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Chemical Education from Data collection to Systems-Thinking

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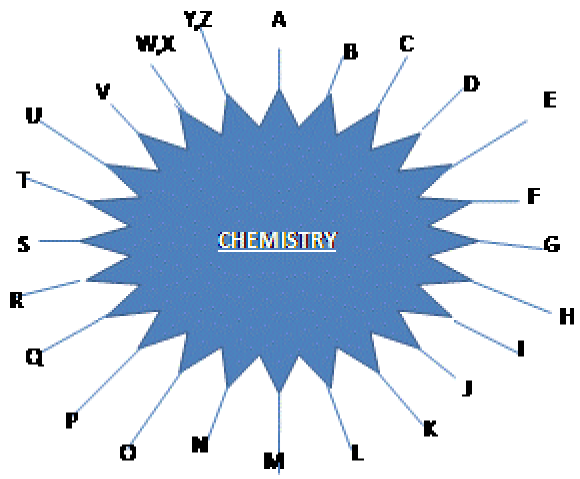
Man is made up of material. Man consumes material, eliminates material, uses material for his comforts and well-being, makes alternate materials to suit his life style from time to time, creates waste materials indiscriminately and so on and so forth. This is the man- material saga. The fundamental scientific aspect of material is its composition, structure and properties. The essence of Chemistry is the study of these characteristics of materials. Besides, chemistry also deals with the perturbation aspects in the mass and energy parts of the materials [1]. Perturbation in mass of the material gives new products. Perturbation in the energy is useful in designing new techniques for quality control. Thus chemistry has a distinct bearing on the man's different activities and requirements.

Chemistry not only has a significant relationship with materials that man requires, uses and throws as waste but has the connectivity with A to Z of scientific fields.

Figure (the expansions for A to Z in the Table) below highlights that chemistry is central to A to Z of varied fields of science & technology [2].

Chemistry & A to Z Connectivity



Chemistry & A to Z connectivity - 2

(1) Agriculture , Aerosphere	(9) Immunology	(17) Quantum
(2) Biosphere	(10) Jute, Jewels	(18) Radiation,Rubber
(3) Cement,Clinical, Communication	(11) Kerogen	(19) Sonochemistry
(4) Dietetics, Dairy, Drugs	(12) Luminescence, Lubricants	(20) Tribology, Textiles
(5) Electronics, Energy, Environment	(13) Medicinal, Metullurgy, Mineral,	(21) Urology
(6)Food, Forensic, Fuel	(14)Nuclear, Nutrition	(22) Virology
(7) Geochemistry, Gems	(15) Ocean chemistry	(23) Water chemistry, (24) Xerography
(8) Hydrosphere, Health, Hygiene	(16) Phytochemistry, Photochemistry,Plastics	(25) Yeast, (26) Zeolite

Chemistry is diverse in application but unified in content and approach. Learning, understanding and application of chemistry is a continuous activity to develop and enhance our knowledge of chemical processes and their molecular basis and the resulting impact on the technological advancements, the fruits of which man enjoys.

N. Lipscomb. Jr. Nobel Laureate (1976) [3] opined for a new kind of chemistry course because Chemistry is connected with the man's well-being, environment, resources, and energy for the long term future of humanity. Chemistry is a hopeful key to the deprivations and ills of human society: e.g., it provided a chemical fertilizer through ammonia synthesis (Haber's process), pesticide, D.D.T to combat the Minamata disease, introduced actinotherapy for cancer (discovery of Radium with its radioactivity by Madam Curie; incidentally let us remind ourselves that 2011 is IYC –International Year of Chemistry, the centenary year of Madam Curie's Nobel Prize in Chemistry).

Chemistry is a catalyst for development and is a service science to society, involved in every aspect of our daily life-food, housing, clothing, raw materials etc,[4]. The UNESCO document [5] ,UNESCO SC/631/03(1981) listed 18 types of problems facing mankind which may also be recognized as pertinent global challenges, namely, **sustainable living, sustainable energy and sustainable environment.** 67% of these problems are amenable to solution by science and technology. Students (knowledge seekers), teachers (knowledge dispensers) and researchers (knowledge promoters) need to get the awareness that chemical knowledge helps in the attempts to solve more than half of these problems.

