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ABSTRACT

This report on the conference on the graduate preparation of scientists for undergraduate teaching in liberal arts institutions presents: (1) the highlights and recommendations of the conference; (2) the conference and background papers which include: "Alternatives to the Ph.D.," by R. D. Anderson; "Teaching Versus Research," by Horace W. Davenport; "The Liberal Arts College and Scholarly Activity in the Sciences," by C. A. Vander Werf; "The Preparation of College Physics Teachers," by John M. Fowler, Richard W. West, and Kathryn E. Mervine; and "Putting Our Own House in Order," by Neill Megaw; and (3) summaries of the discussion groups which included: "Undergraduate Preparation in the Sciences," "The Graduate School and the Developing Scholar," "The Graduate School and the Developing Teacher," and "Postdoctoral Development of College Teachers." A bibliography and a list of the participants conclude the report. (AF)

THE GRADUATE PREPARATION OF SCIENTISTS FOR UNDER-GRADUATE TEACHING IN LIBERAL ARTS COLLEGES AND UNIVERSITIES

A Conference Report

May 2-3, 1969
Washington, D.C.

Louis Norris, Chairman
John Gillis, Director

**Association of American Colleges
and
Council of Graduate Schools in the
United States**

1970

The Association of American Colleges is the national organization of undergraduate colleges of liberal arts and sciences. Its spokesmen represent the views of 900 members on federal policy affecting undergraduate education. AAC commissions seek to stimulate and communicate ideas which promise to improve the quality of undergraduate education.

The Council of Graduate Schools in the United States is the comprehensive organization of the 291 major graduate schools in the universities of the United States. It acts as the representative and the spokesman for the graduate schools in their relations to government agencies, to the general public, and to the universities themselves. Its purpose, as stated in its constitution, is to improve the quality of graduate education in the United States.

PREFACE

Background of the Conference

FOR a number of years the Association of American Colleges and the Council of Graduate Schools in the United States have shared a concern for the improvement of college teaching. In 1965 a conference on "Preparing the College Professor for Liberal Arts Teaching" was held in Washington, D.C. At that conference college and university presidents and deans and a number of other educators discussed problems related to the preparation of college teachers. They explored the nature of liberal education, the desired characteristics of college teachers, their recruitment and graduate preparation, and the incentives to good teaching. At the conclusion of these discussions it was indicated that attention should now be focused on specific programs and activities that might contribute to the solution of the problems identified during the conference. Therefore, it was recommended that a series of additional conferences be held to explore the graduate preparation of college teachers in specific disciplines or groups of disciplines. It was suggested that these conferences should include heads of graduate departments and other members of the graduate faculty who have a direct influence over the content and organization of graduate study. It was also suggested that national representatives of the various academic disciplines or learned societies be invited to participate.

This report summarizes the proceedings of the first of these conferences. On May 2-3, 1969, forty-nine educators and scientists gathered in Washington, D.C. to explore "The Graduate Preparation of Scientists for Undergraduate Teaching in Liberal Arts Colleges and Universities." Sponsored jointly by the Association of American Colleges and the Council of Graduate Schools, the conference was supported by a grant from the National Science Foundation. Participants in the conference included undergraduate educators, graduate deans, university scientists from leading Ph.D.-granting departments and representatives from the commissions concerned with teaching and curriculum development in the scientific disciplines. Although most of the conference sessions were devoted to small group discussions several background papers were prepared in advance and were reviewed at the conference.

The discussion groups were organized in two ways. First, interdisciplinary groups discussed problems and issues related to each phase of the development of a college teacher. The general topics for these groups were as follows:

I. Undergraduate experiences related to the choice of and preparation for college teaching in the sciences

II. The graduate school and the developing scholar

III. The graduate school and the developing teacher

IV. Postdoctoral and internship experiences in the years immediately following completion of the doctorate

V. The professor and the college

A second series of discipline-oriented discussion groups considered problems and issues specifically related to the preparation of college teachers in each science discipline. Six disciplines were represented in these groups: chemistry, physics, mathematics, biology, the earth sciences (including geology and geography), and psychology. In this report, the outcomes of the discipline-oriented group discussions have been consolidated with those of the interdisciplinary sessions.

Since small group discussion was the principal format of the conference no effort was made to prepare or gain formal endorsement of a specific list of recommendations. However, many suggestions and recommendations did emerge from the discussion groups. These suggestions and recommendations are summarized in this report and are presented to the educational community for further consideration and, hopefully, for implementation.

The participants in this conference, whose names appear at the close of this report, contributed in many ways toward its success. Some prepared background papers and others chaired and recorded the results of the discussions. All of the participants contributed thoughtfully to the deliberations of the group and the AAC and CGS are grateful to them for their contribution to this effort to improve college teaching.

As staff director for this conference I would like to express my thanks to the planning committee for their assistance and counsel in developing the program. Members of that committee included:

Louis W. Norris, Chairman
President, Albion College

Gustave Arlt
President, Council of Graduate Schools in the United States

John Gillis
Executive Associate, Association of American Colleges

James Hornig
Dean of the Graduate School, Dartmouth College

Lewis Pino
Director of Research Services, Oakland University

Irwin Sizer
Dean of the Graduate School, Massachusetts Institute of Technology

Staff members of the various science commissions were most helpful in preparing for the conference and are included among its participants. However, special thanks are due to Dr. Martin Schein, former director of the Commission on Undergraduate Education in the Biological Sciences, for his special help in developing plans for this conference.

I am grateful also to Mr. William G. Land who, with the assistance of Miss Janet Long, assumed major editorial responsibility for this report and to Mrs. Robert Patchell both for her assistance at the conference and in the preparation of this report.

Finally, of course, the Association of American Colleges and the Council of Graduate Schools in the United States are especially grateful to the National Science Foundation who provided financial support for this conference.

John Gillis
Executive Associate
Association of American Colleges

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INTRODUCTION

Archimedes Today

EVERY responsible educator asks himself regularly and relentlessly whether his work is successful. He looks to the number and quality of students with whom he may work, the funds to provide facilities and conditions for his efforts, but above all, to the character of teaching he carries forward.

Numerous conferences between college and university administrators with deans of leading graduate schools preparing college professors have been held. This conference reflects the efforts of the professor at work in the sciences, for the showdown in successful teaching depends on the kind of professor going into college teaching of science. Deans manage the mechanics, but the dynamics of preparing professors operate within the graduate departments themselves. Such consultations in the arts and humanities are in order too. This conference concerned the scientists first because they have been especially active in their disciplinary commissions recently struggling with these questions.

The time has passed when successful teaching is assigned to mere communication of information about subject matter or indoctrination in fixed methods of instruction. Mastery over the technique of involvement in the process of being a scientist is the thrust of this symposium. The graduate student so involved is then assisted to bring about this temper of mind in his own teaching when he begins it.

Supposition that telling is not teaching is growing within the leading pedagogues of science. The frequent references here to the social output of science reveals a live awareness that the good teacher has some kind of "relevance" in his work. To be sure this term is threadbare from overuse in recent years, but it expresses an acknowledgment that teaching must make a difference. Such a difference is not merely advancement toward vocational success, or toward mere answers to curiosity. It provides some guide to history making that can be taken seriously.

Willingness of highly competent scientists to join in this symposium reflects the conviction that a society of "two cultures" will not do. C.P. Snow, himself an example of the fusion of these cultures, is a useful symbol of success for the educator. The scientists at work in this conference were attempting to discover how professors of science can avoid becoming aliens in their culture while they qualify as competent teachers of science. They are seeking to encourage their students to think of "success" in such pertinent terms.

It is a temptation to seek some special prescription of courses guaranteed to produce good professors. Some new degrees are devised now and then for this purpose. Interdisciplinary programs are set up to make sure some cross-reference or neglected coverage or relevance is included. But teaching remains an art for which success cannot be fully, uniformly, or finally prescribed. Successful teaching remains a result of a temper of mind that resolves collisions of ideas in new contexts and lures the student into following clues to dealing with nature, man and God that he dare not neglect.

Archimedes with his shout of "Eureka" remains another untarnished symbol of the teacher's task. When the grid of thought having to do with the weights of metals collided with the grid of thought concerning the weight of water displaced when Archimedes took his bath, the "aha!" moment about specific gravity came. A meaningful context was supplied for factors previously unrelated. Such moments of insight are the continual quest of the professor.

To be educated is "to understand what it is to be awake, to be living on several planes at once," to use words from T. S. Eliot. The discerning student of science realizes that decisive advances in science have come from mental cross-fertilization. More students are studying more subjects in more places now than ever before in history. The successful educator, and thus the successful science teacher, is one who insures that cross-fertilization comes about, and that its pursuit is regularly his diet.

This conference presumes, therefore, that the continuous interrelation of professors, administrators, and students provides the milieu in which judgment of successful teaching in science may be made. No ironclad, foolproof, epoch-making formulae are set forth here, consequently. Nor is it implied, on the contrary, that no one knows what good teaching is. A judgment about the success of teaching is made every day about every course by every student, every professor, every dean, every president, and the ultimate paymaster for the service rendered!

Some say teachers are born and not made, certainly every participant in the academic community has an opinion as to which teacher was stillborn. But such inevitable judgment about the success of the professor allows also for some reliability in judgment about how he is to be prepared. Though no one formula perhaps assures his successful preparation, such collaboration as reported here reflects the concern that is bound to yield some pertinent ingredients.

Just any conversation any time among any group of interested people will not necessarily yield successful plans for preparing professors, of course. It is in the hope that this report on an effective consultation about the subject of preparing professors in the sciences will provide the stimulus, and some useful roadmaps, that will lead to new country where other successful professors will want to live.

