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AN INDIVIDUATED APPROACH TO LABORATORY-BASED INDEPENDENT STUDY

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The concept, flexible program possibilities and external resources of Empire State College, the new non-residential college of the State University of New York,[2] offers excellent opportunities for new and novel approaches to teaching chemistry. Two of the fundamental assumptions of Empire State's programs are that learning can be pursued by student independent work in non-traditional collegiate settings, and that this work can be done at times and in ways which are commensurate with the students' needs, purposes and prior experience. In science education, the merits of laboratory experience in the learning process has long been recognized. The rationale for this recognition is not simply the obvious one of developing techniques, but moreso, to instill insight into the inductive nature of the physical sciences. Within this framework, we are attempting to develop a program for laboratory-based independent study projects. Students for whom such a program is ideally suited are laboratory technicians, high school science teachers, and others who may have free access to a laboratory to pursue their projects. Although these conditions may not be applicable to large numbers of students, one must recognize that the programs of Empire State College and similar institutions are committed to respect the individuality and special needs of each student. One of the reasons for the rapid growth of this type of institution is precisely the increasing demand for individualized and independent approaches to learning, especially in connection with the education and retraining of adults.

A course developed for these purposes was one in organic analysis by the systematic identification of organic compounds. Our approach is similar to that described in the text by Shriner, Fuson and Curtin,[3] and we take from it the following quotation to describe the rationale of the approach and its ideality for independent study.

> The importance of this type of course in the training of the chemist is now universally recognized. The ability to identify compounds - valuable as it is to organic chemists - is, however, not the primary reason for the great popularity of laboratory courses in the subject. The great difference between this and other types of laboratory courses usually included in chemical curricula is that as yet no scheme has been devised which reduces this work to the mere following of directions. At every step in the identification of compounds by present methods, the student is required to exercise his own judgment. The student's faculty for careful observation, his ability to make correct deductions from his observations,

and his originality in planning his work are at a premium in this type of course.

The instructional module which we developed required the student to have reasonable access to laboratory facilities. However, within that requirement, there is a good deal of flexibility. The first student who undertook this independent study project was a high school science teacher, who found that her typical high school chemistry laboratory was generally adequate for the purpose. We will use the work of this student to illustrate the application of the module.

The first stage of the project consisted of having the student familiarize herself with the subject matter and plan for implementing the laboratory work. In addition to the assignment of a number of standard texts, she was also provided with a set of supplementary notes and laboratory aids. A large part of this step required exercise of the student's judgment in ascertaining which reagents and apparatus were absolutely necessary and which were not. Surprisingly, the standard reagents available in high school chemistry laboratories satisfied the vast majority of the minimum requirements. Loans of equipment and small quantities of specialty reagents from nearby universities were also a great asset. At this stage, as with all subsequent stages, the student was free to consult with her project tutor. Emphasis was placed, however, on establishing the student's independence in both planning and implementing the project.

The second step of the project consisted of having the student identify a number of unknowns which were provided by the tutor. The student was given three unknown pure compounds [Pinacol (a glycol), oxalic acid and menthol (an alcohol)] to identify, and a mixture of three unknowns [1-bromopropane, o-Iodobenzoic acid and triphenylamine] whose components are to be separated and identified. The choice of unknowns was based on providing a variety of different classes of compounds in order that the student experience a wide range of experimental techniques and procedures. Obviously, attempt was also made to accommodate what was within the realm of the student's capability and available laboratory facility. The student's performance was judged not merely on the basis of the number of unknowns correctly identified, but rather on her resourcefulness and ability in attempting to identify each unknown and moreso, on the manner (i.e., scientific judgments, deductive processes, etc.) in which each problem was carried out.

For the third set of activities, the student was to choose one common organic household product (e.g., a cologne, medicine, cleaning agent, etc.) and to attempt to characterize the product by separating the various components and identifying them. The degree to which the product is characterized obviously depends on both the combination of chosen products and the student's ability. Most products consist of a simple major component, e.g. alcohol or petroleum distillates, and small amounts of other compounds. Some of these minor components can be very complex and/or can be present in only very small quantities, making them much more difficult to characterize. The student's success with these minor components provides the real challenge to her capabilities. Our first student chose a popular water soluble linament which was a good choice from an instructional point of view since it contained a substantial number of different functional group classes of compounds and it required a separation scheme different from that previously used in her unknown mixture. In addition to discovering that the major portion of the product was simply water, she ascertained that it contained small quantities of an acidic compound (possibly a phenol or enol), an amine, methyl salicylate (oil of wintergreen) and possibly a colored weak base. Although the student was unable to unequivocally identify each component which was separated, or for that matter guarantee that any one fraction was a single component, this was a fairly good characterization. The partial identifications which were obtained provided a considerable amount of general information on the components in the product. Furthermore, this exercise most assuredly gave the student a healthy respect for organic analysis.

The fourth and last part of the project consisted of supplementing the laboratory work with written gedanken analyses. That is, since there would undoubtedly have been a number of experiments which the student would have been unable to perform because of lack of facilities, she was given written descriptions of typical laboratory results and was expected to piece together these results and draw the necessary conclusions to make a correct identification. A typical example follows:

> Liquid compound A, an optically active hydrocarbon, burned with a sooty flame and gave 0.67 $C-CH_3$ determination (Kuhn-Roth method). On careful oxidation with neutral potassium permanganate solution, it was converted into solid acidic compound B, which had a neutralization equivalent of 95±3 and was also optically active. On more vigorous oxidation with hot alkaline potassium permanganate solution, compounds A and B each gave rise to solid acidic compound C. Compound C gave a neutralization equivalent of 85±3, was optically inactive and could not be resolved into optically active isomers. On being heated above its melting point, compound C was converted into neutral compound D, which in turn could be reconverted into compound C by either mild acid or base treatment. Give structural formulae for compounds A through D inclusive, demonstrating the mode of attack and reasoning involved in deducing the structures from the experimental data given.

The above example utilizes experimental information on optical rotation and Kuhn-Roth $C-CH_3$ determinations which the student may not otherwise become exposed to. Further examples can be found in Chapters 12 and 13 of Shriner, et al.[3] The extensiveness of this last section of the project will depend to a large part on the previous experimental work carried out by the student, and should attempt to complement and supplement this preceding work.

Obviously, this type of laboratory-based instructional program is not restricted to just a project in organic analysis. Similar programs could be employed in virtually any other field of chemistry, or for that matter in many other areas of science. For example, one could envision projects in chemical soil testing or aquatic microbiology in which the student would plan and conduct a limited survey and be responsible for all sample collection and subsequent analyses and examinations. Both of these projects could be implemented by students with little background training given access to suitable but modest laboratories. For those who are not enrolled in professionally-oriented programs, this type of laboratory-based independent study could make chemistry and science more meaningful than would the conventional more traditional curricula.

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References and Footnotes:

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[2] "Empire State College, University Without Walls: New Venture in Higher Education," U.S. News and World Report, 73, No. 14, 64 (Oct. 2, 1972); Current, No. 146, 40 (Dec., 1972).

[3] Shriner, R. L., Fuson, R. C. and Curtin, D. Y., "The Systematic Identification of Organic Compounds," Fifth Ed., Wiley, N.Y., 1964.