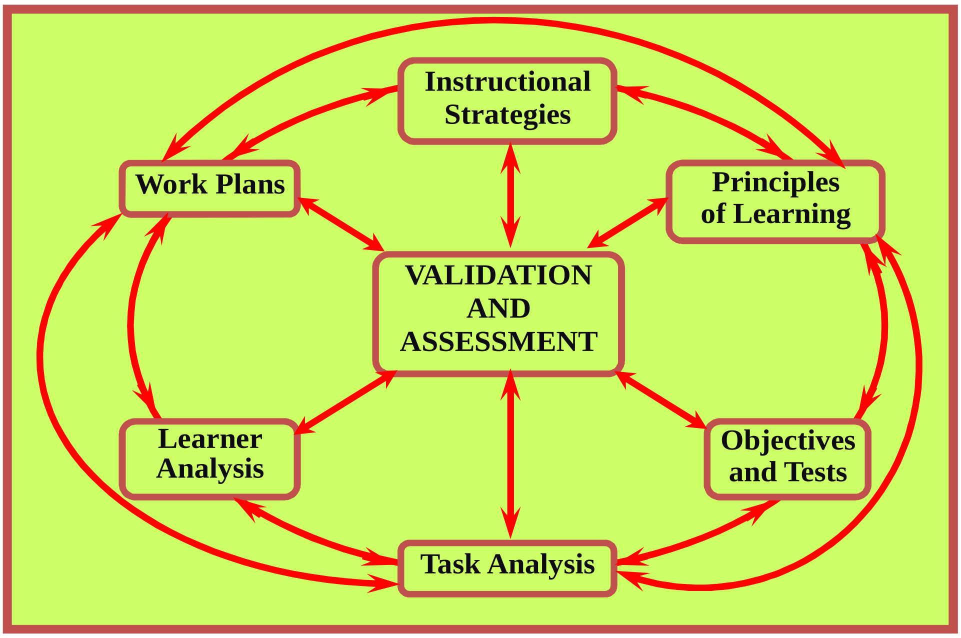


Fig.3: Systemic diagram of the Chemistry Curriculum Design Procedure

II-SYSTEMIIC CONTENT [SC] OF THE CHEMISTRY COURSE MATERIALS

The second part of our study about SCER is the systemic content [SC] of course materials. In systemic chemistry education we arrange the course content materials in a systemic way (1). This means arrangement of concepts or issues through interacted systemic in which, all relationships between concepts and issues are clear as shown in Fig.4.

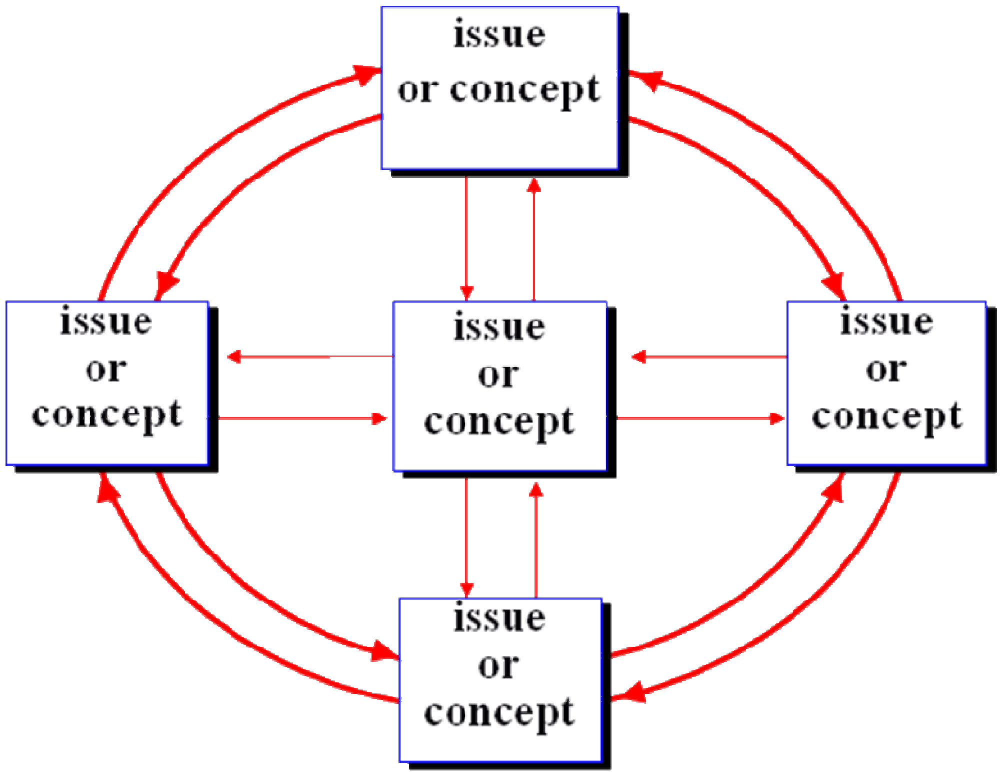


Fig.4: Illustrates the idea of systemic arrangement of chemistry course materials.

However, linear presentation of chemistry course materials means arrangement of chemistry issues and concepts in a sequential presentation as in Fig.5.

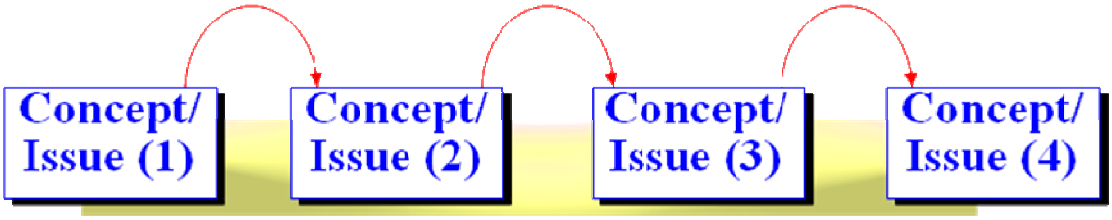


Fig.5: Illustrates the idea of linear arrangement of chemistry course materials.

In practice, the systemic building strategy allows the teacher to build up sequentially a single concept map starting with prerequisite concepts required for the student before he/she starts on a systemic approach to learning. Figure 6 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 (1).