Louis William Norris
President, Albion College

Highlights and Recommendations

SINCE the conference was organized primarily for the purpose of discussion it did not act formally to approve a list of recommendations. However, the discussion groups did offer several recommendations and suggestions which were reported to the conference and seemed to receive general support. These recommendations and suggestions are noted here in capsule form.

GENERAL RECOMMENDATIONS
Undergraduate Preparation

*The introductory science course should be a model of how to teach, and should be taught by the best senior faculty.

*Creative thought and experimentation in devising new approaches to the introductory course and its laboratory experiments should be encouraged.

*The problems of science and society should be given a place in the undergraduate curriculum.

*Further efforts should be made to teach the history and philosophy of science to undergraduates.

*In spite of pressure from graduate schools—either real or imagined—specialization and excessive course requirements in the major field should not crowd out other important components of the curriculum.

*Federal fund-granting agencies should develop flexible criteria for judging the excellence of undergraduate programs in the sciences so as to encourage interdisciplinary programs and other curricular experimentation as well as preparation for graduate study in a single discipline.

*Undergraduates should be given opportunities to participate in teaching because teaching stimulates learning.

*Interest in science and in science teaching needs to be fostered early in the student's career. Minority students especially need opportunities to meet professional scientists and learn about their work.

*College and university budgets should contain funds specifically designated for curriculum research and development.

The Graduate School and the Developing Scholar

*Graduate training should place greater emphasis on broadening interdisciplinary concepts of scientific activity.

*Graduate departments need to reexamine their allocation of time and resources with a view toward achieving a better balance between teaching and research.

*Federal and private agencies granting fellowship support should allow institutions to pool funds so that they could offer "support packages" to graduate students for better balanced programs of study, teaching experience and research.

*Universities having strong graduate departments could help faculty members of nearby liberal arts colleges to keep current in their disciplines by offering postdoctoral seminars and other opportunities for scholarship and research.

The Graduate School and the Developing Teacher

*Proposals for the development of alternate degree programs at the doctoral level for those whose primary interest is teaching rather than research have never been greeted with much enthusiasm by scientists. However, the special needs of two-year colleges suggest that the Ph.D. is probably not the appropriate credential for the vast majority of their faculty members.

*Experimentation and innovation in the training of graduate students to become good teachers must be encouraged.

*Although senior graduate students and postdoctoral fellows can contribute a great deal to a training program for future college teachers there is no substitute for the active involvement and interest of the senior faculty.

*Graduate departments concentrating on programs at the master's degree level should accept major responsibility for training science teachers for the two-year colleges.

*Staffing an increasing number of colleges and courses having varied educational goals implies that the improved preparation of college teachers must be directed towards securing the best possible results from those whose talent for science may not be of first rank.

The Professor and the College

*An understanding by both administrators and faculty of the relationship between the goals of the college and those of the individual faculty member as teacher-scholar will improve faculty morale and enhance the educational program of the college.

*Ways of recognizing good teaching include support for summer activities designed to enhance teaching, money for experimentation with new teaching methods and materials, and just plain moral support.

*The young scholar should have a lighter teaching load, freedom from administrative duties, and opportunity for leaves of absence to pursue research and scholarly activities.

*While some liberal arts colleges are well ahead of many universities in the development of innovative science programs and inspired science teaching, more institutions of both kinds should follow this lead.

*Additional internal funding for research is needed in the liberal arts colleges, especially seed grants to get projects started and for the encouragement of cross-disciplinary projects.

*Involving students in faculty research and undergraduate teaching not only aids learning but also encourages mutual understanding and respect.

ADDITIONAL RECOMMENDATIONS

*The fruits of this conference should not be permitted to lie fallow on some dusty bookshelf. The results should be communicated directly to universities, colleges, educational organizations and individuals who can really generate interest and effect changes that will enhance college teaching.

*The Council of Graduate Schools, in collaboration with the several college commissions, should undertake a detailed and searching survey of existing programs for the training of graduate students in instructional matters. The results of this survey and resulting recommendations should be made available to all graduate deans and graduate department chairmen.

*The organizations which have assembled this conference should consider supporting regional programs for the continuing revitalization of college science faculties. The science discipline commissions could establish seminars and workshops for this purpose.[1]

*A mountain of paper has already been developed on the subject of this conference, countless discussions have been held. What is needed now is an action program that will have a marked impact on the improvement of college teaching.

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[1] Since the conference at least two of the discipline commissions, those concerned with physics and biology, have held one or more of the specialized programs suggested in this recommendation.

Alternatives to the Ph.D.

R. D. ANDERSON, *Louisiana State University*

IN this discussion we shall be primarily concerned with the training in science or mathematics of a prospective science or mathematics teacher in a four-year college. Traditionally, this training has ideally involved the prospective teacher completing a Ph.D. in his discipline in a recognized university graduate program. The acceptance of the Ph.D. degree as the desired formal qualification for college faculty status has been almost universal. Colleges have generally sought faculty members with Ph.D.'s but have frequently accepted alternative (and formally lesser) qualifications out of necessity. In the Survey of the Conference Board of Mathematical Sciences which appeared in 1968 it was revealed, for instance, that in colleges with less than 150 faculty members, only 19 percent of the full-time mathematics faculty had Ph.-D.'s whereas in most of the other sciences the comparable figure was slightly over 50 percent. Thus while four-year colleges sought faculty with Ph.D.'s they frequently did not find them. It should be noted that because of the nature of much freshman and subfreshman level course work in mathematics, one should not expect all mathematics faculty members to have Ph.D.'s. Indeed, we call attention to the publication "Qualifications of a College Mathematics Faculty" by the Committee on the Undergraduate Program in Mathematics.[1] In this publication, an attempt is made to consider mathematical (not degree) levels of competency needed for teaching mathematics in a four-year college. It is pointed out, among other things, that suitable qualifications other than Ph.D. status are quite appropriate for some faculty members who teach lower division undergraduate mathematics.

We now turn to a brief examination of the Ph.D. program and its relevance to college teaching. For mathematics, the "Qualifications" publication listed above gives a much fuller discussion.

[1] Free copies may be obtained on request from CUPM, P.O. Box 1024, Berkeley, California 94107.

THE TRADITIONAL Ph.D.

For some time, the Ph.D. in mathematics or the sciences has customarily required a dual type of training: first, a rather broad-based training in the discipline at the early graduate level followed by one or more comprehensive examinations, the qualifying, the preliminary or the general; second, intensive training in research in the discipline culminating in a dissertation and a final oral examination in defense of the dissertation. While the broad-based training in the discipline is a necessary part of the training, it has always been felt and maintained that the Ph.D. was primarily a research degree that was awarded only for successful research work as judged by the major professor, the advisory committee and the department concerned. The broad-based early-graduate-level training provides a background both for the dissertation research and for prospective further research. It has also served as the basis of the professional qualifications necessary for the recipient to begin a career of undergraduate teaching.

Most undergraduate teaching is concerned with the knowledge and ideas which are related to the work of the broad-based early graduate study and not to research per se. However, many consider the research training to be vitally important for the continuing competence of the college teacher. In the rapidly changing science and mathematics of today, the college teacher must run hard just to stay in place; he must actively continue his professional study to remain competent as an undergraduate teacher. He simply cannot afford to become professionally stagnant. His graduate training must provide him with the basis for substantial further self-motivated study. The Ph.D. level research training in depth has been considered to provide this basis.

A factor other than technical professional competence has put added emphasis on the Ph.D. degree. Since successful Ph.D. level graduate work requires sustained effort over several years, the achievement of a Ph.D. indicates that the student has demonstrated both the ability and the determination to succeed. Thus academic administrators rightfully consider the Ph.D. as partial evidence of certain personal characteristics desired in a prospective faculty member.

We now shall review certain alternatives to the Ph.D. for college faculty members. We restrict ourselves to a discussion of five formal alternatives—leaving to such statements as the "Qualifications" publication of CUPM a more detailed analysis of the required training in the disciplines.

THE DOCTOR OF EDUCATION DEGREE

The Ed.D. degree has played an interesting and valuable role in the American educational scene. It was conceived as a professional degree in education per se and its role in mathematics and science has been rather specialized. With only a small number of exceptions, the Ed.D. degree in mathematics or science education has represented a study related to the educational or pedagogical processes at an elementary school, high school or college or university level with very little substantive science or mathematics involved. Those studying for and receiving the degree in mathematics or science education normally are in a college or school of education and need take very few if any courses normally taken by regular graduate students in the discipline. In mathematics, for instance, except at a small number of universities—among them Oklahoma State and perhaps Wisconsin or Illinois—the students do not take even the usual first year graduate mathematics courses such as those in analysis, algebra and topology which provide indispensable background for teachers of most undergraduate mathematics courses. In general the subject matter of science and mathematics education has not been the subject matter of the discipline itself but rather has been subject matter concerned with the learning process or with elementary statistical analyses of educational phenomena.

It should be mentioned that there are, in fact, many very competent mathematics and science faculty with Ed.D. degrees. Customarily these are people who have started in a graduate program in the discipline itself and then have switched to the Ed.D. program. Their competence in their discipline comes from serious and prolonged study in their discipline and not from their graduate education study as such. Because of the wide variation in levels of competence in the disciplines themselves among holders of Ed.D. degrees in mathematics or science education, college administrators have not been able to take the degree itself as meaningful for hiring, retaining or promoting faculty members in the appropriate discipline.

