RESEARCH OR TEACHING--RESEARCH AND TEACHING--RESEARCH IN TEACHING

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It is appropriate that a conference called for the purpose of considering how "the teaching of chemistry in liberal arts colleges may be improved" be held under the sponsorship of Monmouth College, now celebrating its first century of outstanding service to the young people of its constituency. It is even more appropriate in the light of the high quality of the teaching in the Monmouth Chemistry Department over the last quarter century. Professor Haldeman and Professor Thiessen and the administration of Monmouth College remind me just a little of the bon mot which was first tossed out by the Democrats in the recent campaign: "You've never had it so good." and the reply of the Republicans: "Maybe so, but it can be a lot better." I've used considerable poetic license in my quotations, as you will all recognize, but nevertheless such political repartee is more useful as a watch word for this conference than it was in the campaign.

I have undertaken to consider this evening the way in which the general subject of research might fit into our program. I must apologize for the laborious title listed in the preliminary program. Some time back, I was sitting in a conference room on the 23rd floor of the Shell Building in San Francisco when my secretary reached me from Appleton to tell me that Professor Haldeman wanted a subject for the program and he wanted it in a hurry, so I tried to pull my thoughts away from redwood to Monmouth and this conference. On returning home and reading what I had too quickly passed on to Monmouth via Appleton, I was most unhappy.

What I really want to talk about is the paradox which faces the college chemistry teacher when he listens to people talking about research and then considers his own teaching assignment. I speak in part from personal experience of 25 years ago, but I know that the conditions of the twenties and the fifties are much the same. I'm forced to this conclusion after hearing of the contents of a paper on the teaching load of college chemistry teachers presented recently by D. G. Nicholson of the Fisher Scientific Company on the teaching load of the chemistry professor in the average small college. He mentioned one of my friends who had a teaching load of 30 hours a week.

The paradox to which I referred may be stated in a few phrases, and these are the real subject of this talk. As the college chemistry teacher looks at research he is faced with three alternatives,

Research or Teaching, Research and Teaching,
or Research in Teaching.

Before discussing these alternatives, it might be a good idea for me to define the term "research" as I would apply it in the college chemistry department. "Research" is a process of planning and doing and recording whereby some little known or imperfectly understood phenomenon of our environment is brought more sharply into focus. Since we are talking about research and chemistry, some portion of the research might be expected to deal with the operations of chemistry, but this is not essential to the application under discussion. It makes no difference whether the process be small or large, relatively insignificant or extremely important. The means used, the reproducible experiment, is

always the same. The research process in all its ramifications can only be taught by one who does research. It is not amenable to the lecture method, nor can it long be shared as a vicarious experience. The uninitiated learns by first participating and then by doing. The younger he begins, the better it is. Lavoisier at 23 was awarded a special gold medal designated by the King of France for the best theoretical paper presented before the Academy of Science dealing with the lighting of the streets of Paris. At the age of 22, he presented his first paper, "The Analysis of Gypsum," to the Academy.*

But now to return to our alternatives. The first was Research or Teaching. I suppose it is this alternative which is followed by the majority of the chemistry teachers in the liberal arts colleges of the country, and they always choose to follow the teaching part of the alternative. Research alone is a luxury rarely allowed to the members of the staffs of the liberal arts colleges, especially the colleges of this section of the United States. It is possible in some universities, and there it is tempered by the fact that such a select individual may have to handle one or more graduate students.

If we believe with Dean Elvehjem of the University of Wisconsin that all "good teachers need the research experience. It broadens their knowledge, enables them to bring up-to-date ideas to the students." and further that we are concerned here with better teaching, then we have to look with suspicion on the first alternative.

*S. J. French. Torch and Crucible, p. 28. Princeton University Press, 1941.

