Concept Formation in School Laboratory: Analysis of a Chemistry Laboratory Curriculum

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Abstract— This paper attempts to delineate the nuances of chemistry laboratory curriculum in terms of its ability to impart chemistry concepts to the school students who opt the subject at senior secondary stage of schooling. The paper describes the structure of CBSE (Central Board of Secondary Education, India) chemistry syllabus of senior secondary school level and explains the related concepts that could be imparted with the help of the laboratory exercises, if effectively undertaken. The paper contends that teachers need to put in sincere efforts in order to make the subject more interesting and comprehensible; only then they would be able to check the downward pace of the chemistry education in our school system.

Key words: Concept Formation, CBSE Chemistry Laboratory

I. INTRODUCTION

Chemistry as a subject is generally perceived by the majority of students as a subject which is relatively a tough subject and requires a lot of mugging up drills in order to memorize the concepts that form the discipline of chemistry. This perception somehow leads one to develop an indifferent taste towards chemistry. The fact is - Chemistry stands at the pivot of science. It is known as the 'central science' because all other fields can relate back to chemistry. It helps us to understand the world around us, and that helps us to know what's going on and how to react to things. Chemists constantly experiment and prepare new substances for use in daily life. The list of the practical uses of chemistry is endless. All aspects of our life – food, clothing, shelter, hygiene, health, transportation, lighting, heating, entertainment, etc, are influenced by chemistry.

It is well known that chemistry is an experimental science which provides familiarity with the scientific method and in turn means doing something, observing, measuring, analyzing and describing. It also provides an opportunity to the teacher to teach chemistry as a way of investigation. Laboratory work is an essential component of chemistry curriculum. Students can be stuffed with facts and theories but without experiments they cannot experience the reality of chemistry as a science. The development of powers of observation, measurement, prediction, interpretation and decision making are dependent on laboratory work experience of students. But unfortunately at present chemistry is generally taught as a subject which calls for abstract thinking, writing long formulae and complex structures and handling complicated equipments. This method of teaching chemistry has discouraged both teachers as well as pupils. The main reason for this process is that the experiments which form a part of the syllabus are not relevant or interesting and are not related to the issues connected with the real life situations. Besides this, there are various constrains such as large teacher-pupil ratio in the class / laboratory, lack of physical facilities for performing experiments as required by the rigid and time-bound heavy syllabus.

Another reason that is the one of the root causes of the distaste towards chemistry is the lack of proper explanation regarding the subject-content and its application in our daily life. There is a serious lacking in the classroom processes regarding relating the laboratory exercises with the theoretical components of the subject as well as genuine efforts from teachers' side for acquainting the students with the laboratory experiences in chemistry and letting the students understand the implications of laboratory work in chemistry for the concept formation in chemistry.

This paper delineates the structure of chemistry syllabus of CBSE of class XI an XII and attempts to explain the concepts that could be better imparted with the help of chemistry laboratory exercises. This may prove to be helpful for all those who are related to the teaching of chemistry at school level.

II. STATUS OF THE PRESENT CBSE CHEMISTRY LABORATORY CURRICULUM AT +2 LEVEL

The CBSE Chemistry Laboratory Curriculum for +2 level is based on the recommendations of National Curriculum Framework-2005. The syllabus of chemistry practicals for classes XI and XII has been designed according to the disciplinary approach, as per the recommendations of NCF-2005. The +2 level CBSE chemistry course structure for both theory and practicals is almost similar to what has been prescribed by the NCERT, with a very little variation.

The evaluation scheme for + 2 level chemistry is a mix of theory and practicals, and internal as well as external examinations. Class XI examinations are conducted internally by the schools themselves. The Board (CBSE) conducts the external examinations at the end of Class XII. The total marks allotted for Chemistry is 100. Out of that, a written examination of 70 marks is conducted for theoretical component of chemistry course. The practical course in chemistry has been assigned 30 marks.