THE DOCTOR OF ARTS DEGREE

A few universities, e.g. Dartmouth and Yeshiva, have recently instituted Doctor of Arts programs. Abstractly, the Doctor of Arts program is designed more for the training of college teachers than for research oriented university teachers. The program involves broad-based early graduate training comparable to (or even better than) that of a Ph.D. program, but with either no dissertation or a dissertation which is more expository or historical than creative in the scientific sense. The history of proposed Doctor of Arts programs in mathematics is perhaps revealing of the inherent difficulties facing establishment of such programs.

When the shortage of Ph.D. level mathematicians seemed most acute in the early 1960's, a conference was organized at Yale by various mathematical organizations to consider the possible development of a Doctor of Arts program. The conference resulted in great controversy and considerable bitterness. Those *for* establishment of such D.A. programs argued that the classical research training of the Ph.D. was not of great value to the prospective undergraduate teacher—indeed perhaps 70 percent of those getting the Ph.D. in mathematics published no mathematical research beyond their dissertation. Only a very small number of mathematics faculty members in non-Ph.D.-granting institutions published any research at all. Their research training was simply not relevant to their future activity. Those *against* establishment of such D.A. programs argued that D.A. programs would result in second-class academic citizenship for those who earned D.A.'s and would in all likelihood result in the long run in a reduction in the level of professional competency of college mathematics teachers. The controversy was sufficiently substantial and bitter that only a few universities moved to establish D.A. programs in mathematics.

THE MASTER OF PHILOSOPHY DEGREE

Several universities, e.g. Yale, Michigan and the University of California at Berkeley, have considered the introduction of a Master of Philosophy degree, conceived of as an intermediate degree between the M.A. (or M.S.) degree and the Ph.D. Such a degree might be suitable for a prospective undergraduate teacher if it were widely accepted and if, as seems unlikely, the status of a college teacher holding such a terminal degree were equivalent to that of a teacher holding a Ph.D. Unfortunately there seems to be no evidence that college administrators and/or accrediting agencies would consider such a degree as comparable to a Ph.D. for a college teacher. Particularly in the light of the predictions by Cartter and others that the overall shortage of Ph.D.'s on college faculties will be at an end by 1975 or earlier, it seems unlikely that the Master of Philosophy degree will become an important adjunct to the academic scene. Incidentally, the shortage of Ph.D.'s for college teaching positions in mathematics and physics seems to be disappearing very rapidly. Perhaps by 1970, Ph.D.'s in mathematics and physics will be available in sizable numbers for teaching in non-Ph.D.-granting institutions. In the spring of 1969 many prospective Ph.D.'s in these disciplines had trouble finding suitable positions in the academic world. In another year or so, colleges should have excellent opportunities to get very competent younger people. We are "tooled up" to produce such relatively large numbers of Ph.D.'s that the academic community may have difficulty absorbing the supply. Of course, factors such as the possible end of the war in Vietnam and/or a possible major increase in funds for higher education may make such predictions invalid.

THE REVISED Ph.D. IN THE SCIENCES

With the apparent failure to get widespread support in the academic community for a Doctor of Arts degree, it may well be that a number of universities will seriously consider alternate routes to the Ph.D. in mathematics or the sciences. Such an alternate route would involve the same type of successful broad-based training through the general or preliminary examinations and then involve an expository or historical dissertation or a dissertation onpedagogical aspects of mathematics or science. Such a degree would be controlled by the department in the discipline and not by the school or college of education. The University of Wisconsin is at present awarding such degrees in mathematics, for example. Whether the academic community will fully accept such degrees remains to be seen. However it is my belief that such degrees will be accepted and indeed be sought, since the individuals trained in such programs will serve a very useful role in the academic community. For example, I have recently advised a college of the City University of New York to consider a prospective graduate in this program for a faculty position in its Mathematics Department. She would serve in a dual capacity, both as a well trained mathematician and as a mathematical educator. Until recently there have been very few people with comparable qualifications.

THE SUPER Ph.D.

No discussion of alternatives to the Ph.D. would be complete without a consideration of a degree program like that found in many European academic circles. In Germany, for example, the *Diplom* corresponds roughly to our master's degree, the degree of *Doktor* corresponds roughly to our Ph.D. and the *Habilitation* represents a higher status which can be earned several years after the degree of *Doktor* on the basis of significant additional research work. Traditionally the *Habilitation* has been necessary as qualification for a professorship in a German university. Perhaps in this country with a much larger number of Ph.D.'s being produced in science and mathematics, these disciplines will tend to develop more highly structured status systems augmenting the present extensive use of letters of recommendation in assessing the qualifications of mathematicians or scientists for professorships at universities. Such a development would be more likely to occur if it were felt that there had been a reduction in quality of the Ph.D. However, in this connection it is interesting and encouraging to note that in the mathematics community there seems to be a general feeling that in recent years the level of competence of the average Ph.D. has not been falling but has probably been rising. New Ph D.'s both know more mathematics than their predecessors and are more research oriented. A greater percentage seem personally committed to mathematical research. There are indications that a greater percentage are indeed publishing research.

Teaching Versus Research*

HORACE W. DAVENPORT, *University of Michigan*

NEVER apologize! But if I am not to apologize, I must lay the whole blame for my shortcomings on the organizers of this conference who invited me. I am to discuss the relation between research and teaching in liberal arts colleges. I know nothing whatever about the subject. I have some claim to distinction in research and some claim to distinction in teaching. But I have done no research in teaching, and I am ignorant of the work of those who have. In short, I have not applied the principles I use in the scientific half of my life to the pedagogical half. What I say will be based on experience, thirty-five years as a scientist, thirty years as a teacher and twenty-four years as a department chairman. We all know that experience is a bad teacher. What I have learned has the same value as a physician's "clinical impression." Dr. Benjamin Rush knew that phlebotomy was an efficacious treatment, and by copious bleeding he killed more Philadelphians than did yellow fever. I hope my prescriptions are not equally fatal.

I have a further limitation. My life has been spent in a relatively few professional schools of the highest quality. In them research flourishes, but their teaching problems are peculiar. Experience so obtained is not sufficiently general to be applied to the liberal arts college. I have never been through the gates of such a college except as a visitor, and I have no firsthand knowledge of its problems in choosing between research and teaching or in attempting to encourage both. Do most colleges really have a choice between teaching and research? Except for a couple of dozen great universities and a score of elite colleges, is there really an alternative? We use shoddy words, and we call a disgusting tyranny a Democratic Peoples' Republic. We call our third- and fourth-rate institutions "developing universities." Will the president or the provost or the dean of a developing university actually have, in the foreseeable future, the opportunity of choosing between a first-rate scholar and a first-rate teacher when he selects a new member of his faculty? I do not think so.

*This paper has also appeared in *Bioscience*, v. 20, no. 4 (February 15, 1970), pp. 228-230.

Here I must make explicit a theme which will be implicit in the rest of this talk. My own interest is in only the very best. I want to be preeminent in my scientific field, to be chairman of the best department of physiology and to be a member of the best university. I eat my heart out knowing I will never achieve these goals, but the aspirations remain. I know that men and institutions sharing this attitude must work skillfully and unrelentingly if they are to avoid disaster and that they are always in danger of being destroyed by circumstances or swamped by mediocrity. Nevertheless, the remnant for which I pretend to speak has an obligation to preserve and propagate its qualities.

I have had the honor to be an undergraduate at the two best colleges in the world, one devoted to research, one to teaching, so I am the product of a controlled experiment. I say this to point a distinction between learning and teaching. At my first college, instruction in the first two years was largely in the hands of beginning graduate students. When one undergraduate complained to a senior member of the faculty—whom he had met by accident—about the quality of instruction he was told: "Sir, this is an institution of learning, not of teaching!" This raises a question I have never heard discussed: what are the obligations of the student on the other end of the log? What must he contribute to his education? We know what he demands, but is what he demands what he needs?

Students in professional schools are particularly demanding, and the way we meet their demands reveals our assumptions about teaching and learning. Students demand skillful and economical organization of material, clarity and relevance. (Who, might I ask, is to be the judge of relevance, the student or the teacher? I am frequently told by a first-year medical student who has not yet been within fifty feet of a patient what will be relevant to his future clinical training.) This kind of teaching is spoon feeding. Those of you who know my elementary textbooks, particularly *The ABC of Acid-Base Chemistry,* understand that I am an expert on this process. I know exactly the angle to hold the student's nose while I pour the predigested pap down his throat. This is a by no means contemptible skill. When one is teaching that part of a profession which is correctly and inescapably a trade one should do it as cheaply and as effectively as possible, and one can be proud of the results. It is as laudable to contribute to the training of a technically competent physician or lawyer as it is to train an accurate accountant, but on neither end of the spoon does the process have much to do with learning. For me its only relation to research is that research is the haven to which I escape when I am nauseated by my own performance in the classroom.

My second college venerates Benjamin Jowett who had a major influence on English higher education in the 19th century. By every test, the statistical one of counting the number and magnitude of the accomplishments of his pupils or the private one of testimony, Jowett was a great teacher. We see him huddled before his fire, poker in hand, crooning to himself. His face bears a trace of that intellectual arrogance caught by Watts in his portrait of the Master of Balliol. He waits for his pupil to speak or to read his essay. None dares present to this tutor anything short of the best work he can do. Jowett would use any device, even discouragement, to prod his pupils. One reports that he ventured to ask Jowett if he had any chance of even a second class in Moderations. "No, no!" said Jowett, rubbing his hands, "You needn't trouble yourself." The student stamped angrily out, and the pleasantest moment of his life was when he met Jowett after getting his first. "All evidence is united on one great point: that intercourse with Jowett was impossible, intolerable, unless you used your mind as well as you could."*

This kind of teaching has no relation to research. Although Jowett did much to foster research at Oxford his own scholarship would hardly allow him to be a dozent in a German university. I instance him as I could others to remind us that when we worry about the conflict of teaching and research we should have a reasonably clear idea of what we mean by teaching. We must know what students we are addressing: the passive recipients of training or the active pursuers of learning. I betray an aristocratic bias when I assert that the latter are as important as the former. Out of the 200 million persons who infest this country, only 20 thousand or 200 thousand—the number depending on the method of counting—maintain or advance civilization; the rest merely occupy space. If we devote our efforts chiefly to making life comfortable for the space-fillers there is no problem of conflict between teaching and research. The only problem is achievement of efficiency.