The second choice is Research and Teaching. Not too large a percentage of our chemistry teachers apparently have adopted this slogan, if we are to take stock in the chemical publication record of the liberal arts colleges. In a recent article, Professor Sampey* of Furman University has analyzed the published reports appearing in the Journal of the American Chemical Society. He has this to say: "We are forced to conclude that the research published by teachers in liberal arts colleges occupies a place of negligible importance in the program of such undergraduate teachers. By Sampey's calculations, the liberal arts college publication in the Journal of the American Chemical Society was only 1.7% of the total material published during the 15 years preceding World War II. In some ways it seems as though there is less being done today than there was 40 years ago. Some time back I had occasion to compare the research output of the three men composing the chemistry staff of my college, Wesleyan University, during 1909 (my sophomore year) with the total output of the liberal arts colleges as given by Sampey. Those three men published from the laboratories of Wesleyan University the remarkable number of 69 pages of research in a wide variety of technical subjects compared with the average 82-page yearly output of the top ten colleges together in the 15 year pre-World War II period. Maybe it had something to do with the fact that all three were research minded--two going on to become authorities in the fields of potassium and rubber whereas the third went on into a successful career of university research. There were not too many opportunities in the chemical industry in that year, hence teaching positions provided facilities and equipment where he who would research could. I am sure that the teaching

*J. R. Sampey. J. of Higher Education, XX, pp. 208-210(April, 1949).

loads were no lighter and equally sure that the faculty in those days were just as interested in the students. Possibly they were on fewer faculty committees, and I am rather certain the faculty were not writing and rewriting the aims and objectives of the college for insertion in the catalog. I think that faculty members of that day believed that a college was a place devoted to the purpose of training students and that the teacher was the judge of what he taught and how he taught it. Life on the campus may have been less complex. There must have been such things as lecture courses and artist series but I cannot recall, at this distance in time, having attended either (with the exception of the annual concert of the Glee and Mandolin Club). I remember further that the laboratories were opened and lit up at night for the use of either staff or students, and the last light to be turned off was the one in the chemistry library. There are old fashioned colleges where this same situation still exists--some represented here, more power to them.

There is of course more research being carried out by college instructors than appears in the pages of the Journal of the American Society. Mattill* in a recent article summarizes the survey project undertaken by the Engineering College Research Council dealing with American college and university research resources. The extent of participation in chemical research by college and university teaching personnel will be found in Table 2 of Mattill's article. Out of almost 1000 institutions, 104 universities report that only 89% of qualified faculty have research in progress. For 93 smaller universities, the figure is 62%, while for 279 liberal arts colleges less than half of qualified

*Mattill, John L. J. Chem. Ed. 29, no. 11:556-559(Nov., 1952).

faculty (48%) are currently not engaged in research. Some 750 colleges and universities responded to the questionnaire so it seems probable that an additional 200-300 colleges have no research at all going in the physical science fields. Much of this research is either not published or, if published, is distributed throughout a number of technical magazines apart from those published by the American Chemical Society. A rapid check of the 1951 Journal of the American Chemical Society, Industrial and Engineering Chemistry, and the Journal of Organic Chemistry showed that less than one per cent of the pages of publication during that period was emanating from the liberal arts colleges.

I would like to spend a little time expanding on the possibilities and opportunities for Research and Teaching. I believe we are coming into a period when more money will be available from agencies and industrial sources to support such college research. The grants already made over the years to some 250 institutions in 48 states (many to liberal arts colleges) by the Research Corporation alone would seem to indicate that for the period covered by the donations of the corporation there has been research activity in certain college circles. I know that Monmouth, Grinnell, and many others represented here received this encouragement and support.

There are a number of other ways of handling and financing research in colleges. A few of my friends synthesize new compounds for the fine organic chemical industry. Programs of this kind are flexible enough to fit the researcher's schedule. A number of companies carry on continuous screening programs for compounds of medicinal value and welcome the opportunity for testing new compounds. One modification of this is to use seniors or new graduates during the summer following graduation and concentrate research activities at that time. Grants from the Atomic Energy Commission and from the Office of Naval Research have been used to finance college research programs. A number of industrial organizations will work with colleges by supporting small problems. The income from these various sources is used to cover the cost of special equipment and to pay for personal services for the staff man. Augmenting an income through such grants-in-aid may make summer school teaching unnecessary and thus make research possible. It is even possible in some schools, through careful planning of time, to squeeze in regularly scheduled periods which may be devoted to small research projects. When I began my teaching at Grinnell College in 1917, Professor Hendrixson at Grinnell was following such a rigorous schedule and was publishing frequently in the field of oxidation-reduction titrations. I found research in science to be the rule rather than the exception at Grinnell, with Professor Conard working in Botany and Professor Norris in Zoology.