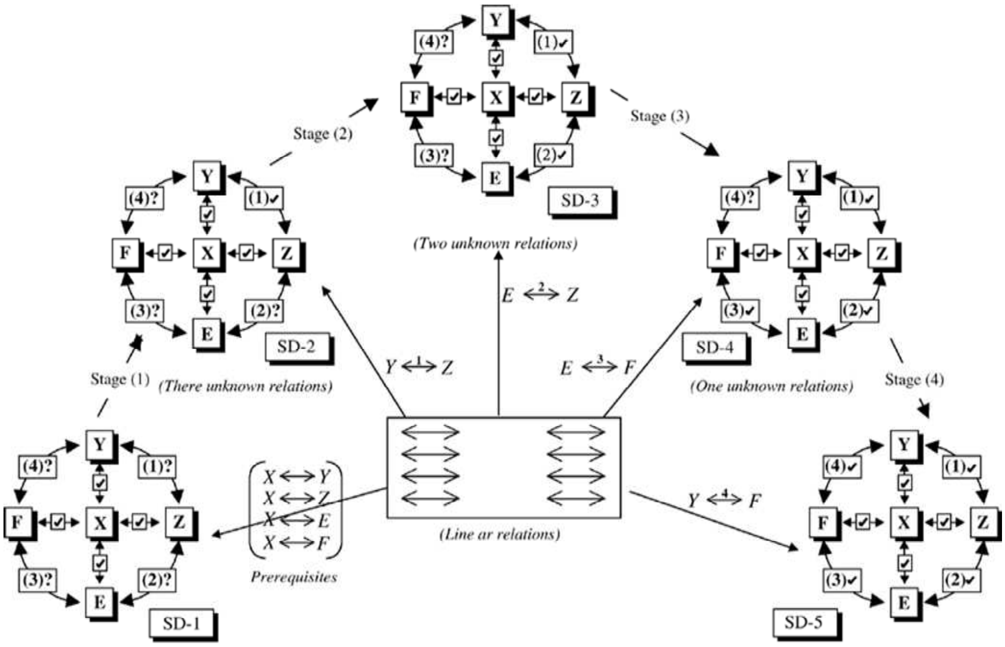


Figure 6. The evolution of a completed closed chemistry concept cluster from a starting point

The instructor has in mind the linear concept structure shown in Figure 5, which he/she wants to develop into the closed cluster (systemic) shown as Figure 4. The prerequisites are simple bi-directional relationships between the concepts. Thus, initially, there are four unknown (to the student) relationships in the final cluster of concepts (Figure 6). The full closed cluster concept map [SD5] can be developed in four stages by sequentially introducing the (initially) four unknown concepts. At each step, another part of the final closed concept cluster is added and developed. This process clearly illustrates the systemic constructivist nature of systemic arrangement of the course content materials. This building strategy could be used in different branches of chemistry.

APPLICATION OF SYSTEMIC BUILDING STRATEGY IN CHEMISTRY

Systemic building strategy of course content materials was used to develop courses in Organic chemistry, Inorganic chemistry, physical chemistry, and analytical chemistry. Systemic chemistry courses were produced by the Science Education Center at Ain Shams University, and experimentation in different university and school settings.

Pre-College Courses

SATL-Classification of Elements

We present now the details of the transformation of the usual linear building strategy fig.5, usually used to build this subject that involves separate relationships, to the corresponding systemic building strategy fig.4, which involves closed concept cluster (systemic) that presents the systemic relationships (9).

Stage-1: Linear arrangements of periodicity of the properties of elements

The periodicity of the properties within the horizontal periods is linearly arranged and illustrated as in the diagram in Figure 7, and within the vertical groups is linearly arranged as illustrated in the diagram in Figure 8.

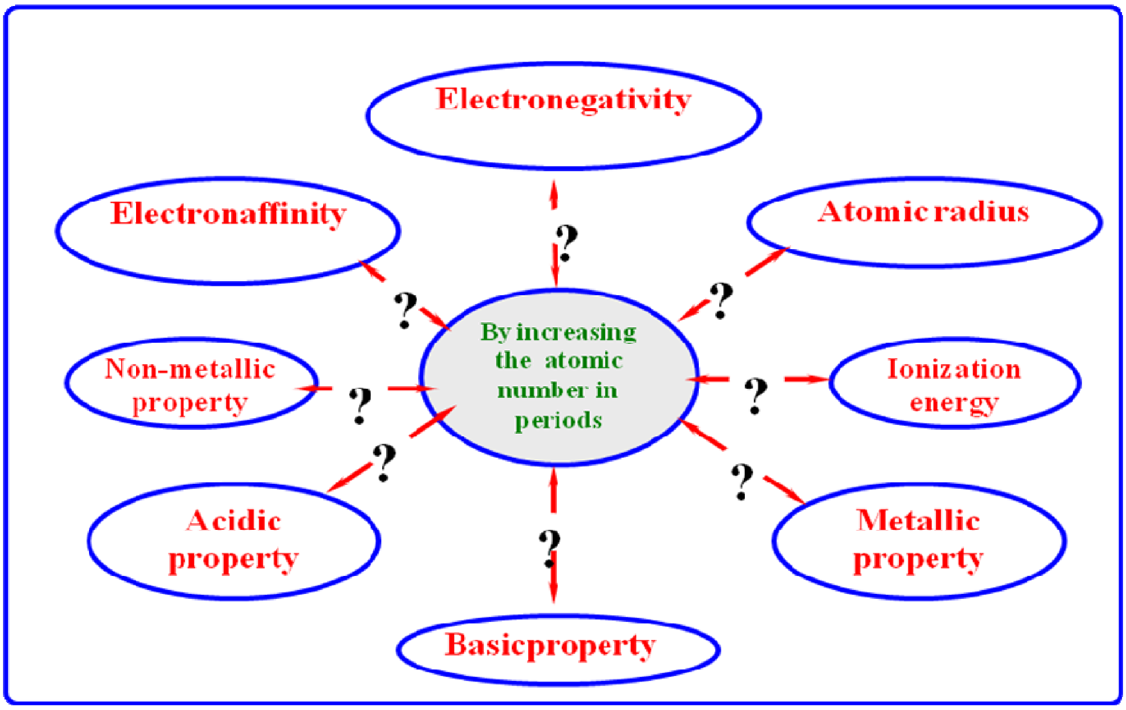


Fig.7: Linear arrangement of periodicity of properties of the elements within the periods.