The chemistry laboratory curriculum has two components. There are core experiments to be undertaken by the students in the laboratory and these core experiments are part of external examination while each student is required to carry out one investigatory project and submit the report for the examination. The evaluation scheme for chemistry practical examinations for class XI and XII is given in the following tables:

Practicals	**Marks**
Volumetric Analysis	10
Salt Analysis	6
Content Based Experiments	4
Class Record and Viva	5
Investigatory Project	5
Total	**30**

Table 1: Evaluation Scheme for Examination in Chemistry Practicals (Class XI and XII)

The following tables 2.2 and 2.3 show the Unit wise syllabus and corresponding number of periods as prescribed by the CBSE, for chemistry experiments at + 2 level:

Experiment Units		Periods
A.	Basic Laboratory Techniques	2
B.	Characterization and Purification of Chemical Substances	6
C.	Experiments based on pH	6
D.	Chemical Equilibrium	4
E.	Quantitative estimation	16
F.	Qualitative analysis	16
G.	Detection of nitrogen, sulphur, chlorine, bromine and iodine in an organic compound.	10
PROJECT		10
Total Periods		**70**

Table 2: Chemistry Practicals Syllabus for Class XI

Experiment Units		Periods
A.	Surface Chemistry	6
B.	Chemical Kinetics	4
C.	Thermochemistry	4
D.	Electrochemistry	2
E.	Chromatography	2
F.	Preparation of Inorganic Compounds	4
G.	Preparation of Organic Compounds	4
H.	Tests for the functional groups present in organic compounds	6
I.	Characteristic tests of carbohydrates, fats and proteins in pure samples and their detection in given food stuffs.	4
J.	Determination of concentration /molarity of $KMnO_4$ solution by titrating it a gainst a standard solution of: (i) Oxalic acid, (ii) Ferrous ammonium sulphate	8
K.	Qualitative analysis: Determination of one cation and one anion in a given salt.	14
PROJECT		10
Total Periods		**68**

Table 3: Chemistry Practicals Syllabus for Class XII

III. Details of Experiments Suggested for Class XI

A. Basic Laboratory Techniques (Periods 2)

Under this section, basic laboratory techniques are described and explained, and students are supposed to exercise these laboratory skills. Two periods have been prescribed for this section.

1) Cutting glass tube and glass rod
2) Bending a glass tube
3) Drawing out a glass jet
4) Boring a cork

B. Characterization and Purification of Chemical Substances (Periods 6)

In this unit, students are required to learn the technique of crystallization for purification of a compound; and in order to check the purity of a compound, techniques of determination of melting point and boiling point are also described, which students are supposed to get exposed to. The following experiments are listed in this section:

1) Determination of melting point of an organic compound
2) Determination of boiling point of an organic compound
3) Crystallization of an impure sample of any one of the following: alum, copper sulphate, benzoic acid.

C. Experiments based on pH (Periods 6)

This unit provides experiments that help consolidating the concepts of self-ionization of water and pH of some solutions. Three experiments are prescribed for determination of pH out of which students are supposed to conduct one experiment. Besides, there is another experiment prescribed to study the pH change by common ion effect. The following experiments are listed in this section:

1) Students are required to do any one of the following experiments:

- Determination of pH of some solutions obtained from fruit juices, varied concentrations of acids, bases and salts using pH paper or universal indicator.
- Comparing the pH of solutions of strong and weak acids of same concentration.
- Study the pH change during the titration of strong and weak acids of a strong base using universal indicator.

2) Study of pH change by common-ion effect in case of weak acids and weak bases

D. Chemical Equilibrium (Periods 4)

In order to consolidate the concept of reversible reaction and irreversible reaction, two experiments have been given in this unit. Students are required to conduct any one of the following experiments:

1) Study the shift in equilibrium between ferric ions and thiocyanate ions by increasing/decreasing the concentration of either ions

2) Study the shift in equilibrium between $[Co(H2O)_6]^{2+}$ *and chloride ions by changing the concentration of either of the ions.*

E. Quantitative estimation (Periods 16)

In this unit, experiments are listed to acquaint students with technique of using chemical balance and preparation and determination of solutions using various methods of quantitative analysis. The following activity and experiments have been suggested under this category:

- Using a chemical balance.
- Preparation of standard solution of oxalic acid.
- Determination of strength of a given solution of sodium hydroxide by titrating it against standard solution of oxalic acid.
- Preparation of standard solution of sodium carbonate.
- Determination of strength of a given solution of hydrochloric acid by titrating it against standard sodium carbonate solution.