This is a good place to refer to the stimulation of chemical research in small colleges in the south by visits by Emeritus Professor E. Emmet Reed of Johns Hopkins. For better than 13 years or ever since Dr. Reed retired from Johns Hopkins University, he has been giving his

services as a traveling research consultant to southern colleges and universities. During the year 1950-51 he had 11 colleges on his list; these were visited four times each year. The number included Birmingham Southern College, Emory University, Furman University, Georgia Institute of Technology, Howard College, Marshall College, Stetson University, the University of Richmond, the University of Alabama, the University of South Carolina, and Washington and Lee University. He serves the program as research advisor and not as research director for programs which both students and staff carry on. As the result of this unusual service, better than 54 publications have appeared, and these have been of a high order of technical quality. The fine research publication programs of both Emory and Furman Universities bear testimony to the effectiveness of the program. Some universities have been effective stimulators of college research. To return to my Cornell College experiences, summer grants were occasionally made available to staff men in science by the University of Iowa and were effectively used. I do not know whether this practice is continued. For several summers I was given research space for myself and a student assistant [one summer from Cornell College, one summer from Ohio Wesleyan] together with a salary and in return taught one term of organic chemistry. To one accustomed to the full college teaching load, the assignment left plenty of time for research. Publications resulted from each of these summers.

For those individuals who would like to do some research but who find themselves burdened with administrative duties, extra-curricular activities, or who are collectors of just plain frog's feathers [see Ellis

Parker Butler for the definition of frog's feathers], there is still the third alternative--namely, Research in Teaching. This is also open to the proponents of the Research and Teaching school. In essence, it suggests a reshaping of a portion of the conventional chemical curriculum.

A few moments ago I spoke of the means for carrying out the research process as the "reproducible experiment." Our undergraduate laboratory work serves both to illustrate the theory being covered in lectures and recitation and also to develop understanding and skills necessary before the student can carry out "reproducible experiments." Witness the semiquantitative experiments now included in the General Chemistry laboratory course and the quantitative experiments in Analytical Chemistry and the exact measurements in the Physical Chemistry laboratory. Some experiments in Organic Chemistry might also fall under this same category.

These all serve a useful purpose. If we could supplement the experience thus gained in the laboratory work with some training in the research process through a reshaping of a certain number of the present experiments, we would achieve in some degree the objective of Research in Teaching. To me this offers the best way to make available the values gained through research to both staff and students in those schools where, for one reason or another, the research experience is denied and to the students in those schools where faculty alone participate in the research experience. At the same time it may put new life in some "dry-as-dust" courses which have been taught for years without change in pattern, and that new life would benefit the instructor as well as the students.

May I illustrate with a more or less hypothetical laboratory problem in Organic Chemistry--a field particularly susceptible to this treatment. Laboratory work in Organic Chemistry has certain objectives besides keeping students busy making small lots of smelly chemicals which are filed over the years in small bottles in the chemistry storerooms all over the country. The first is to develop a working experience of the generalizations described in the formal class work; unfortunately, the laboratory experiment rarely develops the answer to the question why the particular reaction being studied fails to yield the theoretical amount of the product. A second objective is that of training the student in the safe handling of functional glassware, dangerous reagents, and uncertain reactions. A third would certainly be the additional training in report writing. There are other objectives but these will serve.

In many schools it is customary for the student in Organic Chemistry to use a laboratory manual which is written either by the instructor who is responsible for the laboratory coverage or by the author of the particular text being used in the course. The student reads the description of the experiment, notes the equipment and chemical requirements, sets up the equipment, weighs out his chemicals and carries out the experiment as described. In preparing his report on the experiment he may be provided with mimeographed sheets requiring only the filling in of blank spaces or he may write his report in the manner prescribed either by the manual or by the instructor. Nowhere in the process is the opportunity provided for the student to plan his experiment. Only infrequently is he provided with the opportunity to speculate on what might happen if he

did not follow directions. Certainly in the early part of the course he will need to be directed, but there should come a time when he might better become an active participant in outlining the experiment.