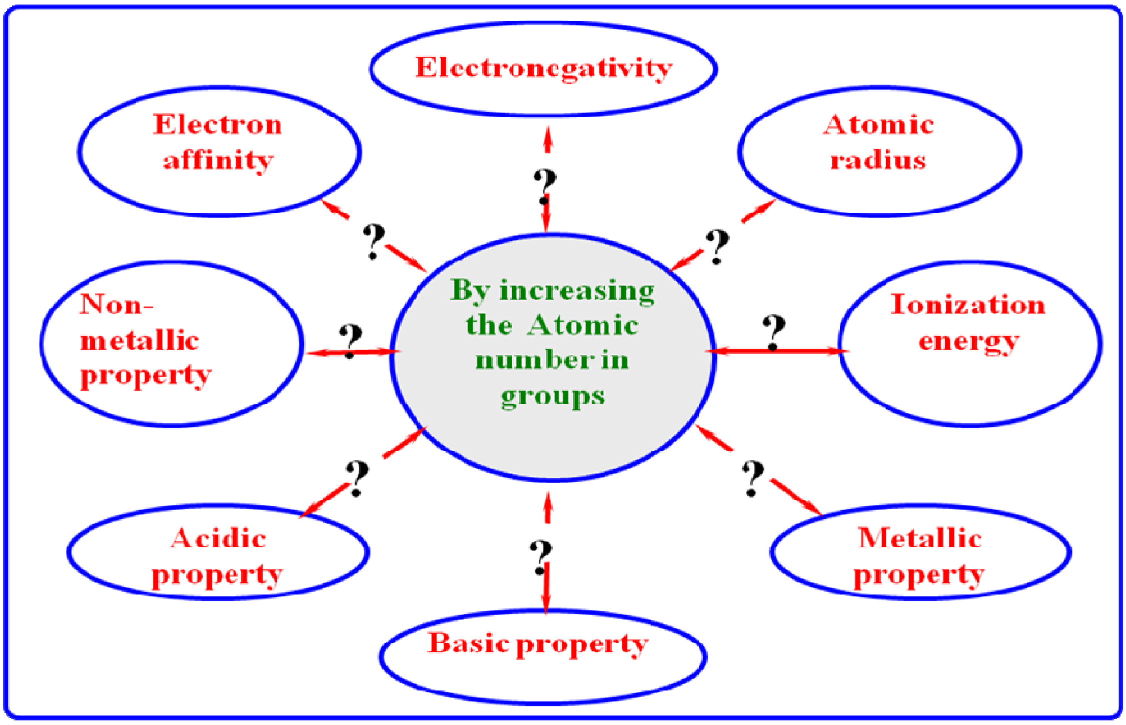


Fig.8: Linear arrangement of periodicity of properties of the elements within the groups.

The previous diagrams of periods and groups represent linear arrangement of properties with separated chemical relations between the atomic number and Atomic radius – Ionization energy - electron affinity - electro negativity - metallic and non-metallic properties - basic and acidic properties.

Stage-2: Systemic arrangement of periodicity of the properties of elements

The periodicity of the properties through the periods can be arranged systemically by changing the linear arrangement in the linear diagram Figure (7) to systemic arrangement as illustrated in the systemic diagram (SD1-P) Figure (9).

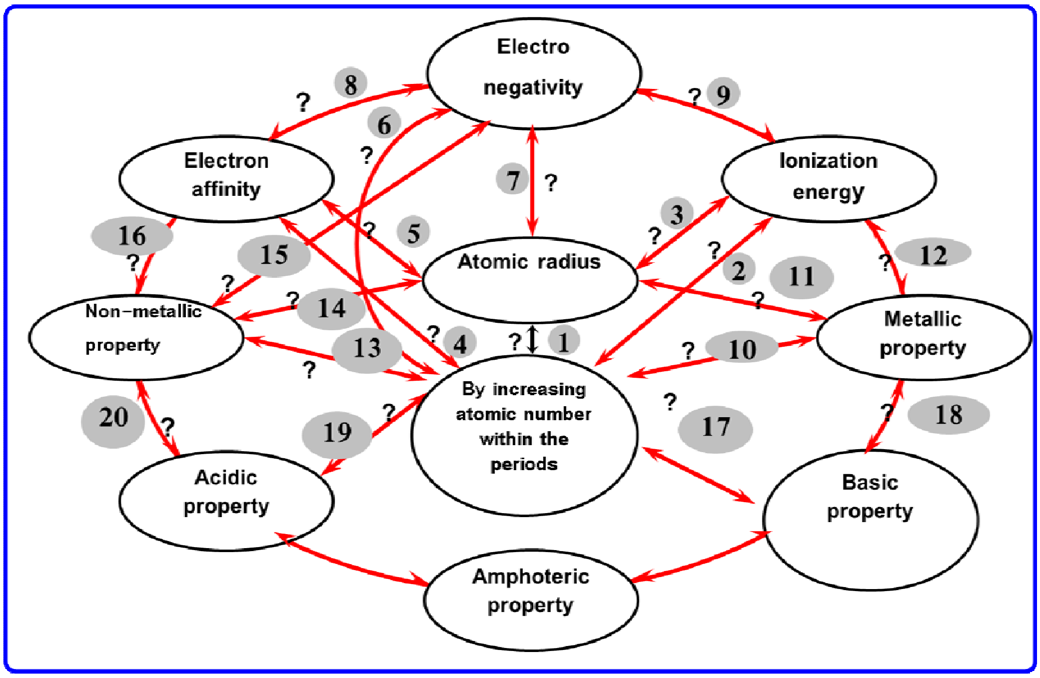


Fig.9: Systemic Diagram (SD1 - P) for the periodicity of properties of elements within periods.

Also the periodicity of the properties within groups can be illustrated systemically by changing linear arrangement in Figure 8 to systemic arrangement in systemic diagram (SD1-G) Figure 10.

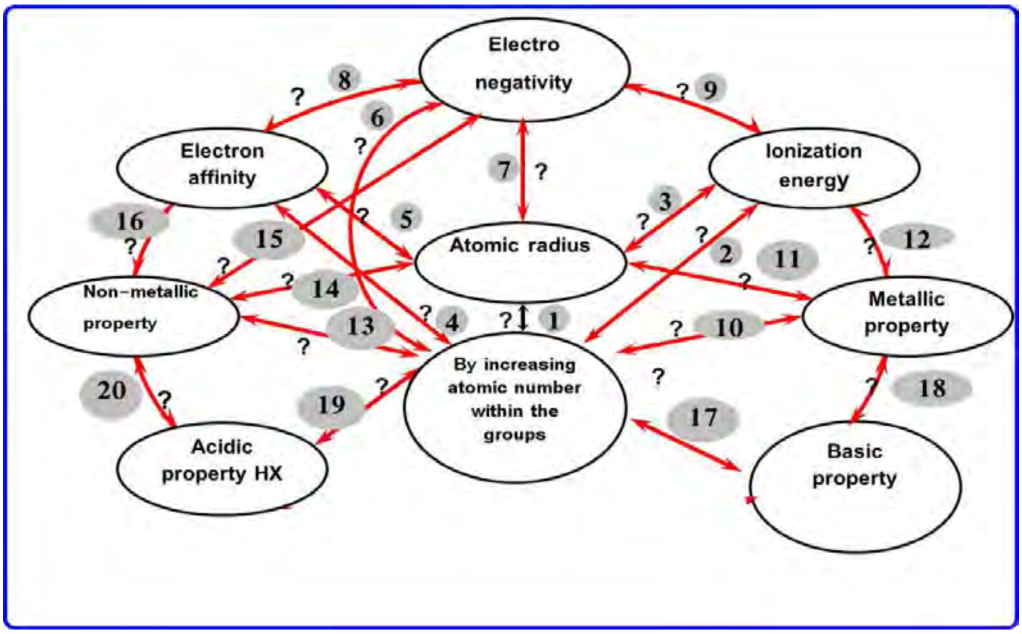


Figure (10): Systemic Diagram (SD_1- G) for the periodicity of properties of the elements within groups.