F. Qualitative Analysis (Periods 16)

Qualitative analysis involves a series of tests to identify and determine acidic and basic radicals in a given salts. In this unit, determination of one anion and one cation in a given salt, having composition from following anions and cations, has been prescribed.

Cations- Pb^{2+}, Cu^{2+}, As^{3+}, $A1^{3+}$, Fe^{3+}, Mn^{2+}, Ni^{2+}, Zn^{2+}, Co^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mg^{2+}, NH_4^+

Anions- CO_3^{2-}, S^{2-}, SO_3^{2-}, SO_4^{2-}, NO_2^-, NO_3^-, Cl^-, Br^-, I^-, PO_4^{3-}, $C_2O_4^{2-}$, CH_3COO^-

G. Detection of Nitrogen, Sulphur, Chlorine, Bromine and Iodine in an Organic Compound (Periods 10)

In this unit, students are required to conduct experiments pertaining to the detection of nitrogen, sulphur and halogens in organic compound. Ten periods have been prescribed for exercising these experiments.

H. Project (Periods 10)

In order to provide an opportunity to the student to get acquainted with the process of scientific investigation, project work has been added in the + 2 level chemistry laboratory curriculum. The following projects have been suggested to carry out scientific investigations involving laboratory testing and collecting information from other sources. However, students have been given flexibility to choose any other projects also, which involves about 10 periods of work, with the prior approval of the teacher.

1) Suggested Projects:

(i) Checking the bacterial contamination in drinking water by testing sulphide ion; (ii) Study of the methods of purification of water; (iii) Testing the hardness, presence of iron, fluoride, chloride etc. depending upon the regional variation in drinking water and study of causes of presences of these ions above permissible limit (if any); (iv) Investigation of the foaming capacity of different washing soaps and the effect of addition of sodium carbonate on it; (v) Study the acidity of different samples of tea leaves; (vi) Determination of the rate of evaporation of different liquids; (vii) Study the effect of acids and bases on the tensile strength of fibers; and (viii) Study of acidity of fruit and vegetable juices.

IV. Details of Experiments Suggested for Class XII

A. Surface Chemistry (Periods 6)

In this unit, experiments pertaining to colloidal solution and related concepts have been given. Students are required to perform the following experiments:

1) Preparation of one lyophilic and one lyophobic soln

- Lyophilic sol - starch, egg albumin and gum
- Lyophobic sol - aluminium hydroxide, ferric hydroxide, arsenous sulphide.

2) Study of the role of emulsifying agents in stabilizing the emulsions of different oils

B. Chemical Kinetics (Periods 4)

Under these content specific experiments, students are supposed to learn the technique of determining the rate of a reaction and technique of studying the effect of concentration and temperature on the reaction rate. The following experiments have been prescribed for the students in this unit:

1) Effect of concentration and temperature on the rate of reaction between sodium thiosulphate and hydrochloric acid.

2) Study of reaction rates of any one of the following:

- Reaction of iodide ion with hydrogen peroxide at room temperature using different concentration of iodide ions.
- Reaction between potassium iodate, (KIO_3) and sodium sulphite: (Na_2SO_3) using starch solution as indicator (clock reaction).

C. Thermochemistry (Periods 4)

Technique for measuring the enthalpy changes are given in the following experiments. Students are required to do any one of the following experiments:

- Enthalpy of dissolution of copper sulphate or potassium nitrate.
- Enthalpy of neutralization of strong acid (HC1) and strong base (NaOH)
- Determination of enthalpy changes during interaction between acetone and chloroform (hydrogen bond formation).

D. Electrochemistry (Period 2)

There is only one experiment prescribed in this unit: To study the variation of cell potential in $Zn/Zn^{2+}||Cu^{2+}/Cu$ with change in concentration of electrolytes ($CuSO_4$ or $ZnSO_4$) at room temperature. Total two periods have been assigned for this experiment.

E. Chromatography (Periods 2)

The technique of chromatography is vastly used for the separation, purification and identification of compounds. According to IUPAC, chromatography is a physical method of separation in which the components to be separated are distributed between two phases, one of which is stationary while the other moves in a definite direction. Following two experiments have been prescribed for students to various learn techniques of chromatography.