How might this participation be developed? There is at least one possibility. Remember we are talking about chemistry classes in the colleges; Organic Chemistry will rarely exceed 15 or 20 in the average school. This class, together with the instructor, can be turned into a research team for some particular experiment. Let us assume that the reaction under consideration is the Wurtz reaction involving the action of sodium on the alkyl halide. I use this as an illustration because at Cornell College during the twenties we were interested in making various octanes for use in research work on the Anti-Knock program at Mellon Institute. Let's assume the particular class was given the assignment of making 2,5-dimethyl hexane-di-isobutyl, as happened to be the case one year. In a planning meeting of the research team the various factors which might influence the production of di-isobutyl were studied. Among these might have been considered variations in the relative amounts of sodium and the halide, variation in temperature, nature of side reactions, use of appropriate solvents to slow down main and side reactions, probable relative rates of desired reaction and side reactions, methods for estimating the relative amounts of main product, side products, and unchanged starting material, effect of changing the particular halide, etc., etc. In this case, the group found by investigating that refractive indices and specific gravities could be used for analytical control of the main products and unused halide; other means were developed for the estimation of the by-products. Following this (which did not take as long as it sounds) the

team planned a limited number of experiments sufficient to establish the general condition of reaction of the factors controlling the yield of di-isobutyl. The selected method was then utilized for the production of several liters of di-isobutyl. A class report was then prepared covering the entire operation. Let me point out that the students all received experience in all the objectives described above and in addition participated in program organization (which is extremely important) and in the preparation of a significant report.

Other reactions may be similarly studied. A report of an early study on the preparation of diethyl carbinol illustrates the publication opportunities.* Let me point out that the students all received experience in all the objectives described above and in addition participated in program organization (which is extremely important) and in the preparation of a significant report. Furthermore, in almost every case new information can be gained which contributes to the knowledge of our environment and, where the work has been carefully done with appropriate checking, this constitutes scientific research. True it is not always significant to the field of chemistry in general, but it is extremely significant to the students who participate in the experiment.

Planned experiments of the same type can be undertaken in Analytical Chemistry. It is not absolutely essential that all students go

*H. F. Lewis. J. of Chemical Education, 7, 856-58(1933).

through the same detailed analyses for specific groups. Indeed it might be good if for one experiment there was selected one of the less known elements or groups; from test tube solubility experiments, most likely precipitants might be selected. For these solubility product measurements might be made, the effect of pH and temperature developed, and possible analytical methods proposed and tested. You say it takes a lot of time; provide the time and eliminate some of the routine.

There are other methods for achieving in part Research in Teaching. For example, the senior thesis program offers the opportunity for the instructor to participate with the student in the research experience. For an illustration of the results of senior thesis research there is a recent report from the Independent Study Program of the College of Wooster by Kieffer and Grabiel* on the subject of the "Azeotropes of 2-Ethoxy Ethanol with Allyl Benzenes."

I may have seemed to suggest rather casually adding work to an already overburdened load. If so, it has been done to stimulate thinking and discussion. Not everyone can jump into a research program for himself either because of the time lapse since he did research or because of an inadequate research experience. Such individuals may be stimulated in their thinking by a review of the active questions assembled by industry. For example, our own industry has prepared a book entitled "Technical Problems of the Pulp and Paper Industry." Research funds are available through the committees of the Technical Association of the Pulp and Paper Industry to support studies in these fields. The committee of which I am the chairman, the Fundamental Research Committee, has during the past year sponsored work at Bucknell and Maine. Other

*Kieffer, W. A. and Grabiel, C. E. Ind. Eng. 43, No. 4:973-75(April, 1951).

industries have similar programs. Still other methods have been suggested for locating interesting problems and initiating worthwhile work. It is a fact that not all college chemistry teachers are able to carry on or direct research due to limitation of time, equipment, funds, or for other reasons. These men can still perform a service of great benefit by keeping constantly before the undergraduate student the desirability of his having a good research training through the medium of the graduate school and by acquainting that student with the fruits of research as these develop in the literature. Such a service has been performed over the years with striking success by our friend, Professor Haldeman. I should like to pay this tribute to him in closing.