* G. FABER, *Jowett, A Portrait with Background* (Cambridge, Mass.: Harvard University Press, 1957).

I have a democratic bias as well, the only one shared by the founder of the University of Virginia and the Corsican bandit who boasted that he opened careers to talents. The bias is that no one should be classified and treated as a space-filler until he has had the opportunity to demonstrate that he is something better. This means that the chance to learn and not merely to be taught should be distributed on both sides of the Appalachian watershed and up and down the economic scale. That it is not widely distributed is one of the tragedies of American education. Every year thousands graduate from our state universities without having discovered there is such a thing as an idea or such a process as thought. I suspect that many graduate in like ignorance from our colleges. I know there are many reasons, including original sin, responsible for this condition. One, which Jefferson would not have tolerated, is that many students who have clearly failed the eleven-plus are allowed to continue to clog our colleges and universities. I wonder whether another is not the expense of spirit in a waste of inappropriate scholarship. Might not many colleges and some departments in universities become real seats of learning by ceasing to support inferior research and, instead, cultivating the virtues of 19th century Balliol?

There are two kinds of research. Research is a trade like shoemaking, or research is a vocation like the priesthood. The essence of a trade, for all that it may involve craftmanship, is that it is practiced to make money. I shall not dicuss research done outside the academy, but I remark that non-academic research need not be a trade. It is possible to make a great deal of money and still work for the fun of it.

In the academic world research as a trade is that done to get or to hold a job or to earn promotion. It is the response to the command to publish or perish. Competence in the trade of research is the essential foundation for any superior achievement; it is obvious that anyone essaying to do research must learn how to do it. It seems equally obvious that he must avoid perishing. Having learned his trade and survived, the scholar can aspire to one of three levels of quality. The highest is that of true creativity. At this level the scholar is a creator and illuminator, the equal of the greatest poet: Milton or Wordsworth much of the time, Shakespeare engaged in his customary occupation of turning a sow's ear into a silk purse or Shelley in those rare moments when he said something that need never be said again so long as our language lasts. The second level of quality is shared with Swinburne and Matthew Arnold. In science this level is occupied chiefly by men who extend to unexplored fields concepts developed by others. In my own speciality of gastroenterology there is no "Shakespeare, Newton, a new Donne," but there are about a dozen men doing good and enormously useful work expending the intellectual capital accumulated by others twenty to fifty years ago. The third level is that of downright incompetence where one meets the Robert Montgomerys of research.

The student with great natural powers or special opportunities may learn his trade almost as a child, or he may learn it only when he is writing his dissertation. He may at first flight be a Perkin or an Arrhenius, or he may all his life be only an industrious gleaner from a worn-out, worked-over field. His first publication may be *Über die Erhaltung der Kraft*, of it may be a fragment generated by industrious crank-turning in a Ph.D. factory maintained by the proprietor of an easily parcellated body of knowledge. Without genius the student's situation is particularly pathetic if he earns his degree in a developing university which—on account of its history, its resources or its location—is actually incompetent to guide him, no matter what accrediting agencies say. One such institution which I knew well was superb in anthropology and pharmacology, but it also gave a Ph.D. in English which pretended to admit its owner to the company of a Yale man.

The natural career of such a student begins with teaching and grows into a mixture of teaching, service and administration. He remains subject to the demand for research proroutivity until he reaches the age of fifty and high rank. By that time his trips to Washington are accepted as legitimate substitutes for scholarship. In the meantime he may do any amount of good research, or he may respond to the demand to publish by doing work which is the antithesis of research in that it is unoriginal. The results of the latter kind may be published, frequently after cascading from the best to the worst editorial offices, but they are almost worthless.

In saying that the results are almost worthless I am troubled by the thought of one qualification. In those fields of science which have a fairly immediate practical application a place where research of any quality is kept going is probably better than a place where it does not exist. One enormously important reason is that the practice of research keeps up the level of technical skill, and technical skill cannot be let slip. Another reason is that going research provides an example and a point of entry for the especially able student who would not otherwise have the opportunity to discover his powers and to excel his teachers. I do not know whether in nonscientific subjects any research may be better than no research, but I am willing to listen to the argument that it is.

Barring these dividends, I would admit there is a conflict between teaching and inferior research insofar as that kind of research detracts from learning or teaching. I would like to see the candidate for the advanced degree, the one who is doing research merely to gain his union card and to earn his living, thoroughly learn his subject. He might even learn others as well! If he has not wasted all his time he might, at the moment of receiving his doctorate, have the mastery of his subject approaching that of an Oxford undergraduate ready for Final Honour Schools. He might also learn something about teaching without being thrown on one hand unassisted to the hyenas of a freshman quiz section or on the other to the wolves of Education. He might learn that many of his elders who are good scholars are also deeply committed to being good teachers, and he might be enlisted as their colleague in planning and executing the innovations which keep teaching alive. Since it is essential that the man applying for a job at East Cupcake State University or St. Elsewhere College be allowed to call himself doctor, these are the reasons I support the move to create a degree of Doctor of Arts which has no nonsense about research in its requirements.

If we release our candidate from the research treadmill, can we be sure that he will be a better teacher? Is the man who is demonstrably an inferior scholar likely to be a superior teacher? Alas, I am afraid the answer often is no. Otherwise our colleges and universities which do not rigidly enforce the rule of publish or perish (and, unfortunately, some which do) would not be inhabited by the professor who all but retires at forty, who meets his classes regularly at 11:00 on Monday, Wednesday and Friday and who otherwise does nothing, nothing, nothing at all.

Now let me consider research of the second kind and of the first or second quality, research as a vocation and its pursuit as a form of religious life. I am old enough to have grown up in the last days of the primitive church before research was institutionalized by Federal grants—before the conversion of Constantine. In those days the pentacostal fire lighted on the brow of Harvey, Newton, Lavoisier or Darwin, and a voice from the clouds said in words of thunder: "Follow me (if you happen to have a successful practice or a college fellowship or a bit of the tax farm or some shares in Josiah Wedgwood and Co.), and you will understand the secrets of the universe." Understanding and—remembering Newton's interest in priority—being known to understand, were the rewards.

In these latter days there is a new kind of research saint, very much in the world and of it. His laboratories or his social research centers resemble in all except the inelegance of their architecture the flamboyant monasteries of the very late middle ages. He is supported by offerings of the faithful and by a tithe of the gross national product. Accepting fruits of pomegranate and peach without thanks and asking for more, he justifies his greediness on the ground that only through his mediation can we escape the hellfire of cancer or ascend to heaven, beating the Russians to St. Peter's gate. This characteristic priestly arrogance is really not his fault, but realization that it is the product of seminary training and of public support of scholarship for its ends rather than for its means, does not make it any less tiresome.

The parallel with 15th century monasticism may be apt. Then as today the nature of the institution drew into it a fair proportion of novices without a real vocation who might better be employed doing the world's work, perhaps even teaching school. And no one who knows what happened to English monasteries in the 16th century need be surprised to see Congress, that two-handed engine at the door, threaten a second dissolution.

I shall add nothing to an endless controversy: research interferes with teaching, because time and effort required for good teaching is drained into research. Research is necessary for good teaching, because only continuing scholarship keeps a teacher alive. There is a great deal to be said on either side but not nearly so much as has already been said. It is an observed fact that all possible combinations of research productivity and excellence in teaching do in fact exist, but any relation which might be established between them is probably the result of spurious correlation. The two are not directly related to each other, but each is related to a third variable. This last is the quality of the scholar and teacher as a human being.

There is no point in discussing those who are constitutionally inadequate in both teaching and research; let us consider only the superior men. I have no experience with men of equal stature in the humanities, but I know scientists whose ability has been certified by the Nobel Prize or by early membership in the National Academy who devote almost as much thought and effort to teaching of one kind or another as they do to their research. If you doubt the pervasiveness of interest in teaching I invite you to observe who gives the first-year course in biology at Harvard, to attend department meetings, to follow the work of education committees of professional societies and to listen to the sessions devoted to teaching at national meetings. You will see that men who are good at research try to be good at teaching.

These men teach because they want to teach. In them is neither conflict between research and teaching nor reinforcement of one by the other. In them the relation between teaching and research is that each activity is the expression of superior intellectual and personal qualities. They are not good teachers because they are good researchers: they are good teachers and good researchers because they are good men.

That a good scholar wants to be a good teacher is the delight of his department chairman, but the chairman's dependence upon the willingness of his staff constrains him. If he, as I said I do, selects his staff for its qualities in research, he takes what he gets in teaching. One result is that it is hard to discharge the duties imposed by service courses. I meet one of my brilliant young men in the elevator, and he says: "Gee, I hate teaching dental students." He actually does teach dental students out of a sense of obligation to the department, but I must be careful to see that he is not pushed to his limit of tolerance. The department would very quickly be destroyed if only one of its stars found teaching a burden instead of a pleasure. When I lie awake nights worrying about how I am going to get the dental teaching done I comfort myself by remembering that the man who hates teaching dental students is very good indeed at three other kinds of teaching he likes to do. The teaching done willingly is not necessarily only in advanced or graduate courses; much is at the lowest level. In terms of the number of students demanding it, my department's most successful course is that in human physiology offered to college and other non-professional students. Our best men have taught it out of missionary zeal. Lying awake worrying, I also tell myself that if I staffed my department with those willing to do the academic dirty work I would have neither good research nor good teaching.