- Separation of pigments from extracts of leaves and flowers by paper chromatography and determination of R_f values.
- Separation of constituents present in an inorganic mixture containing two cations only (constituents having large difference in R_f values to be provided).

F. Preparation of Inorganic Compounds (Periods 4)

Following two experiments are listed to be conducted in this unit:

1) Preparation of double salt of ferrous ammonium sulphate or potash alum

2) Preparation of potassium ferric oxalate

G. Preparation of Organic Compounds (Periods 4)

Five experiments are given in this unit. Students are required to prepare any two of the following compounds: (i) Acetanilide, (ii) Di-benzal acetone, (iii) *p*-Nitroacetanilide, (iv) Aniline yellow or 2 - Naphthol aniline dye, and (v) Iodoform

H. Tests for the functional groups present in organic compounds: (Periods 6)

In this unit, experiments are prescribed in order to get students acquainted with various tests and techniques of identifying functional groups of organic compounds. The following functional groups are prescribed to be tested by performing various tests:

Unsaturation, alcoholic, phenolic, aldehydic, keton, carboxylic and amino (primary) groups.

I. Characteristic tests of carbohydrates, fats and proteins in pure samples and their detection in given food stuffs. (Periods 4)

In this unit, students are supposed to get familiar with various methods and techniques of detection of carbohydrates, fats and proteins in food stuff.

J. Determination of concentration / molarity of $KMnO_4$ solution (Periods 8)

The experiments listed in this unit supposedly help students revisit their understanding of redox reaction and related concepts. Students are required to perform experiment for determination of the strength / concentration / molarity of $KMnO_4$ solution by titrating it against a standard solution of:

- Oxalic acid,
- Ferrous ammonium sulphate

Students are required to prepare standard solutions by weighing themselves.

K. Qualitative analysis (Periods 14)

In this unit, determination of one anion and one cation in a given salt has been prescribed. Students are required to conduct a series of tests to identify and determine acidic and basic radicals in a given salts comprising radicals from the following list:

Cations: Pb^{2+}, Cu^{2+}, As^{3+}, Al^{3+}, Fe^{3+}, Mn^{2+}, Zn^{2+}, Co^{2+}, Ni^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mg^{2+}, NH_4^+

Anions: CO_3^{2-}, S^{2-}, SO_3^{2-}, SO_4^{2-}, NO_2^-, NO_3^-, Cl^-, Br^-, I^-, PO_4^{3-}, $C_2O_4^{2-}$, CH_3COO^-

L. Project (10 Periods)

The syllabus has listed a few suggest for students as the following. However, students have been given freedom to choose any investigatory project, which involves about 10 periods of work, with the prior approval of the teacher.

M. Suggested Projects:

(i) Study of the presence of oxalate ions in guava fruit at different stages of ripening; (ii) Study of quantity of casein present in different samples of milk; (iii) Preparation of soybean milk and its comparison with the natural milk with respect to curd formation, effect of temperature, etc.; (iv) Study of the effect of potassium bisulphate as food preservative under various conditions (temperature, concentration, time etc.); (v) Study of digestion of starch by salivary amylase and effect of pH and temperature on it; (vi) Comparative study of the rate of fermentation of following materials: wheat flour, gram flour, potato juice, carrot juice etc.; (vii) Extraction of essential oils present in Saunf (aniseed), Ajwain (carum), Illaichi (cardamom); and (viii) Study of common food adulterants in fat, oil, butter, sugar, turmeric powder, chilli powder and pepper.

V. Concepts to be Imparted by the Chemistry Laboratory Curriculum

Researcher analyzed the contents of the existing CBSE + 2 level chemistry syllabus (Theory papers) to identify the concepts which could be developed through laboratory exercises. The researcher further categorized the concepts into two parts – concepts which could be imparted or developed through the present practical curriculum, and concepts for which new laboratory exercises are to be designed. The following section presents the analysis of + 2 level chemistry syllabus to identify concepts that can be transacted through the existing chemistry laboratory curriculum as well as those for which new laboratory exercises could be designed to develop / strengthen them.

