DISCUSSION AND CORRESPONDENCE

LABORATORY INSTRUCTION IN CHEMISTRY; ITS AIMS AND ITS LIMITATIONS

It is now well over half a century since the laboratory has been regarded as a necessary feature in the study of science—elementary as well as advanced. Before that laboratory methods of instruction were rarely practised and were available only for the exceptionally fortunate, or probably exceptionally able, student who had first demonstrated in a purely intellectual way his aptitude for science.

The greatness of the achievement of the brilliant scientific men before, say the middle of the nineteenth century, with poor facilities for work, and inadequate knowledge upon which to build, certainly furnishes an argument that intellect may be stimulated rather than discouraged by lack of practical facilities.

The question must present itself to every one connected with training students in scientific schools, to what extent expensive laboratory facilities are justified, particularly for the great numbers of elementary students, when compared with the results achieved. No one will argue that direct observation of scientific phenomena in experiments performed with the student's own hands does not increase the student's familiarity with the phenomena. Perhaps we might say that the impression made upon the student's mind by a personally performed experiment is so much more vivid than the impression made by a written statement in a text-book, or even by an experiment performed by the professor on the lecture table, that the phenomenon is remembered with much less intellectual effort. Since however progress is attained only through the expenditure of effort, we may well ask, will the student of science reach as high a plane of intellectual development if the laboratory is used too freely for demonstration purposes.

The writer acknowledges as the immediate stimulus to present these thoughts, the article in Science of May 30, 1919 (page 506) upon "The Freas System," written by Dr. W. L. Estabrooke.

The Freas System is obviously a recognition of the problem of balancing the costs of laboratory instruction against the results. It is to be hoped that further details of this system promised by the writer will bring its advantages fully to the knowledge of those who have the administration of the laboratories of our schools and colleges. Certain rather broad aspects of the question are suggested by the first article and it is to be hoped that they will be discussed by the advocate of the Freas System.

The Freas System seems to be a species of modern factory efficiency management applied to laboratory administration. There can be no doubt that all possible efficiency in obtaining, distributing and conserving laboratory supplies and apparatus is to be desired, nor is there any doubt that without careful planning and a capable administrator in charge the efficiency will be low. But how far will the enthusiasm for efficiency in handling supplies tend to reduce the instruction to a lifeless routine. It would almost seem as if in the Freas plan the structure of the laboratory course had been built around the framework of the system of supply distribution. For we are told that at the beginning of a term the student receives supplies exactly sufficient for a whole term's work in a carefully planned kit. Such a kit contains for some of the courses as many as 140 different bottles of materials.

Modern American factory methods are marvelous when measured by the material output, but they do not rank so high when measured in terms of the welfare of the individual worker. Perhaps the solution of the factory-labor problem will recognize that the welfare and happiness of the individual workers is the framework around which the structure of industry must be built. No educator thinks other than that intellectual development is the aim to which educational effort must be directed. The writer does not see how a standardized routine of laboratory experiments can stimulate the intellectual development of a student any more than the intensive drive of production in a textile mill can stimulate the joy of life in the worker standing day after day in the same place over noisy looms.

The primary purpose of the experimental laboratory was to carry out original investigations. It is well not to lose sight of the fact that the laboratory of elementary chemistry can appear to the beginning student a place of original investigation. Indeed it is probably safe to say that the amount of intellectual stimulus he receives in the laboratory is in direct proportion to the extent to which he takes the attitude of an investigator.

It is more often the case than not that after a student has performed a routine experiment in a routine manner, he will retain of it so vague a recollection that he will be unable to relate his observations the next day in the class room. When however the experiment has developed some unexpected feature which perplexes him enough to incite him to try out variations of the experiment upon his own initiative, he will be found full of information and argument in the class room.

Elementary experiments may be classified into two kinds: (1) isolated short experiments, and (2) sustained experiments. The short experiments may be planned in a beautiful sequence, each building on the results of the preceding ones in a manner to arouse the admiration of an instructor. Yet to the student they seem just isolated experiments and he is only too likely to receive the impression that the standard of his work is measured by the number performed. Even when the student is above the average of intelligence and sees pretty clearly the sequence as planned by the instructor, he still does not develop very much enthusiasm for a thing which has been all planned out for him.

(2) The type of experiment referred to as sustained is illustrated by the "unknowns" of qualitative analysis, and by chemical preparations. In each of these cases there is a definite objective set to work toward, the work is prolonged enough to awake a sustained interest, and there is a tangible result obtained when the experiment is finished. Moreover, the manipulations require judgment and develop incidental problems not foreseen in the directions.