I am proud of my department's research, and I am proud of its teaching. Research comes first, but teaching is not a bad second. I see no reason to reverse the priorities, and I conclude that although there are some kinds of conflict between good research and good teaching I am unlikely to get the second without the first. In my position in a professional school it would be fatal not to put high quality research first. It is probably possible to put research second in other situations, but those who do so must insist on high quality teaching as I insist on high quality research. Mere rejection of research is not enough.

The Liberal Arts College and Scholarly Activity in the Sciences

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INTRODUCTION

THREE facts stand out in stark relief: (1) The supply of educated, competent scientists to be produced in the next two decades will be inadequate to meet the demands of our national welfare and of our well-being and progress as a society and a civilization. (2) In this age of the scientific revolution, when science should be inseparably at the core of liberal education, we as a nation are in general doing a less than satisfactory job of imparting an understanding of the meaning and spirit of science to our "liberally educated" undergraduates. (3) The nation's liberal arts colleges are now being written off by many experts—and nonexperts—as a source of supply of professional scientists in the future.

For a century the record of our outstanding liberal arts colleges in supplying the scientific leadership of our society has been a proud and distinguished one. Even today, almost half of the entering graduate students in the sciences continue to come from the nation's liberal arts colleges. Yet on every hand we hear the hue and cry: that the liberal arts colleges have had their scientific day, that the moment of truth has come, that at this turn in history—when competent scientists are needed as never before—we can no longer look to the liberal arts colleges to play a significant role in their production.

The argument is both simple and straightforward. It is said that the independent liberal arts colleges can no longer attract gifted teacher-researchers to their science faculties nor provide their students with adequate laboratory facilities and a sufficiently wide spectrum of specialized courses. To stand any scientific chance at all today, the embryonic scientist must jump in early, polarize strongly, and swim fast. By choosing a liberal arts college, rather than a large university, he delays his entry into his chosen field and damages his career irreparably.

Well-meaning friends of the liberal arts colleges declare rather patronizingly that the liberal arts colleges may as well concede the scientific day and leave the training of professional scientists to the universities, contenting themselves with educating scientifically literate laymen.

CAN THE LIBERAL ARTS COLLEGES SURVIVE SCIENTIFICALLY?

Will our liberal arts colleges refuse to raise the white flag of scientific surrender? Whether the answer is yes or no, I am not sure. I am convinced that a no—nonsurvival—answer will represent an irredeemably tragic development from the standpoint of the welfare of our nation and society. I am also convinced that what the answer is to be depends upon us as educators, upon what we think and how we translate that thinking into virile action. We can determine the answer: but first we must decide what we want our answer to be. We can also determine the outcome. I propose that we make that answer a positive and ringing "yes"—not alone for our own national interest, but for our long-term goals and aspirations as human beings.

In our own enlightened self-interest, both as scientists and as responsible members of society, we should do this for several reasons. The first reason is quantitative in order that we may maintain our pool of competent, well-educated scientists and science teachers at a maximum level. The history of tomorrow, I predict, will record—as did the history of yesterday—that scientists are truly born and preserved in those institutions where the welfare and development of the undergraduate is not a secondary, or even a tertiary, but rather the primary and sole concern. I have a strong conviction that the scientists and science teachers of tomorrow will still be born and preserved when patient and noble professors whose lives are totally dedicated to the undergraduate student ignite the spark and fan the fire in young minds and hearts, inspiring them to a greatness they never before knew they possessed. In the making of scientists, the externals may have changed but the fundamentals remain the same. We must still do it, as it has been done in the past, on a one-by-one basis, through interest, concern, recognition, stimulation, and inspiration.

Even more important than the quantitative advantage may be the qualitative aspect of the question. Who can assess, in this age of specialization, the importance of educating a substantial percentage of our future scientists in the liberal arts tradition with emphasis not alone on skills but also on attitudes, insights, judgment, and values? Many of us, I am sure, share the uneasy feeling that the educating of first-rate scientists and science teachers who are both prepared and disposed to bridge the gulf between the two cultures—that of the artists and humanists, on the one hand, and that of the scientists, on the other—may well be the most crucial educational challenge of our day. The liberal arts college, with its broad and unrestricted interplay among students and faculty of all disciplines provides the ideal climate for the wedding of the two cultures. The very struggle for existence of our free society demands that this climate be nourished and nurtured.

I would be less than honest, however, if I should lead you to believe that my concern is only for the liberal education of future scientists. Something much broader and more inclusive is at stake—the whole concept of liberal education. If we were to relegate science in the liberal arts colleges to the servicing of scientifically literate laymen—to remove rigorous scientific instruction by scientists of true integrity—we would be cutting the heart out of our liberal arts colleges. Such a course of action overlooks completely the humanizing and liberalizing influence of science in the liberal arts curriculum, as well as denying science the reciprocal liberalization which comes from other disciplines. At the core of the truly great liberal arts colleges of our nation there will be found strong and viable science departments. If we force the liberal arts colleges to abandon science then we will, in fact, abandon the liberal arts colleges themselves—and with them perhaps liberal education itself.

I maintain that scientists of the future will continue to come in large measure, as they have for decades, from distinguished liberal arts colleges—those undergraduate institutions which have in the past been the cradle of our nation's scientists. I hold the conviction that these colleges can continue to perform this function better at the undergraduate level than can institutions primarily concerned with graduate study and research. But, to do the job, high quality liberal arts colleges need honest understanding and additional down-to-earth assistance.

Some of the signposts pointing to the early demise of science in the liberal arts colleges may be exaggerated or quite misleading. One of these is that senior science majors from the liberal arts colleges are winning less than their share of National Science Foundation Fellowships. But what does this prove? It may merely indicate that a good student who has had 32 hours of biology, or chemistry, or physics, or geology, or geography, or mathematics at a liberal arts college will perform less brilliantly on an achievement examination in biology, or chemistry, or physics, or geology, or geography, or mathematics than a good student who has had 50 hours, including a significant number of advanced or graduate courses, at a university. The 18 hours of chemistry missing from the liberal arts student's curriculum might have been very well spent in other fields. Indeed, let us not be tyrannized by numbers. As President Bowen, then of the University of Iowa, pointed out in discussing the tyranny of numbers in another connection, objective tests reduce the evaluation to stark essentials. They perpetrate "no nonsense about the student's curiosity, his moral fiber, his dreams and aspirations, his social consciousness, his human decency, his imagination, his philosophy of life, or his aesthetic sensibilities."

Then there is the signpost—frequently read and cited—that the high school senior National Merit Scholars are choosing the large graduate universities over the undergraduate liberal arts colleges. This may be in large measure a commentary on the relative efficiency of recruiting programs. In this competition, the universities have the great advantage of glitter.

THE TEACHER IS THE KEY

How can we maintain strong, vital, viable science in the liberal arts colleges? The problem ultimately reduces to this: how can we attract and hold competent, top flight, exciting, and inspiring scientist-teachers to permanent careers in college teaching? The caliber of the faculty is the heart of the matter. The teacher is the key. Think of the great departments of science in liberal arts colleges. Have you ever known one with a sustained record of high productivity and achievement in which there could not be found one or more superb and consecrated teachers? In the liberal arts college great departments of science with long traditions of excellence are invariably the lengthened shadows of great teachers.

To understand the problem of attracting and holding great scientist-teachers, look at what a young Ph.D. sacrifices when he chooses a liberal arts college. For one thing, his major time, energy, and effort goes into an activity toward which, in a real sense, his primary training was not directed. Admittedly, a Ph.D. degree in science is a research degree, and the hierarchy of subsidies and of values is such today that few of the best graduate students in science—even those who plan careers in teaching—log any significant amount of time as teaching assistants. The better the candidate is, the less teaching he is likely to do. Secondly, in the minds of the professional community and academic fraternity, by locating at a liberal arts college he may sacrifice prestige and status. He may well lose out on opportunities to travel, to attend meetings, be on professional committees, or to obtain support for research. He may indeed suffer financially—not so much in salary, but in opportunities for consulting, writing or lecturing as a visiting expert. He will be going out of the mainstream into an eddy where there is not the same burning research excitement, nor as many colleagues with whom to communicate. He may even jeopardize his chances of staying alive professionally, for a heavy load of teaching duties means that he must sacrifice time for creative and scholarly work. Actually, because the major emphasis in a liberal arts college is on its concern for undergraduate education, he may be sacrificing the many conveniences of having graduate students at hand and buying instead the drudgery of grading papers, maintaining his own storeroom and setting up his own laboratory demonstrations. Why would any competent young scientist, with his eyes wide open, walk into such a situation?

The answer may just possibly be because he loves to teach. It may be because he can achieve maximum satisfaction and self-fulfillment through creative and inspired teaching, because he finds it exhilarating and exciting to pass the torch to undergraduate students. It may be because he is the type of creative individual who wishes his contribution to be judged primarily on the basis of his teaching. Or he may be deeply interested in research as an integral part of the complete teaching of undergraduates. He may believe that the best hope of and ideal balance between teaching and research can be achieved at the liberal arts college. Underlying all these, it may be that he believes in the distinctive character, quality, and integrity of the concept of liberal arts education.

