

Micro-Scale Chemistry Laboratory Techniques at Senior Secondary School Level and Its Effectiveness

Dr. Gopal Krishna Thakur¹

¹Director (School of Education)

¹Noida International University, Greater Noida

Abstract— Micro-scale chemistry techniques are proving to be very useful for performing chemistry experiments in school laboratory. These are not just cost effective but also reduce wastage and health hazards. The techniques enable students to perform experiments in an environmentally safe and pollution free atmosphere using small quantities of chemicals without compromising the quality and standard of experiments. A typical micro-scale experiment consumes only, say less than 10% of the required quantity of reagents used in a corresponding traditional chemistry experiment. This paper presents the outcomes of a study that attempted to assess the effectiveness of the experiments in terms of students' understanding of chemistry related concepts and their overall achievement in chemistry subject. The paper discusses the result of the study and accentuates the economy model of micro-scale chemistry experiments and further delineates the educational implications of this technique for all the stake holders of school education.

Key words: Micro-scale chemistry, Space and Furniture Requirement, chemistry experiments

I. INTRODUCTION

Laboratory experiments are an integral part and essential features of chemistry teaching at all levels of education. The laboratory work in chemistry supports, enhances, and extends the concepts and principles presented in the classroom. They also provide students with the opportunity to learn and apply new laboratory skills, foster collaborative relationships with others, and improve problem-solving skills. Chemistry practical classes (experiments) are believed to help students in understanding theories and chemical principles which are difficult or abstract otherwise. Moreover, they offer several opportunities to students. Some of these opportunities include handling chemicals safely and with confidence, gain hands-on experience in using instruments and apparatus, develop scientific thinking and enthusiasm to chemistry, develop basic manipulative and problem solving skills, gain opportunities to students as investigators of the experimental work, identify chemical hazards and learn to assess and control risks associated with chemicals. Experiments in Chemistry significantly help students to understand theories and principles of chemistry. Moreover, in addition to consolidating theoretical knowledge of students, practical courses help students to identify and solve problems, learn how to handle chemicals, operate different instruments and apparatus. They also help to develop in students, scientific attitude and spirit of innovation.

In thinking of laboratory work, there are some important and inevitable issues. Students are not always best placed to see the relevance and importance of all the elements of their course. On the other hand, there is a tendency for teachers to think in terms of completing their syllabus rather than of meeting the students' needs. The laboratory part of the schooling always suffers in terms of

quality due to negligence and other priority shifts. If we look into the status of chemistry laboratory and its use particularly at school level, we find that the quality of our practical work is poor and our science laboratories continue to be underdeveloped educational resources. Students perform and complete a prescribed list of experiments, but these are done in a mechanical manner, and consequently they fail to excite and challenge them.

If we look at the evolution of school science in India, we see a clear trend of including more and more content – overwhelmingly in the form of factual information – in the syllabus. Laboratories have declined, and even demonstrations, once common, are now confined to elite schools. Thus the factual information that dominates the syllabi is not supported by any kind of activity, which can make it plausible or even comprehensible. Students therefore have no option but to memorize the facts. The consequence of this is that students find science not only difficult but also boring. As a result, the school education and eventually higher education is witnessing a growing trend of students' disinterests towards science subjects. One of the main reasons of this disinterest is lack of adequate provision of chemistry practical or experimental classes in schools. While the government schools lack of laboratory resources and chemicals, the private schools have their own reservations regarding spending money on laboratory expenses which demand recurring expenditures in terms of chemicals and glassware, i.e. apparatus and other laboratory instruments. This situation of unavailability of resources in Govt. schools and cost cutting in private schools leave students with very little scope of adequate practical experiences of laboratory experiments. Formalities are completed by conducting demonstration classes in laboratory by teachers themselves. By and large, the experiments have continued to be marginalized in school education, and have not been given due importance. In general, as discussed above, there is a crunch of financial resources for constructing a separate conventional chemistry laboratory in Govt. schools and unwillingness to spend more on labs by private school management. Increasing cost of chemicals, handling a large number of students, constraints in maintenance of equipment and accessories, recurring cost to replace the breakages, problems in disposal of waste, handling of toxic chemicals, etc. are some of the major contributing factors of this disappointing situation. However, with the introduction of micro-scale chemistry laboratory techniques, there have been efforts to answer these perturbing questions of unavailability of resources and lack of willingness. This development of micro-scale chemistry experiments characterizes the use of small quantity of chemicals and simple equipment. The concept was first introduced by D. W. Mayo, S. S. Butcher et. al. at Bowdoin College in Brunswick about 30 years ago. In India, NCERT significant work has been done to develop and improvise this technique.