Stage-3: Completion of the systemic arrangement of the periodicity of properties

After we start systemic arrangement of the periodicity of physical and chemical properties of the elements, we can introduce more relations to complete the systemic diagram by modifying systemic diagrams (SD1-P) Figure (9) to (SD2-P) Figure (11), for periods, and (SD1-G) Figure (10), to (SD2-G) Figure (12) for Groups.

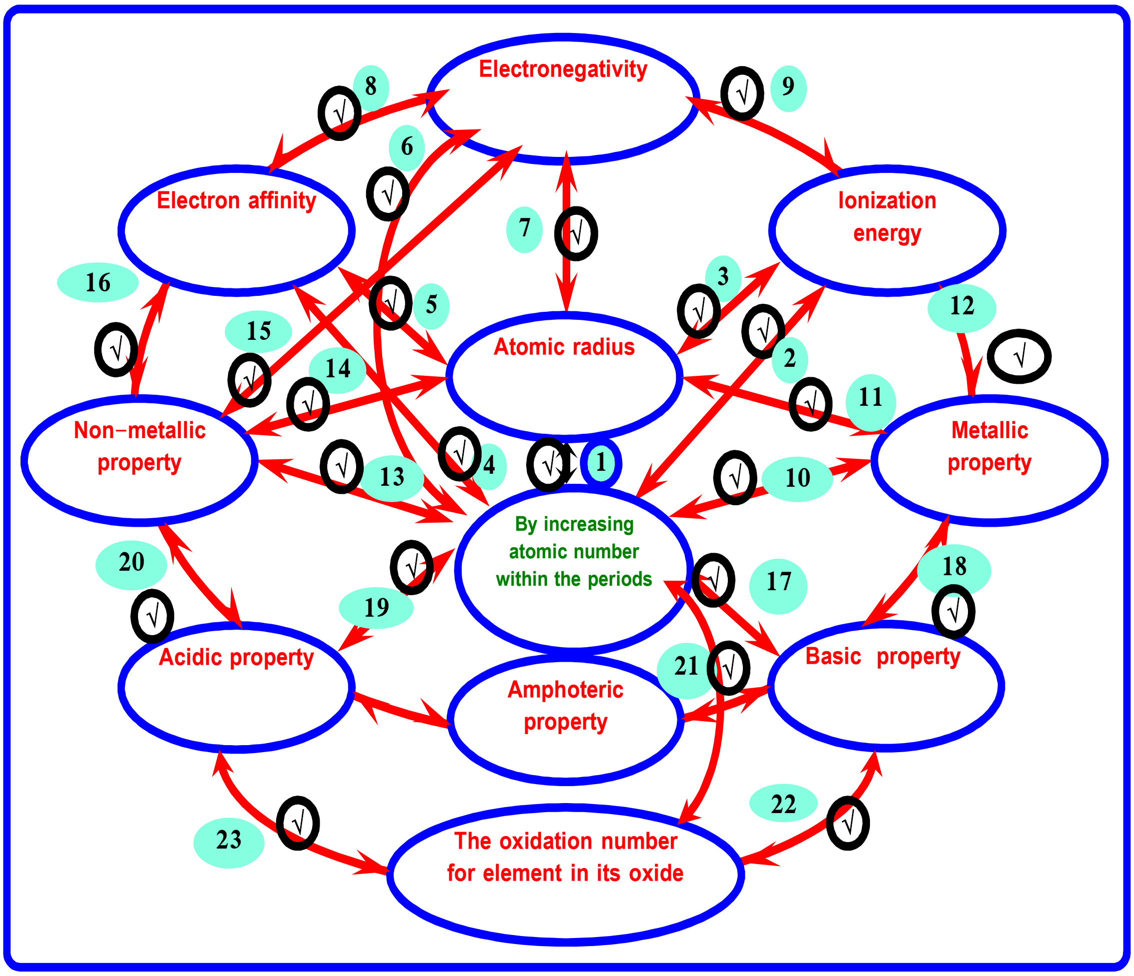


Figure (11): Systemic Diagram (SD_2 - P) for the complete systemic arrangement of Periodicity of the properties of the elements within periods.