The writer believes that efficiency methods which increase the output of material products of an industry are not directly applicable to the development of intelligence. True, the Freas method may double the number of experiments which the student will perform in a laboratory period. But can we measure the development of the student by the number of experiments performed any more than we can measure the happiness of the mill operative by the number of yards of fabric which he can get through his looms in a day.

Scientific research is in its nature inefficient if judged in terms of the formulas of production experts. Yet research is recognized by large industries as a vital part of their organization.

The value of laboratory work depends mostly on the extent to which the students feel the research spirit—even if in but a very feeble way in elementary laboratories. The acquiring of manipulative skill and the learning of properties which are better stated in the textbooks than they can be observed by the student, are for the most part incidental to the more important purposes. To encourage this spirit of research, reagents must be available on the side shelves for free use within reasonable bounds. In fact a well-stocked outfit of reagent shelves serves as a chemical museum and time spent in going to these shelves, inspecting the chemicals there, and sometimes in trying out reactions not specified in the directions, is surely not time wasted. Naturally the student should be expected to work industriously during laboratory time and he should perhaps be expected to perform at least a certain minimum number of "required" experiments. But he should not be continually driven to realize the highest value of the ratio of experiments done to length of laboratory period. He should rather be distinctly encouraged to work thoughtfully and be made to feel that quality is given more recognition than mere quantity.

At all events there must be a compromise in elementary laboratories handling large classes, between efficiency of the supply service on the one hand, and the scientific inspiration to the individual student on the other hand. It is hard to see how cut and dried laboratory experiments, with all materials measured out in advance ready to be put together, can interest an intelligent student so much as experiments performed on the lecture table.

The writer realizes that many will deem him guilty of heresy even for putting the question: Do we give too much laboratory work in our science courses? If it becomes necessary on account of expense to so standardize the laboratory work that it loses nearly all its stimulus, were it not better to omit laboratory from the program until at least the point is reached where experiments described earlier as of the sustained type apply?

Some students are at school or college for a general liberal education—not to specialize in science. How shall they be treated if they elect to study the elements of chemistry? Is the expense of even a standardized and denatured laboratory course justified? When chemistry is chosen mainly for the object of intellectual development does not the class room work without the laboratory serve the purpose? Indeed does it not require a higher order of intelligence to visualize a chemical phenomenon from a text-book statement alone, than from a laboratory demonstration?

The writer has ventured to raise questions in the foregoing some of which have an obvious answer, others of which have been viewed for more than a generation in a uniform dogmatic manner, but ought now to be reopened and reconsidered on their real merits. The Freas System involves these questions, and it constitutes a compromise between two unreconcilable conditions. So far as the evidence presented in the article referred to goes, it seems like the case in which the compromise was effected by one party acceding to all the demands of the other. However, a misconception may have been gained from the first article of the series and the other numbers should be awaited with interest.

Furthermore, if an issue seems capable of adjustment only through an unsatisfactory compromise, is it not the part of wisdom to reexamine the conditions underlying the issue to see if perhaps the issue itself ought not be reconstructed in such a manner as to avoid the necessity of a compromise.

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METEOROLOGY AND THE TRANS-ATLANTIC FLIGHT

Within the past few months many millions of people have had their attention directed, as never before, to the importance of meteorological conditions in connection with the question of trans-Atlantic flight. A popular interest has thus been aroused which has been but partially satisfied by the often contradictory and usually rather meager information supplied by the daily newspapers. Many persons doubtless have a real desire to inform themselves more fully in regard to the weather conditions which are likely to be met with at various altitudes over the North Atlantic Ocean. A recent paper on "Trans-Atlantic Flight from the Meteorologists' Point of View"[1] brings together, in compact form, just the sort of information of which the intelligent public is in search. The author, Willis R. Gregg, of the Weather Bureau, was actively concerned as a meteorological expert in connection with the flight of the U. S. Navy planes. The fact that Mr. Gregg's article was in print before the recent trans-Atlantic flights were accomplished does not in any way detract from its interest or value.

Mr. Gregg's chief conclusions are as follows: Favorable conditions of wind and weather are necessary for the safety of airplanes which attempt the trans-Atlantic flight. In order to obtain the requisite knowledge of the prevailing atmospheric conditions, frequent and widely-distributed observations are necessary. When a favorable day comes, the meteorological expert can indicate the successive directions toward which the airplane should be headed in order to keep to any desired course, and can also calculate the assistance which the winds will furnish. Favorable conditions for an eastward crossing are found at 500–1,000

[1] *Mo. Wea. Rev.*, Vol. 47, 1919, pp. 65–75.