II. WHAT IS MICRO SCALE CHEMISTRY?

The micro-scale chemistry laboratory techniques enable the students to perform experiments in an environmentally safe and pollution free atmosphere using small quantities of chemicals without compromising the quality and standard of experiments. The experiments can be performed quickly and are pollution and hazard free. Even smaller area is adequate for laboratory space and a few milligrams and drops of solutions are used in experiments. A typical micro-scale experiment consumes only, say less than 10% of the required quantity of reagents used in a corresponding traditional chemistry experiment. Thus it reduces expenditures chemical wastage and minimizes lab hazards.

III. THE PRESENT STUDY

In order to assess the effectiveness of the micro-scale chemistry techniques, a study was planned to be conducted on class XI students of a privately managed school of Gautam Buddha Nagar district of Uttar Pradesh. The researcher attempted to identify the concepts that could be transacted through the laboratory activities and took a stock of the prevailing facilities to transact the existing laboratory curriculum. This was followed by designing a chemistry laboratory curriculum filling the gaps as inferred from the analysis of the data received. The so designed chemistry laboratory experiments were tried out for the identified group of students. Two groups of chemistry students were randomly selected from class XI for this purpose. These two groups of students were randomly assigned as experimental and control groups. The designed chemistry laboratory curriculum was transacted on the experimental groups and the students of the control groups were taught by the conventional methods. The schedule of transacting the designed curriculum covered one academic session. At the end of the schedule, the experimental and control groups of both the classes were administered a test to assess students' achievement of desired objectives. The difference between mean scores was subjected to a test of statistical significance.

IV. BASIC TENETS OF MICRO-SCALE CHEMISTRY LABORATORY TECHNIQUES

Keeping the concerns discussed in the above section in the context of this study, the researcher attempted to develop a laboratory curriculum which could fill the gap between what exists and what ought to be there. The underlying tenets of developing the proposed chemistry laboratory curriculum were articulated as the following:

- The chemistry laboratory curriculum should be cost effective, i.e. economical in terms of cost of apparatus and chemicals to be used. It should have minimum recurring cost on resources.
- It should be environment friendly. The experiments should be less hazardous, and there should be less pollution, minimum chemical disposal as well as minimum wastage at source should be there.
- It should be teachers friendly, i.e. the time consumed in the laboratory process should be minimized so that teachers could get more time and be more comfortable in explaining concepts and managing overall laboratory sessions.

- It should be student friendly, i.e. students should be able to conduct experiments safely with minimum risk of accidents, handle apparatuses safely with minimum chances of breakage and feel at ease while experimenting.
- It should be school friendly, i.e. the curriculum should not put much additional load on infrastructure. The major inhibition of school management is to procure consumables in chemistry laboratory because of its cost factor.
- With the above considerations as the bases, a list chemistry laboratory experiments was designed incorporating useful laboratory activities from the existing CBSE chemistry laboratory curriculum, and adding a few more experiments in the proposed laboratory curriculum.

V. PROPOSED LIST OF MICRO-SCALE CHEMISTRY EXPERIMENTS

The consolidated list of proposed micro-scale laboratory experiments for class XI is as the following: (i) Determination of relative atomic mass; Determining the empirical formula of copper(II) oxide; (ii) Determination of melting point of an organic compound; (iii) Determination of boiling point of an organic compound; (iv) Crystallization of an impure sample of any one of the following: alum, copper sulphate, benzoic acid; (v) Determination of pH of some solutions obtained from fruit juices, varied concentrations of acids, bases and salts using pH paper or universal indicator; (vi) Study of pH change by common-ion effect in case of weak acids and weak bases; (vii) To investigate double Replacement Reactions; (viii) Study the shift in equilibrium between ferric ions and thiocyanate ions by increasing / decreasing the concentration of either ions; (ix) Enthalpy of dissolution of copper sulphate or potassium nitrate; (x) To determine the enthalpy of neutralisation of reaction between 1M HCl and 1M NaOH; (xi) A study of gaseous diffusion; (xii) Preparation of ammonium sulphate fertilizer; (xiii) Using a chemical balance; (xiv) Preparation of standard solution of oxalic acid; (xv) Determination of strength of a given solution of sodium hydroxide by titrating it against standard solution of oxalic acid; (xvi) Determination of one anion and one cation in a given salt; (xvii) Detection of nitrogen, sulphur, chlorine, bromine and iodine in an organic compound.