I am convinced that the number of this type of young Ph.D. is increasing. In larger and larger numbers these bright young teacher-scholar scientists are joining the faculties of the distinguished liberal arts colleges. But will they stay? To this my answer is yes, but on three conditions. They will stay if the liberal arts colleges can create and maintain a climate in which the scientist-teacher can function with dignity and honor and self respect as a creative individual engaged in a mission of recognized significance and worth. They will stay if they can be assured of an opportunity to remain alive professionally and to grow as professional teachers. They will stay provided they are enabled to maintain reasonable standards of living. In all three respects, the needs of the young science teacher at the liberal arts college are not at all unlike those of his counterpart at the large graduate university.

First of all, the young teacher needs recognition. Pay him the respect his service and contribution deserve. Do not classify him as a second-rate scientist and citizen simply because he teaches our sons and daughters as undergraduates rather than as graduate students. The fundamental difference is not one of teaching versus research: that issue is a false one. Original investigation is a vital ingredient of teaching and learning at the undergraduate as well as at the graduate level. The real question is research by whom, for whom, to what purpose, and for whose benefit. Theoretically, at least, the young scholar in the liberal arts college—not under the gun for quick results and early and frequent publication—is in a more favorable position to undertake deliberative, contemplative, long-range problems of great potential significance than is his more harassed counterpart in the graduate school of a large university. Furthermore, the opportunity for an undergraduate student and his professor to be partners in the high adventure of learning is usually much better in the high quality liberal arts college than it is in the large university. Often more of the real spirit of research is infused into the undergraduate courses in the best of our liberal arts colleges than in the courses in our universities. And, if we distinguish research as a personal activity from research as a managerial operation, we can say that there is probably more undergraduate research as a joint student-professor enterprise in our colleges than in our universities.

To remain alive as a teacher, and also to teach his students the thrill of the quest, the young scientist must be able and encouraged to do creative work. A study of thirty outstanding departments of chemistry in leading liberal arts colleges with distinguished records of productivity was conducted at a summer conference at Wooster College some years ago. The study revealed that all these colleges had active programs of original work involving the active participation of undergraduate students. In order to prevent human erosion—to keep bright and creative flowering scientists from going to seed—we in the liberal arts colleges must make it possible for them to undertake the high adventure of creative endeavor with their students right from the outset, before they become either timid and gun shy or embittered and cynical.

ENCOURAGING SCHOLARLY ACTIVITY

How can the liberal arts college encourage continued scholarly interest and activity among science faculty members? The only way I know is the way we are trying to do it at Hope College. The genius of creative scholarly work in the liberal arts college must ever be its spontaneity—the fact that it is not forced, that it is done for sheer love and interest of it. All members—save one—of our departments of biology, chemistry, geology, and physics, and more than half of our mathematicians, are currently engaged, with their students, in some scholarly activity, or research in the broad sense. Yet we do not require this. We do, however, hold several notions about teaching and learning which, in time, seem to engender a certain climate.

The first of these notions is that, as partners in a liberal arts college, we recognize teaching and learning as our primary function. We try to make it clear, not by our words but by our actions, that for teachers the payoff is on good teaching. Then we believe that, to be a good teacher, one must stay alive professionally throughout his career. When a teacher attends a national meeting of his own professional or learned society and discovers that he is not with it and wishes that he had stayed at home, it is time to be concerned. In fact, it may already be too late. How any individual teacher chooses to stay alive professionally is a highly personal matter. We feel that a good teacher awakens in the morning excited about at least two things: his students and his discipline, and how to bring the two together. But, again, how best the teacher can bring the two together is a matter of individual style.

We do make clear our conviction that in the natural sciences, at least, independent research is an important part of the education of majors. This does not mean that every member of the science faculties should be involved in conducting and supervising student research, but it does mean that some must. And research, when undertaken, should be undertaken in the interest of better teaching and better learning. In a liberal arts college it is the senior professor, not the graduate assistant, who is a model and example to whom the undergraduate student looks. And we believe that one of the finest legacies any teacher can leave a student is a vision of the teacher genuinely excited about some phase of his subject or discipline.

Interesting the fresh Ph.D. scientist and teacher-to-be in research is no problem. As they approach their first teaching post, most young scientists are eager for the opportunity to undertake their own research, particularly in the non-pressure-cooker situation which a liberal arts college affords. What they are much less likely to understand, given their graduate school background and experience, is that we are concerned that all of our students learn to see the world as a whole: to see the true body of knowledge as indivisible and to view each particular discipline as a part of a greater reality called civilization; to see that a discipline or profession is meaningful and relevant only when understood within its cultural context. We join with our students in seeking to discover from their teachers what it is scientists have learned that can enrich life and improve the society of which we are a part. But we make perfectly clear our conviction that a certain amount of rather specialized research is not inimical to this function of the science teacher in the liberal arts college. In fact, in an age which reveres competence, few indeed are the broad-ranging oracles with solutions to the world's problems who can be the least bit effective if they do not speak out of a conviction and integrity grounded in an unquestioned and authoritative competence in their own field.

The challenge which we propose to the aspiring teacher is to go beyond specialization: to break down the isolation of specialized disciplines, to bring them together in meaningful dialogue, to fit specialized information into a broader knowledge. It is not the specialization of knowledge, but rather its compartmentalization which creates partial knowledge. Our role is to show that specialization need not be the antithesis of total education and that disciplined intelligence can be not only compatible but also synergistic with wide-ranging knowledge. To us, in the liberal arts college, falls the all-important task of breaking down intellectual isolation, of helping to develop a truly meaningful integration of knowledge, of synthesizing meaningful understanding which will prevent isolation within a speciality. As we interview candidates for positions on our science faculties, this concern is communicated, not alone by the administration, but also by the members of our faculty and by the students who are also vitally involved in the interview process.

We try to make it clear that within this framework we give wholehearted encouragement and support to scholarly activity and creative work. Nothing is more important than getting started. Research, like studying during a vacation, becomes more difficult the longer one puts it off. For this reason, we make it a regular practice to assure a new staff member a stipend for research during his first summer on campus. If he is unable to gain support from some outside agency (and here the Petroleum Research Fund has a particularly enlightened policy in its Starter Grant Program) we supply assistance from special funds raised specifically for this purpose. Because support for research is much more readily available for the sciences than for other areas, except in special cases we restrict our regular college summer grants to the support of scholarly activities in the humanities, the arts, and the social sciences.

Somewhat parenthetically, I should like to emphasize the importance, both for the individual teacher and student and for the advance of science, of an active summer research program. Observing brilliant and capable scientists spending long hot summers painting houses or selling shoes has led me to believe that the thousands of scientists in our liberal arts colleges represent the largest single potential and incompletely tapped scientific research pool in our nation today. Research during the academic year in a liberal arts college is often on a necessarily low key, but in the summer we can go all out. To promote interest, stimulation and excitement, a critical mass of research and researchers is important in any summer program. For this reason, as well as for the development of the students, we do our best to support students in our summer research activities—and here the NSF Research Participation Programs are most helpful—encouraging them to remain even at some financial loss. Leaven has been introduced into the research loaf by numbers of our own graduates away at graduate school who find it both rewarding and enjoyable to return for a summer to work with us. And we have been successful at Hope College, through the appeal of low-cost housing and lake breezes, in attracting a few university scientists—especially from urban centers—for a summer to do research or write papers or books.

So we try to encourage sustained creative effort by our faculty throughout the school year. In the typical liberal arts college setting, there are definite limits; few big and dramatic accommodations can ordinarily be made. But a combination of little things may spell the difference. For instance, we try to make possible at least a slight reduction in total load for teachers who are engaged in significant and productive research involving students. Released faculty time made possible through Sloan Foundation and Research Corporation grants and through the Great Lakes Colleges Association teaching intern program, sponsored by both the Kettering Foundation and NSF, has been an invaluable boon to us. In addition, some of our students work on research programs throughout the year on a credit basis. Special funds, sedulously solicited, enable others to do research on work programs in lieu of waiting on tables or shoveling snow.

As is true almost everywhere, but at different levels, certain types of research will be ruled out at most liberal arts colleges for lack of necessary equipment. At Hope College we have, however, been quite successful in procuring funds for special equipment by telling our story simply and directly to government, industry, and foundations. Often the scientists themselves are the most effective spokesmen in telling what they need and why. Our scientists have been particularly successful in approaching local industries, in part undoubtedly because they are directly involved in setting up shared time and academic programs of great benefit to these industries and their technical personnel.

I should, parenthetically, underscore the fact that the college administration works no less assiduously to make these same advantages possible in the arts, the humanities, and the social sciences. True, it is easier in the sciences. We take advantage of what is available in the sciences because we do not believe that we can raise the floor by tearing down the ceiling. At our particular moment in history it is the sciences which most easily set the pace, but the other disciplines inevitably follow closely.

How can administrators help the scientist in the liberal arts college to maintain professional respect? There are several needs to which we should be sensitive. At Hope College, we have found it important to encourage each member of the faculty to attend at least one national meeting every year and to provide him the funds needed to do so. We are eager to have our faculty members present papers and participate in symposia; often these contributions may deal with innovative concepts in teaching.

The suggestion that they should consider scientists from the liberal arts colleges as consultants and as participants in their lecture series comes as a surprise to most scientists in industry, but after they have considered the idea they find it reasonable. A number of our science faculty are now serving as consultants to industry and give occasional lectures in industrial laboratories, with genuine stimulation both to themselves and their teaching. Textbook writing is natural for scientists in liberal arts colleges, but added encouragement must be provided internally because publishers do not court prospective authors in small colleges with the same fervor with which they do writers located in the large universities. There are other ways of broadening contacts. One of our departments has set up a successful exchange lectureship program with other colleges and universities in the area. Members of our staff with their students regularly attend seminars at neighboring universities. Scientists from university departments throughout the country have also come to lecture as well as to discuss graduate school opportunities with our seniors.