1) Concepts Which Could Be Imparted By the Existing +2 Chemistry Laboratory Curriculum

The activities listed in the existing chemistry laboratory curriculum of class XI could be used to explain the concepts such as: melting point, boiling point, crystallization, purification by crystallization, seeding, pH value, pH change, common-ion effect, self-ionization, reversible reactions, irreversible reactions, dynamic equilibrium, equilibrium constant, law of mass action, Le Chatelier principle, titration, acidimetry, alkalimetry, molarity, normality, qualitative analysis, quantitative analysis, and skills and tests associated with qualitative and quantitative analysis.

The following concepts of class XII chemistry syllabus were identified that could be transacted through the existing chemistry laboratory curriculum: dispersed phase, lyophilic solution, lyophobic solution, emulsion of oil in water, rate of reaction, clock reaction, order and molecularity of reaction, electrolysis, chromatography, retardation factor (R_f value), redox reaction, adsorption, complex compound, isomorphous substances, unsaturated compounds, functional groups of organic compounds and various tests to identify these functional groups, quantitative and qualitative analysis, and various skills and tests associated with it, polymers, biomolecules such as – carbohydrates, proteins, vitamins, and nucleic acids; and tests for their identification.

The following tables 4.4 and 4.5 present the lab exercises of the existing syllabus and the related concepts that could be developed by these exercises:

VI. Conclusion

As discussed above, if the concepts are already articulated by the teachers before starting the laboratory classes for the students, and then those concepts are clarified, explained and connected with the everyday experiences of the students, the chemistry teaching-learning experience would surely be an interesting and not so "boring" experience for the students. And this may have great bearings on the overall status of science education in country improving, eventually, the downward pace of the chemistry education in our school system.

Reference

[1] Adane, L. & Admas, A. (2011). Relevance and safety of Chemistry laboratory experiments from students' perspective: a case study at Jimma University,

southwestern Ethiopia, Educational Research (ISSN: 2141-5161) Vol. 2(12) pp. 1749-1758, December 2011. Southwestern Ethiopia: Department of Chemistry, Jimma University. http://www.interesjournals.org/ER

[2] Agrawal, D.P. (2003). Indian Chemistry Through The Ages. Retrieved on 15.12.2011 from: http://www.indianscience.org/essays/t_es_agraw_chemistry.shtml

[3] Ahuja, Amit (2006). Effectiveness of Concept Mapping in Learning of Science, Ph.D., Education. Delhi University. New Delhi.

[4] Almala, A. (2005). A constructivist conceptual framework for a quality e-learning environment. In Distance Learning, 2(5), 9-13.

[5] Black, P.J. & Ogborn, J. (1979). Laboratory work in undergraduate teaching. In McNally, D. (Ed.), Learning strategies in university science, Cardiff: University College Cardiff Press.

[6] Bodner, G.M. in: Theoretical Frameworks for research in chemistry/science education, 2006, pp. 2– 26, Upper Saddle River, NJ: Prentice Hall.

[7] Bodner, G.M. J. Chem. Ed., 1986, 63, 873–878.

[8] Bodner, G.M. M. Klobuchar and D. Geelen, J. Chem. Ed.,2001, 78, 1107-.

[9] Boud D.; Dunn J. & Hegarty-Hazel, E., (1986), Teaching in laboratories, Milton Keynes, Milton Keynes Open University Press.

[10] Byers, B. (2009). Innovative Methods in Teaching and Learning Chemistry in Higher Education, pp. 5 – 21, I. Eilks and B. Byers (Eds.), London: RSC.

[11] Carnduff, J. & Reid, N. (2003). Enhancing undergraduate chemistry laboratories, pre-laboratory and post-laboratory exercises, examples and advice. Education Department, Piccadilly, London: Royal Society of Chemistry, Burlington House.

[12] Erduran, S. (2003). Examining the Mismatch between Pupil and Teacher Knowledge in Acid-Base Chemistry. In School Science Review, v84 n308 p81-87 Mar 2003. Retrieved from ERIC database. (EJ666870)

[13] Gafoor, K. Abdul, and Narayan, Smitha. (2010). Students' Science Related Experiences, Interest in Science Topics and their Interrelation: Some Implications. In Joshi, R. & Sharma, A. (Eds.). School Science, March – June, 2010. (pp 54 – 63). New Delhi: NCERT