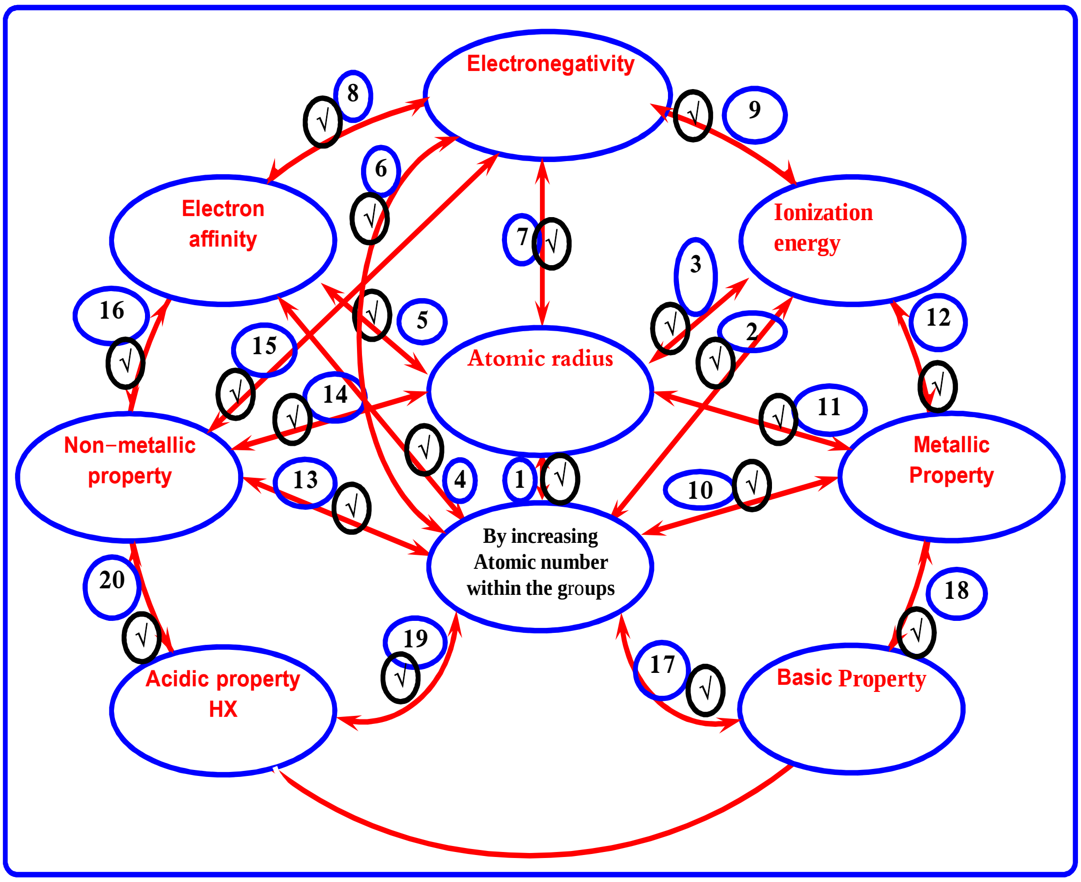


Figure (12): Systemic Diagram (SD_2 - G) for complete systemic arrangement of the periodicity of the properties of elements within-groups.

The above mentioned content was experimented in Egyptian secondary schools. Fifteen systemic content based lessons in inorganic chemistry taught by SATL method over a three - week period were presented to a total 130 students (9). The achievement of these students was then compared with 79 students taught the same material using standard (linear arrangement), and traditional teaching method.

The results of experimentation

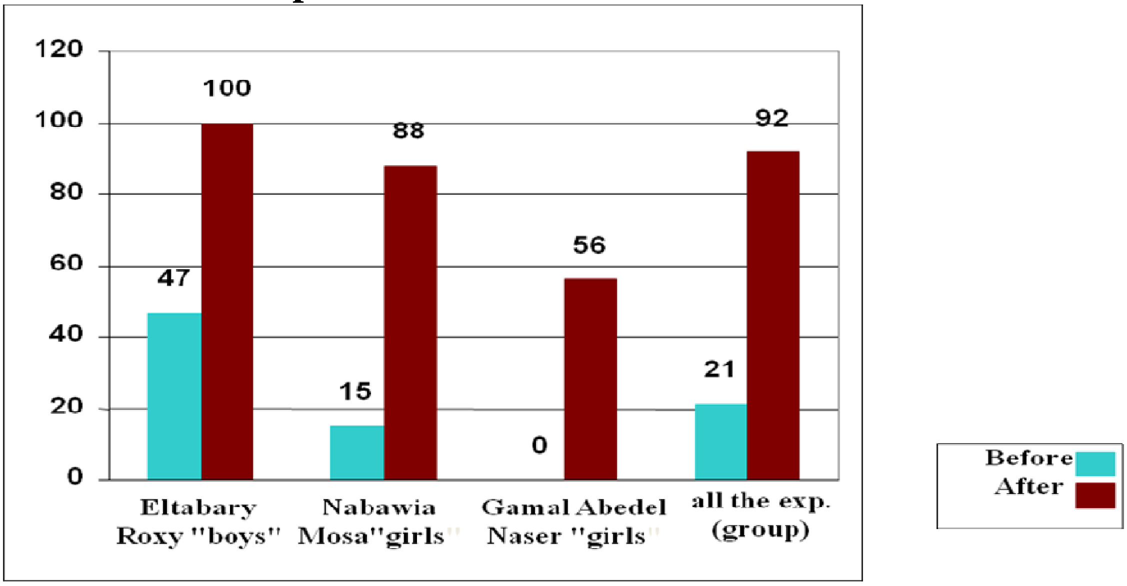


Figure 13: Percent of students in the experimental groups who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the systemic intervention period.

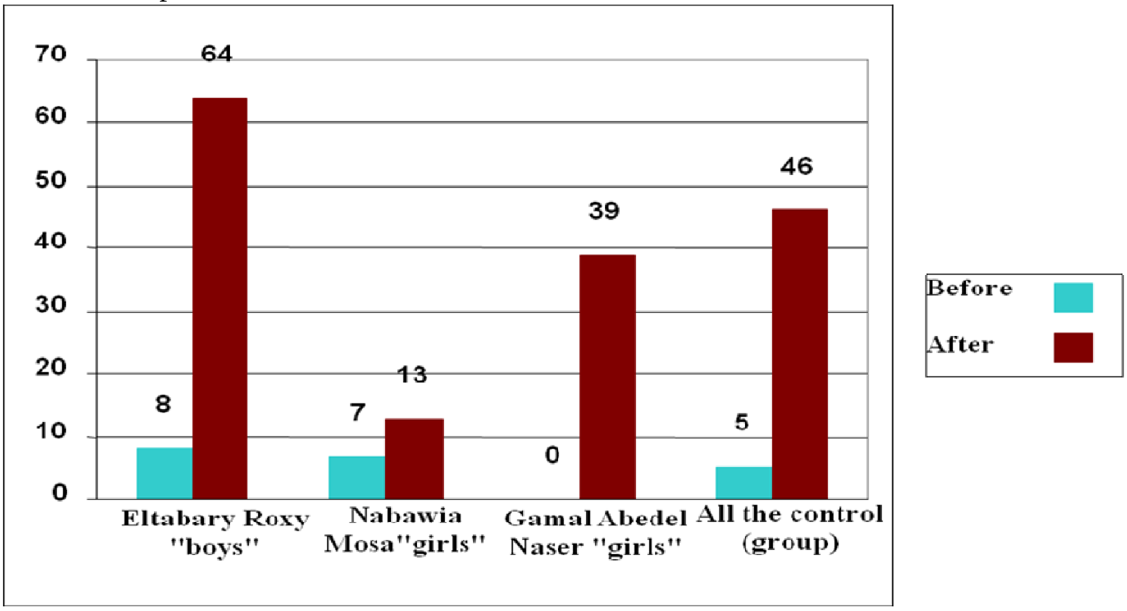


Figure 14: Percent of students in the control groups who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the linear intervention period.

The results from the pre-university experiment point to the following conclusions:

- Teachers' feedbacks indicated that the systemic content taught by systemic approach seemed to be beneficial when the students in the experimental group returned to learning using the conventional linear approach.
- Students used systemic content and taught systematically improved their scores significantly after being taught by using SATL techniques.