VI. FACILITIES REQUIRED FOR THE PROPOSED EXPERIMENTS

The facilities required for the designed chemistry laboratory experiments at + 2 levels did not pose any extra burden on schools except some new apparatus that too were very economical. The detail of the facilities required for conducting micro-scale chemistry laboratory is as the following:

VII. SPACE AND FURNITURE REQUIREMENT

The laboratory activities require as much space as may be convenient for the strength of students in the school. The ideal space requirement in our country is 30 – 35 sq. ft. per student. However, generally a laboratory hall of 825 sq. ft. area is acceptable for 42 students. In the laboratory, one demonstration table and students' practical tables or work

stations are required. For the proposed laboratory experiments, even the smaller room can serve the purpose. The room does not need to have pre-fixed facilities. Experiments can be conducted even with makeshift arrangement with a few tables in proportionate with the number of students. The apparatus and chemicals require smaller space for storage. Hence, there is not much requirement for furniture. Therefore, no additional burden on infrastructure is there.

VIII. APPARATUS REQUIREMENT

The apparatus required for conducting micro-scale experiments are as the following: Polyethylene dispensing bottles (squeeze type), Micro burettes; Micro Test Tube, Test Tube Holder, Test Tube Stand, Dropper with Rubber Bulb, Glass Rod and Stirring Rod, Spatula, Beaker (10 mL), Funnel, Dry Cell with Cell Holder, Torch Bulb with Holder, Beaker (50 mL), Measuring Cylinder (10 mL), W- Tube, Tripod, Kerosene Burner, Laboratory Stand – (1) Boss head, (2) G-Clamp, (3) M.S. Rod; Litmus Paper, Watch Glass, China Dish, Magnet (Bar), Thermometer (Laboratory), pH Paper, Micro Test Tube Brush, Dispensing Bottle, Vials, Double mouthed flask, Stop cock, Chromatographic Jar with Cork, Micro Filtration Unit, Micro Test Plate/Well plate, One way Key, Connecting Wire, Beam balance, Cotton wool, Wash Bottle, Pasteur Pipette (Dropper), Capillary Tube, PVC. Tubes, Scissor.

IX. REQUIRED CHEMICALS

The chemicals required for the proposed chemistry laboratory curriculum are the same as required by the conventional set up though in very little quantity. The advantage of the micro-scale laboratory technique is that it requires chemicals in milligrams and reagents in few drops to carry out the experiments. Therefore, the consumption of chemicals is drastically reduced to almost one tenth of that required in the conventional laboratory.

X. ANALYSIS OF DATA

The descriptive statistics of the post-test scores of the treatment group and the control group of classes XI are given in the following table:

Statistics	Treatment Group	Control Group
Mean	23.875	20.906
Standard Error	0.538	0.649
Median	24	22
Mode	27	23
Standard Deviation	3.045	3.675
Sample Variance	9.274	13.507
Kurtosis	-0.420	-0.573
Skewness	-0.472	-0.377
Range	12	13
Minimum	17	14
Maximum	29	27
Sum	764	669
Count (N)	32	32
Confidence Level (95.0%)	1.097967941	1.325049003

An examination of the descriptive statistics indicates that distributions of sample scores of the treatment group of class XI are approximately symmetrical. Though the result suggests that the distribution is slightly negatively skewed, i.e. the value of Mean (23.875) is less than Median (24) and the Median is less than the Mode (27); and the value of skewness is -0.473 . This suggests that the distribution is skewed to the left. However, with the value of 'skewness' between $-1/2$ and $+1/2$ (-0.473), the distribution appears to be approximately symmetric. The value of 'kurtosis' of the treatment group is -0.421 . This suggests that compared to a normal distribution, this sample is slightly 'platykurtic', and the peak of the distribution curve is just a bit shallower than the peak of a normal distribution.