Prior to 20th century the information in the subject of chemistry is mainly centered round objective observation to understand matter and its changes. That such information is rapidly increasing is evidenced by the following few examples:

(a) Chemical Abstracts service registers approximately 6000 new compounds weekly; (b)preparation of new catalysts, enzymes and organo-metallic compounds;

(c) computer designed synthesis of complex molecules;

(d) advances in instrumental methods of analysis, (the progress in this field is such that today we have computer guided analytical methodologies even);

(e) waste recycling processes;

(f) information about oceans as an alternative source of materials etc,. These are but a few representative examples.

Newly emerging fields like biotechnology, information technology and nanotechnology also add to the chemical knowledge in their own way.

Such a vast panorama of chemical information may be frustrating to have unified course content and may push any student and/or teacher to an enthusiastic cynic. But fortunately chemistry is amenable and has been systematized into branches and subunits. The system of organizing chemistry information is pushed a little forward to 'systems-thinking'. If implemented with appropriate understanding and with dedication this type (system-thinking) of chemical education is expected to change the enthusiastic cynics to enthusiastic realists if not enthusiastic believers.

The discovery and introduction of silicon chip and its use in computers has opened a new shift of efforts to more and more systemization of the ever increasing chemical information. The wonder silicon chip is changing in its capacity from a mere 1000 **bit** capacity in 1971 to that of a few billion gigabyte**s** today. In addition the speed of data handling also is increasing at an incredible rate.

At present computers are playing a significant role in learning, teaching and research in chemistry. We hear quite often the term CAD (computer aided design) not only in science but in many fields of human activity. The training in the use of computers start even in the primary school stage So students coming out with this background to higher level of studies do not have any problem with this new technology though teachers are yet to catch up with it. "Both, however, do have some predicament of the approach to the technique, namely, 'systems-thinking', i.e. an organized way of linking bits of information into networks, trees, modular systems, showing interrelationship between data[6] .The pace of development of appropriate software is not commensurate with the improvements in the sophisticated hardware made available, thanks to the contribution of the fiber optics to the communication system. It becomes, therefore, significant for those concerned with chemical education to be aware as to how to structure the chemical information and data into systems; as how to organize data into knowledge based on the interrelationships. The learner is given the basis of the new approach to the study of chemistry by way of systems-thinking. This approach puts the student to learn from one source and search for data from different sources. The subject material so gathered is used to search for interrelationships. Thus the student is enabled to develop his ability to synthesize data, to recognize the interrelationships and to evaluate both data and systems. The basic aim of such an approach is not simply to produce system but to encourage improvement of the analytical mind. For further reading refer to:

(a) Teaching Chemistry today: what do we aim for(loc.cit[6]);

(b) Computer assisted organic synthesis, Editors, W.T.Wipka and W.Jeffrey Howe,ACS sumposium series, 61, (1977);

(c) Computational chemistry using PC,Donald W.Rogers, 3rd edition, (2003), Wiley Interscience, John Wiley & Sons Inc.]

The example on optical brighteners (loc.cit{6}) is very illuminating with regard to chemical education on the lines of system-thinking and is instructive of the reorientation of the study by the student to apply what knowledge he gains about color, absorption and emission with fluorescence. Such an approach instills hope and purpose of the study to applicable chemistry in the field of the detergent industry. As a consequence of this the student of chemistry can be bold enough to reach out to the society around to say that he is useful to the community.

The traditional method of teaching chemistry prior to 20th century is chiefly concerned with collection of data regarding preparation, properties and uses of materials, which is mono-disciplinary with depth. The present day chemistry, on the other hand, needs to be multi-disciplinary with breadth involving the systems-thinking approach.

This new type of chemical education enables one to translate chemical information and knowledge from the research and industrial fields of activity to wisdom based applicable chemistry.

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