One of our senior professors, whose service on our faculty dates back to the days when almost no research was being carried out, returned to the University of Michigan for a year as a postdoctoral fellow under an NSF grant and has since developed an active research program on our campus. Other staff members have found a summer experience in the NSF College Teacher Research Participation Program worthwhile, notably when the university and the research directors are carefully chosen. Despite the temporary dislocations it may cause, an aggressive policy of aiding faculty members to obtain and take advantage of periods of leave which promise to offer significant and stimulating experiences is, in the long run, highly enlightened. This year, for instance, one of our faculty members is on leave as an exchange professor at the University of Groningen in the Netherlands and one as a postdoctoral fellow at Scripps Institute of Oceanography.

THE CASE FOR THE SUPPORT OF UNDERGRADUATE SCIENCE

On a broad front, I am convinced that presidents of liberal arts colleges should assert much more positive leadership, both individually and collectively, in stating and pressing the case for support of science at the undergraduate level. We must proclaim to leaders of government and captains of industry the fact that the total supply of scientists will, in the future, as in the past, be determined by the number of baccalaureate majors. And in order to increase the rate of production, the catalyst, to be effective, must be applied at the rate-controlling step.

Government and industry are still following the time-honored pattern, developed in an earlier day and under other circumstances, of allotting their educational dollar largely for graduate work. But they should be made to realize that in pouring their funds into graduate fellowships they run great risk simply of distributing largesse over mediocrity and peeling another layer from the already badly shrinking teaching-assistant onion. If their purpose is indeed in part to increase the total supply of scientists, then they should support undergraduate programs and, in so doing, they should not forget the distinguished undergraduate liberal arts colleges in which the development and welfare of the undergraduate student is the reason for being.

The superlative record of the outstanding liberal arts colleges in graduating men and women who go on to become quality scientists is no accident. Scientists are still made largely in the laboratory. And it is in the liberal arts colleges where the undergraduate student can work shoulder to shoulder in the laboratory with inspiring teacher-scientists. The peculiar genius of the liberal arts college in affording rewarding student-teacher interaction is brought to bear most naturally and most effectively in the laboratory. This is precisely why quality liberal arts colleges can always be preeminently successful in the preservation and development of scientists-to-be.

To preserve science of integrity for the liberal arts colleges and for their students will not be easy. The future is not at all assured, but the option is still open. And in our minds, this is one game that is truly worth the candle.

Undergraduate Preparation in the Sciences

FOR the undergraduate student the college years are a time for intellectual searching and personal development. They can be crucially important to the future scientist and college teacher. As an undergraduate the student can explore many academic fields and in doing so may sharpen and strengthen his intellectual interests and commitments. Thus a well-planned and challenging undergraduate science program not only stimulates enthusiasm for science, it also develops a clearer understanding of the nature and importance of the scientific enterprise. Such a program is vital to the intellectual growth of the student, his developing academic interests and ultimately his choice of life work.

The choice of one's career is a very personal and complex decision. Meaningful and rewarding experiences in science can contribute to this process and will encourage students to seriously consider science as a career. On occasion, college teachers have been accused of excesses in their efforts to perpetuate their own kind. In their enthusiasm some professors may approach the introductory course as though all their students are future chemists, physicists, or mathematicians as the case may be. Such enthusiasm is understandable and indeed may contribute to a dynamic style of teaching which will appeal to many students who do not ultimately become scientists. Nevertheless, the undergraduate years should provide a wide variety of educational opportunities. The undergraduate science program can play a vital role in awakening the interest and developing the talents of future scientists and college teachers. At the same time, it must also help other students to understand the scientific enterprise and appreciate its significance and potential contribution to the solution of human problems.

INTRODUCTORY COURSES

The aims and character of introductory courses in the sciences are especially important to those students who seek a valid basis for their career decisions. Whether for the major or the nonmajor, those courses should represent their fields not only in an authentic but in a stimulating way. Because they are so important, introductory courses in the sciences should be taught by the best senior faculty more often than they are at present. Furthermore, increased experimentation with audiovisual and other instructional aids should be encouraged. Most importantly, the introductory course should be a model of how to teach. Good science teaching not only implies the encouragement of social awareness, but also stimulates the able student to consider becoming a professional scientist and/or teacher.

Whether the same introductory course will serve students who expect to major in the subject as well as it will serve nonmajors depends upon several circumstances. Although some scientists seriously question the value of laboratory work in introductory courses, others believe instructional laboratories may serve useful purposes by teaching laboratory techniques as well as demonstrating general scientific principles. Laboratory teaching at the introductory level may reach the student who does not learn easily by means of verbal or other abstract symbols. It can show him that conclusions reached by abstract reasoning frequently conform to common sense or direct observation. He may also learn that the results of some experiments do not confirm commonsense expectations. The introductory laboratory experience may give the student a chance to make decisions and discoveries based on experimental evidence, or simply provide him with an early sample of life in the laboratory.

Some of these outcomes may be irrelevant to the goals of the introductory course; others are seldom achieved in freshman laboratory courses as we now know them. Nevertheless, freshman laboratory experiences inside the major for certain students and outside the major for others are often essential to good teaching in science. Where circumstances do not permit separate introductory courses for prospective majors they may require special supplementary laboratory work, program materials on technical vocabulary, and the like. Then too, students having differing mathematical backgrounds may make it necessary to divide or to section an introductory course on the basis of ability to handle abstract concepts. Creative thought and experimentation in devising new approaches to the introductory course, as well as varied laboratory experiences for students of differing abilities and aspirations, are very much needed.

In the two-year junior and community college, mathematics is an especially important part of the science curriculum. Typically, one finds three types of mathematics programs in these colleges: a college transfer program for those students who intend to continue their studies, precollege mathematics or what is often called remedial mathematics, and applied mathematics taught in connection with various technical and subprofessional programs.[1] It should also be noted that in both two-year and four-year colleges many students want and need mathematics courses in support of their work in subprofessional fields of business and technology. Computer and other applied mathematical skills are becoming increasingly important in the training of future scientists and subprofessionals alike.

Another troublesome curricular problem has been the attempt, never wholly successful, to develop one-year or two-year courses in general science for all students. When conditions are favorable, further attempts ought to be made to develop such introductory programs. Even though many faculty members are reluctant to become involved in such efforts, administrators must encourage and support those who do attempt this difficult task, especially since they risk their professional status by venturing outside their area of special competence.

There are also special problems at the introductory level in psychology. Psychologists who teach undergraduate students and attempt to interpret their discipline to the public require a very broad view of the field. A good deal of what people "know" about psychology is wrong and in introductory courses there is considerable debunking to be done. Thus, the introductory course is often an uneasy compromise between depth and breadth of learning. While this problem of content selection is common to introductory courses in many fields, it is especially difficult in psychology where students have a high expectation for relevance and often a predetermined agenda of personal interest and concerns.

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[1]The Committee on the Undergraduate Program in Mathematics has outlined in some detail, in its so-called "purple" recommendations, the program designed for two-year college transfer students. The report also describes a remedial mathematics course, "Mathematics A." *A Transfer Curriculum in Mathematics for Two-Year Colleges: A Report of the Panel on Mathematics in Two-Year Colleges*, (Dwight Goodner, Chairman), 1969. (CUPM, P.O. Box 1024, Berkeley, California 94701.)

The undergraduate years are the natural and logical ones in which to culminate that part of the student's formal education which supports his later general awareness and sense of the human relevance of science. Therefore the introductory science courses should be considered a vital part of a liberal education. They should explore the social implications of science as well as provide an introduction to the discipline. An example of this growing interfacial activity between an expanding discipline and the humane concerns of the liberal arts is especially apparent in biology. It is clear that increasing numbers of able, serious students are concerned about a wide range of problems that confront our contemporary society. They are asking terribly fundamental, philosophical questions with a new sense of urgency and a willingness to act. They challenge their student colleagues and us—for whom these questions have remained largely academic—to join them in their active concerns. We have talked about the population explosion and the need for population control, the manipulation of genes and the possibilities of genetic engineering. We have discussed the problems of environmental pollution but for the most part our conversation has lacked a sense of urgency. For our students these problems are no longer academic; they are immediate and urgent. Failure to solve them will have dire consequences for their generation. How to deal with interdisciplinary thinking about these problems at the undergraduate level—and especially in introductory and general science courses—is a problem which deserves our attention.

THE UNDERGRADUATE CURRICULUM

It is true that scientists today are less isolated from social problems than they once were and that sudents are both better informed and more concerned about them. But there is still need for furthering this social awareness as maturing students prepare for careers in their chosen fields. Therefore, major field requirements in the sciences should not become so extensive that they crowd out other important components of the curriculum which give breadth to the undergraduate program. The real or imagined pressure from graduate schools for greater specialization in the undergraduate curriculum is most unfortunate. A student who enters the graduate school with 65 hours of undergraduate chemistry may not become a better chemist or college teacher than one with 45 hours, even though he may finish his Ph.D. a year or two earlier.

The college teacher must master his discipline but he must also be able to relate this subject to the world at large. The problems of science and society or the relationship between science and government, for instance, should be given a place in the undergraduate curriculum. Faculty members and guest lecturers on the undergraduate campus should explore their disciplines from a broad cultural or philosophical perspective and seek to discover ways in which the sciences are related to other kinds of human experience.[2] The professional accrediting agencies and graduate faculties should modify their requirements so as to allow, indeed to insure, breadth as well as depth in the undergraduate preparation of those who aspire to professional scientific careers. Federal fund granting agencies which support undergraduate educational programs should be urged to develop criteria for evaluation which encourage greater breadth as well as specialization in the curriculum.