Also, in the case of the distribution of treatment group scores, 62.5 % students fall between Mean ± 1 S.D. and 96.875 % students fall between Mean ± 2 S.D. This implies that 20 students fall between the Mean $\pm 1\sigma$ (i.e. between Mean value plus and minus first standard deviation value), which is just two observations less than the ideal value (22) of normal distribution. Thus it appears that the distribution of post-test scores of the treatment group is slightly skewed to the left yet nearly normal.

Similarly, the distribution of the post-test scores of the control group of class XI appears to be slightly skewed to the left with its Mean value (20.906) less than the Median (22), which is less than the Mode (23), and skewness as -0.378 . However, with the value of skewness as -0.378 and that of kurtosis as -0.573 , the distribution appears to be approximately symmetrical with its peak a bit shallower than the peak of a normal distribution.

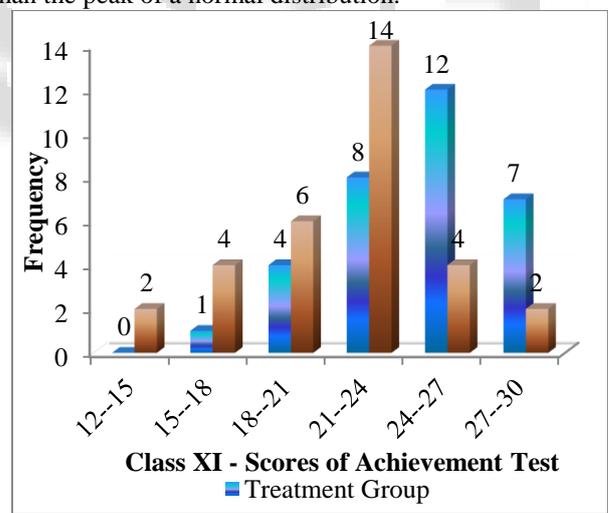


Fig. 1: Distribution of Scores of Treatment and Control Group

The result of the achievement test (Table 1) further indicates that the students of the treatment group performed slightly better in the test than those of the control group. The students of the treatment group of class XI obtained higher mean scores (23.875) than the students of control group (20.906).

XI. CONCLUSIONS

After the chemistry laboratory curriculum was designed and transacted on the randomly selected treatment group of + 2 level students, an achievement test was administered on the students of treatment group and control group. The result of

the achievement test was subjected to the test of statistical significance. A t-Test was performed to analyse the variance of the mean results of the treatment group and the control group. The result showed that the students who practised the laboratory activities of the proposed model chemistry laboratory curriculum, performed better than the students of control group. It can be concluded that the proposed micro-scale chemistry laboratory techniques proved to be more effective in enhancing students' performance in chemistry at + 2 level.

XII. IMPLICATIONS OF THE STUDY

The conclusions drawn on the basis of the study have the following implications for chemistry teachers, school administrators, and institutions / regulatory bodies (CBSE, NCERT, etc.) responsible for development and implementation of chemistry laboratory curriculum in schools.

XIII. IMPLICATIONS FOR TEACHERS

Teachers should give more emphasis on applications of chemistry related experiments rather mechanically following the conventional system of conducting practical works. They should look at the symptoms of the difficulty in chemistry practical work as their own problem and, through proper planning, prepare a programme of action to achieve the desired change through student centered laboratory activities. They should consciously help students to connect the theoretical concepts of chemistry with the laboratory activities and thereby make them able to appreciate the importance of chemistry in human life.

XIV. IMPLICATIONS FOR THE SCHOOL ADMINISTRATOR

The school administrator should ensure that the laboratory facilities are available at optimum level to provide adequate learning experiences to the students. In the light of the proposed chemistry laboratory curriculum, the consumption of chemicals in the laboratory is drastically reduced. So, they should adopt the new format of laboratory activities in order to have best use of available laboratory resources.

XV. IMPLICATIONS FOR THE CURRICULUM PLANNERS AND IMPLEMENTING AUTHORITIES

Sincere steps should be taken by the authorities to promote the adoption of micro-scale chemistry laboratory techniques in schools at all levels. Orientation programme in using micro-scale technique should be organized for chemistry teachers of senior secondary schools. A continuous and formative assessment system for chemistry practical works should be introduced for the + 2 level students instead of the existing summative format of assessment. There should be regular inspection of the physical conditions of the school laboratories since they play an important role in enhancing attitudes, stimulating interest and enjoyment, and motivating students to learn science.

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