University Courses

We have three university courses prepared on the basis of systemic arrangement of content. SATL-Aliphatic chemistry, SATL-Aromatic Chemistry and SATL-Heterocyclic chemistry. A sample of this work will be discuses in this work.

SATL-Heterocyclic chemistry: [e.g. SATL-Furan Chemistry]

We use heterocyclic chemistry to illustrate, again, how a subject can be organized systemically, to help students to fit the new concepts to their own mental framework (10).

<u>Stage-1: Linear arrangement of Furan chemistry</u>: Figure 15 summarizes all the significant linear separate chemical reactions of furan, the model heterocyclic compound.

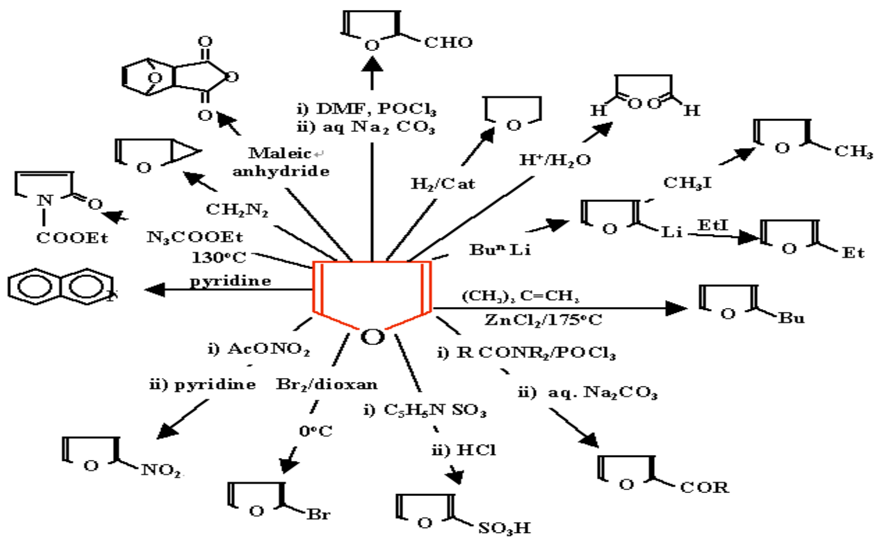


Figure 15. The classic linear arrangement of Furan chemistry

<u>Stage-2</u>: <u>Systemic arrangement of the Furan chemistry:</u>

The Furan chemistry can be arranged systemically by changing the linear arrangement in the linear diagram (Figure 15) to systemic arrangement as illustrated in the systemic diagram (SD1) as in Figure 16.

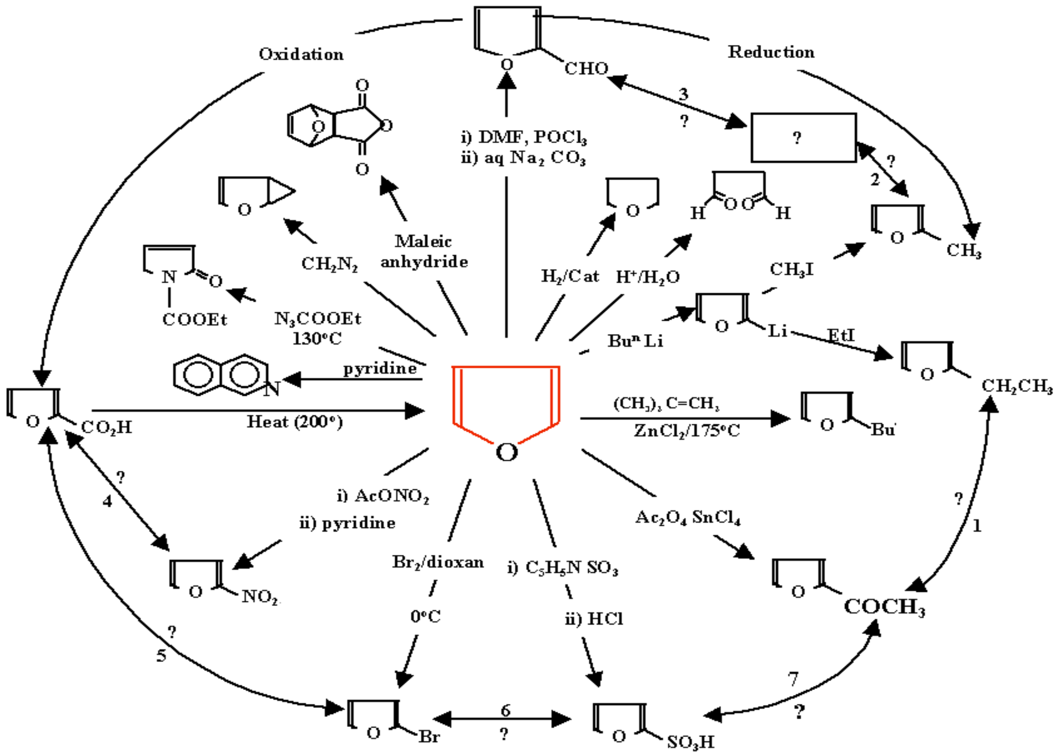


Figure16: Systemic arrangement [SD1] of the furan chemistry

Stage-3<u>: Completion of the systemic arrangement of Furan chemistry:</u>

After we start systemic arrangement of Furan chemical properties, we can add more relations to complete the systemic diagram SD-1 to give SD-2 as in Fig.17.

