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Laboratory Approach to Introductory Chemistry; A Discussion Group Report

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Approximately thirty members of MACTLAC[1], of those present at the tenth annual meeting at Cornell College, Mt. Vernon, Iowa, October 27-28, 1961 participated in a discussion of the functions of the introductory laboratory and the means by which they might be attained. The conclusions reached, though not presumed to be definitive, can serve as a point of departure for others interested in discussing this topic at a more leisurely pace than is possible during a short meeting.

To this end, a summary of the minutes of the discussion is presented here.

The introductory laboratory has four major functions:

I To generate a lively educated interest in chemistry, dependent upon the notion that though much is known, much more remains unknown.

For students majoring in the humanities, this interest should be largely intellectual.

For students majoring in science, pre-medicine and pre-engineering, this interest should be largely knowledgeable.

II To teach the student how to think systematically for himself. This includes:

How to ask a question of nature (in the laboratory).

How to design experiments to find answers.

How to read (texts, reference works), how to observe (in the laboratory), and how to record observations (in a laboratory record book).

Appreciation of the reliability of measurements.

Facility in using mathematics in order to obtain quantitative results from chemical data, the inter-relationship between chemistry and mathematics.

Interpretation of the results obtained.

III To understand that theory and fact are both important, but that theory depends upon fact; hence, in this sense, laboratory is synonymous with chemistry.

IV To acquire, retain, and use information concerning:

The chemical properties of selected elements and compounds.

Manipulative skills.

The habits and practices of safety.

Respect for reagents, as distinguished from the aspects related to safety.

In an effort to arrange these functions in order of importance, it was determined that any such arrangement depends upon the major curricular objectives of the students concerned and upon the nature of the understanding of chemistry which is possessed by a non-chemist colleague with whom these functions might be discussed, and the consequent necessity for emphasizing one function or another in such instances. Restated, all of these functions are, in practice, inter-related and cannot be separated in a practical sense. The separation implied in the above listing is an abstract separation.

The group noted five approaches which can be used to fulfill one or more of the functions. Again, in practice, an assigned experiment would often incorporate more than one of these approaches simultaneously or consecutively. (No importance is attached to the order of listing.)

A. The student is given specific directions and notes his observed results and makes his calculations on a printed page in appropriate blank spaces.

B. The student is given an unknown, which is known to the instructor, and is asked to determine constituents or composition, or both.

C. The student is directed to perform certain manipulations and observe the phenomena which ensue. Either of two actions then follow.

1. The student is asked to account for these phenomena by postulating a hypothesis (which he usually can find in a text or reference work) and then to devise and carry out a method to test his hypothesis (which usually requires that he locate two or more related laboratory procedures from the literature and modify these to suit his unique needs).
2. The student is asked to devise and carry out a procedure which will yield quantitative data which can be related in a meaningful way to the original phenomena. (For example, what is the molecular weight of compound X? How much carbon dioxide is present in a bottle of soft drink?)

D. Identical with C (above) except that the student is required to rely upon what he has previously learned (and remembered) from the classroom and from related prior experimental exercises; he cannot refer to the literature.

E. The student is asked to synthesize a compound, organic or inorganic.

The approach described as A, above, is probably used more than any of the others. It is particularly suited to the requirements implicit in function IV (information), especially those dealing with manipulation and measurement. Often, it is hopefully assumed that the student learns about the properties of the elements and compounds he studies in this manner. It is well known that this approach is the most economical in terms of staff time per student enrolled. Perhaps, it is the most expensive in terms of staff time per student who learns. Also, it is well known that this approach can impart a distaste for chemistry and that it does not give the student a true notion of what chemistry is. Soon, with the now realizable improvement in high school laboratory chemistry, it may become difficult to use this approach for the introductory college laboratory. Nevertheless, economical considerations seem to preclude more than a minor use of the other approaches in institutions with large freshmen enrollments.

It was suggested (and this is considered to be one of the most important practical results of the discussion) that many of the defects of the cook-book approach could be remedied by using a seminar-like discussion period, in conjunction with but separate from the laboratory work, in which reasons why certain manipulative steps were performed are examined, detailed observations are considered, results are interpreted, and other matters similarly treated, by a critical evaluation, conducted by the students, led by the instructor.

The use of qualitative and quantitative unknowns, unless these are used in an exclusively cook-book fashion, probably fulfills functions I and IV (generation of interest, information) effectively. Additionally, it tends to prevent guessing and outright falsification of data; it encourages the student to view his results objectively.

The research approach, C or D, above, probably is the most desirable from an ideal point of view, since it simulates, at the level of the beginning student, the activities of the practicing chemist. However, though students do indeed acquire information when this approach is used, it is not always applicable to the topics curently being discussed in the classroom. (Correlation of lecture and laboratory work was not discussed, except briefly. Some prefer to emphasize correlation; some prefer to consider a topic twice, since a second encounter can serve as a brief review. This question should be examined in detail by others.) Hence, this approach probably fulfills all the functions, with the qualification that it is weakest in imparting specific information at a specific time, and that the approach identified as D, above, does not impart new information, whereas this is the particular advantage of the approach identified as C, above. It is the most expensive in terms of staff time but it also is the approach most likely to insure that students who are enrolled in the laboratory course have learned.

Synthetic exercises can fulfill all four functions, unless the procedure is lifted directly from the printed page with no attempt by the student to adapt, modify, or question, although it probably is weakest in fulfilling function IV (information) in that the information learned is usually restricted in scope.

Probably, the best practical solution to instruction in the introductory laboratory is to use two or more of the approaches, proportioning the emphasis in accordance with the instructor's opinion of the relative importance of the four functions, interpreted in terms of the probable future curricular plans of his students.

Various techniques can be used, whatever the decision concerning the use of two or more approaches may be. Of these, the use of teams consisting of two or more students, audio-visual aids, and programed instruction were briefly mentioned. This aspect should be studied in detail by others. In the brief time available, problems due to the non-contributing member of a team, the necessity for supplementing material learned by the use of audio-visual aids and by programed instruction were noted.

Evaluation of laboratory work, the use of laboratory-bench examinations, and course grades were mentioned but not discussed. These important matters should be considered in any appraisal which purports to be complete.

The group expressed a desire to record its recommendation of a minimum of three to four hours of introductory laboratory, per week, for an academic year. Many felt that more time should be available.

Problems connected with the use of undergraduate, and graduate, laboratory assistants were briefly considered. As a beginning for discussion by others, these points were noted:

Rapport between the students and the assistant is probably the single most important factor. Unless a harmonious relationship is established and maintained, desirable results will be at a minimum no matter how close other aspects of the laboratory approach the ideal. The ability of an assistant to perform satisfactorily is hampered when he does not himself know the specific objectives of each assigned experiment; to be effective, he must be instructed in these matters. Problems which arise in the handling of students, and in instructing them in the laboratory, are new to the assistant, and he can be helped by discussions of actual, typical, examples of problems in these two areas which have arisen in the past and their solution. Also, assistants are not yet teachers, and they tend to think that a good teacher knows how to answer questions which students raise during their laboratory work. It is desirable that assistants realize that a good teacher is characterized by his skill in not answering questions raised by students, and by his ability instead to suggest meaningful related questions to the puzzled student.

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[1] Midwestern Association of Chemistry Teachers in Liberal Arts Colleges