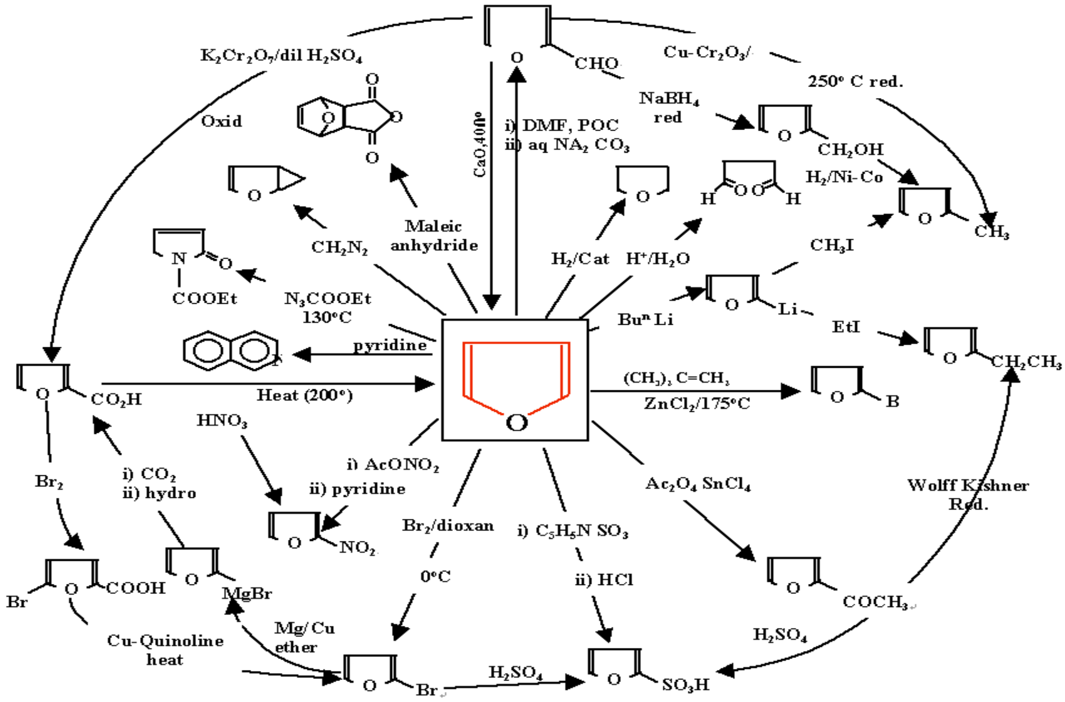


Figure 17. Complete systemic arrangement [SD-2] of Furan chemistry

The above mentioned content was experimented as part of heterocyclic chemistry course taught by using the SATL technique to the 3rd year students at Ain Shams University. A portion of the one-semester course (10 lectures, 20 hours) was taught to students during the academic years 1999-2000 (10).

The data summarized in Table 1 below shows that students use of systemic content were significantly improved after being taught by using SATL techniques.

Table -1: Percent increase in student scores

	Before intervention	After intervention
Linear questions:	37.32 %	49.53 %
Systemic questions:	21.19%	90.29%
Total:	32.52%	69.1%

These results are statistically significant at the 0.01 level.

Systemic to Laboratory Instruction

Applying Systemic arrangement to laboratory instruction reveals the following advantages, which constitute the principles of benign analysis (11):

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

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 18). Applying this approach to laboratory instruction allows students to experience the colors of chemical species, their solubility characteristics, and their redox behavior.

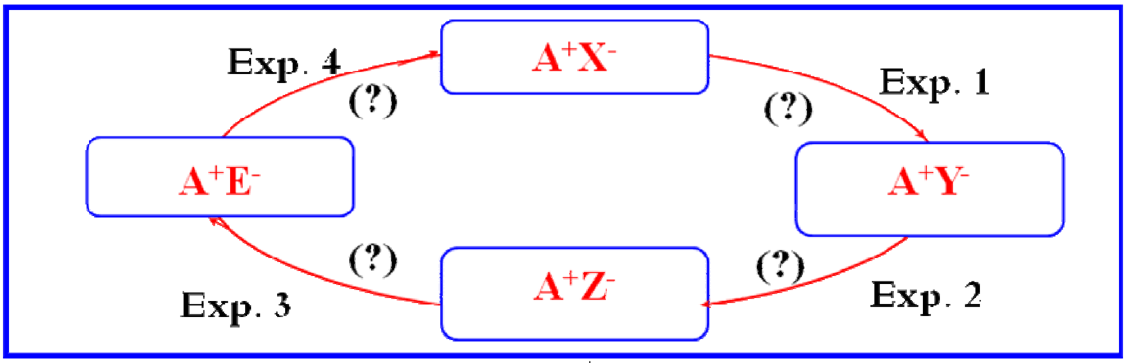
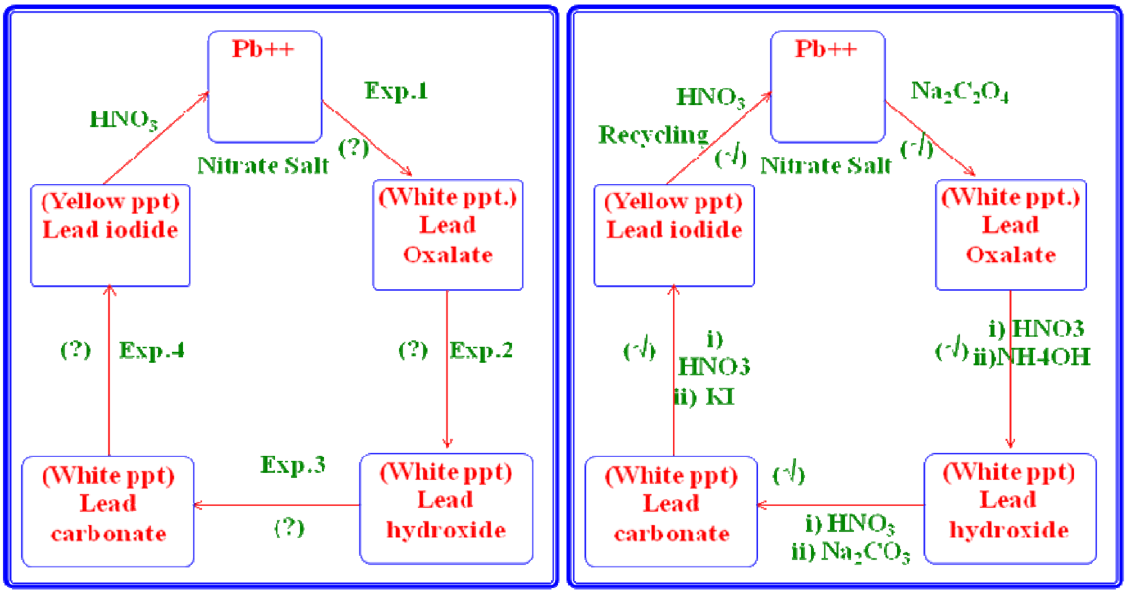


Figure 18: Systemic Investigation of species A^+ (SI-Plane)

This diagram shows the systemic arrangement Investigation Plane [SI-Plane] for qualitative investigation of the species (A^+), the preparation of (A^+) compounds and the conversion of the species.

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

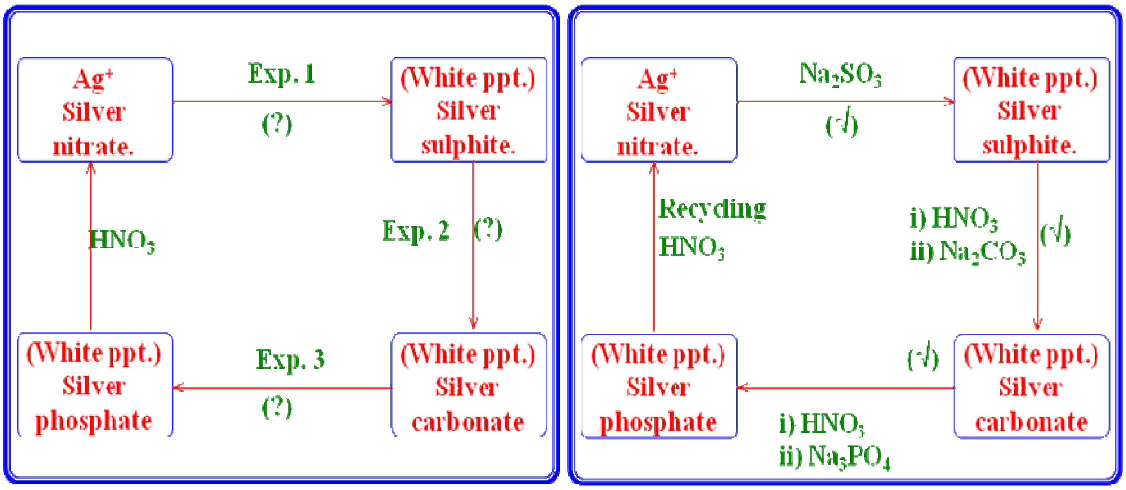
The students follow the plane (SI-1) to investigate (Pb^{2+}) in a series of experiments (1-4) in a single test tube on a small sample of lead nitrate (0.5 ml), then they recycle the product of (Exp. 4) to Pb (NO3)2 (Cf. SI – Final).



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

Example - [B]: 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)

Results of Experimentation

The experimentation results showed that the benign scheme based on systemic arrangement of investigation experiments reduces the consumption of chemicals in comparison with the classical scheme as shown in table (2). This means low cost, and less pollution (11).

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 0.1M 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

The results, of experimentation indicate that a greater fraction of students use the systemic content and exposed to systemic techniques in the experimental group, achieved at a higher learning level than did the control group taught by the linear content and classical approach.

III-SYSTEMIC ASSESSMENT [SA]

The third part of our study about systemic chemistry education reform [SCER] is the systemic assessment [SA] to assess student achievement in chemistry. By SA we actually measure the change in cognitive structure of student after each learning process.

We have proposed systemic assessment (SA) of learners, aiming to a more efficient evaluation of the systemic-oriented objectives in the SATL model and effective tool for assessing students' meaningful understanding of systemic chemistry topics in secondary and tertiary levels (4-7). Systemic assessment is the key component in the systemic curriculum**.** It is used during the systemic course to monitor the student progress (formative) and at the end of the course to monitor the progress of students' cognitive structures (summative).

Students answering systemic assessment questions (SAQs) are able to (i) connect several concepts at once, applying them in a new situation, and synthesize them to create a comprehensive meaningful conceptual structure, (ii) select specific concepts that fit the particular item and combine them into integrated meaning in their systemic cognitive structure, (iii) illustrate systemic meaningful understanding of scientific concepts.

Why Systemic Assessment (SA) in chemistry?

Systemic assessment (SA) has the following advantages:

1. It measures the cognitive structure from the cumulative (quantitative) to the interactive and tuned (qualitative)

2. Assess students higher-order thinking skills in which students are required to analyze, synthesize, and evaluate
3. Measures the students' ability to correlate between chemistry concepts
4. Enables the students to discover new relation between chemistry concepts
5. Gives the students rapid feedback during the term about how well they understand the chemistry course material
6. Assess the students in a wide range of chemistry concepts in the course unites
7. Measures the systemic ILOs, beside separate Linear ILOs
8. Develop the ability to think systemically, critically and creatively, and solve problems
9. Very easily scored
10. Being objective, realistic and valid.

Types Systemic Assessment Questions [SAQs]

SAQs are the building questions of any systemic objective test [SOT] namely Systemic Multiple Choice Questions [SMCQs], Systemic True, False Questions [STFQs], Systemic Matching Questions [SMQs], Systemic Sequencing Questions [SSQs],Systemic Synthesis Questions [SSynQs]. Different examples from different branches of chemistry were previously published (4-7).

Systemic assessment questions forms are valid and reliable tools for assessing students' achievements, treated by systemic content [SC], and SATL at higher learning levels.

REFERENCES

1. Lagowski, J.J. and Fahmy, A.F.M. (2011); The systemic approach to teaching and learning, [SATL]: A 10- year's review, AJCE, 1(1) 29-47.

2. Fahmy, A.F.M. and Lagowski,J.J.(1999); The uses of systemic approach to teaching and learning in 21st century, Pure Pure Appl. Chem., 1999, 71(5) 859 – 863. [15th ICCE, Cairo, Egypt, August, 1998].
3. Fahmy, A.F.M.and Lagowski, J.J. (2003); Systemic Approach to teaching and learning chemistry [SATLC] in Egypt [1998-2011], AJCE, 2 (2) 92-97.
4. Fahmy, A.F.M.and Lagowski, J.J. (2006); Systemic Multiple Choice Questions (SMCQ) in Chemistry. 19th International Conference on Chemical Education, (19th ICCE), Seoul, Korea, August 12-17 (2006).
5. Fahmy, A.F.M.and Lagowski, J.J. (2006/2008); Systemic Multiple Choice Questions in Chemistry, Chemical Education International Vol. 3 (2006/2008) http://www.iupac.org/publications/cei
6. Fahmy, A.F.M., and .Lagowski, J.J. (2012): Systemic assessment as a new tool for assessing students learning in Chemistry using SATL methods: Systemic true false [STFQs] and systemic sequencing [SSQs] question types, AJCE. 2 (2)66-78.
7. Vachliotis, T, Salta,K., Vasiliou, P. and Tzougraki ,C (2011); Exploring novel tools for assessing high School students' meaningful understanding of organic reactions, J. Chem. Educ. 88 [3] , 337-345.
8. Liverpool John Moores University Learning and Teaching Web. http://cwis.livjm.ac.uk/lid/ltweb/curriculum_design/0009.htm
9. Fahmy, A.F.M., El-Shahaat, M.F. and Saied, A. (2003), International Workshop on SATLC, Cairo, Egypt, April (2003).
10. Fahny A.F.M. (2013); Operational steps in building unites in Heterocyclic chemistry, AJCE, 3 (2) 39-56.
11. Fahmy, A. F. M., Hamza, M. A., Medien, H. A. A., Hanna, W. G., Abdel-Sabour, M. : and Lagowski, J.J.(2002); From a Systemic Approach in Teaching and Learning Chemistry (SATLC) to Benign Analysis, Chinese J.Chem. Edu. 23(12),12 [17th ICCE, Beijing, August 2002].