In a number of disciplines the curriculum for undergraduate majors presents special problems. In biology, for instance, because of its expanding interfacial activities with other disciplines, the student preparing to enter the field today must acquire a much broader training in mathematics, chemistry and physics than was formerly necessary. Students who fail to develop an adequate understanding of these disciplines will be poorly equipped to confront biological problems of the next few decades.[3]

The earth sciences also draw heavily upon other disciplines and there is need for more interdisciplinary work at the undergraduate level. Furthermore, many graduate students in the earth sciences come from smaller four-year colleges, and many others begin their undergraduate work in community and junior colleges. Although considerable

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[2] Such a series of lectures was delivered by the distinguished physicist Harold K. Schilling under the title "On Physics as one of the Humanities" at Illinois State University in 1965. The titles of Shilling's three lectures were: "Physics as Decision-Making," "On the Intuitive and Creative in Physics," and "Physics in the Human Quest for Understanding."

[3] The Commission on Undergraduate Education in the Biological Sciences, *Conference on Training College Biologists,* report of a conference held in East Lansing, Michigan, May 9-10, 1969. (Memo no. 69-11, May 28, 1969; CUEBS, 3900 Wisconsin Ave., N.W., Washington, D.C. 20016.)

effort has been made to develop interdisciplinary, problem-oriented teaching materials at the graduate level in the earth sciences little has been done to provide this type of material for use at the undergraduate level.

In psychology the special problems of the introductory course, referred to earlier, extend as well to undergraduate major field requirements. Psychology also has other peculiar problems for the learner. It is less systematic than some other fields in science; the established general principles are few and the structure of the field somewhat loose; the range of topics is broad and at the elementary level it is difficult to relate them to each other. Furthermore, psychology is both an academic and a professional discipline. The interests of academic and professional psychologists are somewhat different and these differing perspectives are sometimes reflected in the undergraduate curriculum, even though all psychologists have agreed that undergraduate courses should be nonvocational in nature.[4]

One good consequence of this approach is that prerequisites for graduate programs in psychology tend to be minimal: the modal number of hours of undergraduate psychology required is about 15. Many graduate departments would just as soon have entering students with undergraduate majors in biology, philosophy, mathematics, or electrical engineering—all of which have their uses in advanced studies in psychology. These graduate departments look for a solid but broader undergraduate background than would

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[4] Many members of the American Psychological Association are practitioners who compete with psychiatrists for patients. Because of the competition, the profession insists upon the highest standards for training and as a result there are restrictions in many states as to who can call himself a psychologist. The Education and Training Board of the American Psychological Association, supposedly concerned with all aspects of education in psychology, has thus had to devote most of its efforts to the accreditation of doctoral-level programs and has had little energy left to devote to other areas of psychological education. Some initial steps have been taken to improve the undergraduate major. The Education and Training Board of the American Psychological Association has secured support from the National Science Foundation for the first phase of a project to study the undergraduate psychology curriculum, to survey present programs, identify places where innovations are being made, and to try to evaluate their effectiveness. The first phase of this project is being directed by Stanford Ericksen of the University of Michigan.

be the case if a high concentration of courses in psychology were required.

The undergraduate mathematics curriculum and the training of four-year college teachers has been discussed in detail by the Committee on the Undergraduate Program in Mathematics.[5] It should be noted, however, that an important source of teachers for the two-year colleges is married women in the community who majored in mathematics in college. The undergraduate major program—particularly for women—could be designed in such a way as to prepare them better for undergraduate teaching. This is not to imply that an undergraduate major is adequate preparation for the two-year college teacher but it can provide a base for later entry into the field.

The undergraduate major in all science fields should provide opportunities for the student to expand his horizon by responding to developments in other disciplines, especially those in applied fields. One example of this type of interdisciplinary activity might involve the exploration of the biological components of an ecology course for engineering students. Urban planning - d regional development provide other examples of developing fields which have implications for the basic sciences. Likewise the relation of scientific development to man's progress in the realm of ideas offers an opportunity to develop an intellectual perspective of science. Even though past efforts to teach the history and philosophy of science in general, and of individual sciences in particular, have not been uniformly successful, students appear to be increasingly interested in these topics. Further efforts to include them in undergraduate course offerings should be encouraged

MOTIVATING CAREER CHOICE

Because teaching can be in itself a stimulating learning experience, undergraduate students should be given opportunities to teach. Those faculty members who have had ex-

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[5] The Committee on the Undergraduate Program in Mathematics, *Qualifications for a College Faculty in Mathematics*, report of the ad hoc committee on the qualifications of college teachers (Richard Anderson, Chairman), January 1967. (CUPM, P.O. Box 1024, Berkeley, California 94701.)

perience with the participation of able undergraduates in the teaching process have been very impressed with the results—both in terms of students' effectiveness as teachers and the favorable attitudes toward teaching which result from this experience. This does not mean that a junior or senior can properly teach a section of organic chemistry, but that he can participate successfully in various low key instructional functions. He may also assist with academic advising and perhaps would learn a great deal about academic life by attending some departmental meetings.

There are other means of stimulating an undergraduate's interest in teaching and identification with his discipline. Membership in the campus science club, the departmental honorary society, state academies of science and national professional organizations all hold promising possibilities for stimulating the desire to pursue a scientific career. While there is a tendency for on-campus departmental science clubs to wither away, the trend could be reversed if these clubs were provided with a small budget for securing outside speakers and for other stimulating program activities.

Opportunities to participate in science research and for summer or term-time employment in science-related activities are particularly fruitful in encouraging undergraduate interest. Students who as juniors or seniors get a taste of research experience are very likely to consider an academic career in science. Science-related employment and the opportunity to see the practical application of scientific knowledge also stimulates interest in science careers.

At the present time, one very serious problem is the need to provide greater educational opportunity in the sciences for minority students. At present these students are seriously underrepresented in scientific fields. Some scientists question whether any considerable number of minority students possess the requisite competence, background and potential for successful work in the sciences. Nevertheless, many minority students, including those who transfer from junior and community colleges, have demonstrated their ability to succeed in the sciences. Even so, there is a problem of self-selection among minority groups. Many minority students limit their consideration of science-related occupations to medicine or dentistry, largely because these are the only scientific occupations with which they have had direct experience and which have attracted minority students in the past. It would be desirable for professional organizations to provide more opportunities for highly talented disadvantaged students to meet and observe professional scientists at work in a variety of fields. Interest in science and science teaching needs to be fostered early.

NEW DIRECTIONS IN UNDERGRADUATE PROGRAMS

Whether or not he majors in a scientific field, the liberal arts student needs to be confronted with some science—especially some acquaintance with the methods of science. Practicing the mental processes involved in doing science is more important than learning the bodies of facts called science. Although some students today claim that they know what is relevant, they are not always able to ascertain what a sound liberal arts education requires. Therefore it is incumbent upon the college faculty itself to evaluate the undergraduate major apart from the process of external instructional accreditation or teacher certification, or in relation to the number of majors admitted to graduate schools. Since most of the currently active forces except inertia seem to be working in the direction of increased social concern—as students often remind us—there may be some danger of yielding uncritically to these forces and selling our scientific birthright for a "mess of relevance." The faculty and the scientific community at large must assume responsibility for curricular reform and at the same time safeguard our priceless scientific heritage.

There is a need to seek new directions in undergraduate programs in science. Colleges should do their share—if not take the lead—in research on undergraduate curricula and programs. College and university budgets in all fields should contain a line item for curriculum research and development. Just as modern industry supports research and development, so should academic institutions regularly provide funds for this purpose. Many exciting innovations are being made but more curricular experimentation is needed. Colleges should have some faculty members who are interested in and are specifically trained to conduct research on curriculum development and the learning process in the sciences. Although change just for the sake of change is not to be encouraged, innovation based on careful study and recognition of the dynamic nature of scientific knowledge is very much needed and constitutes a wise response to contemporary students' demands for educational relevance.

The Graduate School and the Developing Scholar

IN his future career the scientific scholar will have to communicate to others, often to nonscientists, about various aspects of his work in a clear and effective manner. Alfred North Whitehead once advised that if you wish researchers to be good researchers you will require them to explain their work to others who have active questioning minds. Whitehead's dictum suggests that future scientists, be they teachers or researchers or both, will profit from an opportunity for teaching experience during their graduate years. Therefore, while recognizing the need for flexibility in individual instances, graduate programs should provide teaching opportunities for a large proportion of graduate students.

Graduate departments generally recognize their responsibility for providing sufficient depth and breadth in the doctoral program to enable the student to become an effective worker in his discipline. They should also take seriously their responsibility to orient and socialize the student in his discipline and to provide carefully supervised experience in the theory and practice of instruction. It is also important that the graduate training increase the student's awareness of his discipline's relation to other disciplines and to the society in which he lives. Major graduate departments must provide active leadership in the exploration and implementation of effective programs in these areas. A few large institutions have taken encouraging first steps but much more work in many more institutions and departments remains to be done.

The identification of potentially creative scientists is another significant problem facing the graduate schools. The Graduate Record Examination Board has recommended that the Educational Testing Service add a measure of potential for creative and productive achievement in graduate study to the traditional measures of verbal and quantitative aptitude of the GRE.[1] ETS has been working on developing a biographical inventory in order to elicit past evidence of creative

[1] John L. Landgraf, Chairman, "A Report of the Graduate Record Examination Board," *Proceedings of the Seventh Annual Meeting*, Council of Graduate Schools in the United States, Washington, D.C., Nov. 30-Dec. 2, 1967, pp. 9-10.

effort and productive achievement. Such a test assumes that candidates for graduate study who have creative and productive potential are likely to have displayed these qualities in the past. Hopefully, these characteristics are sufficiently independent from traditional verbal and quantitative measure that they will significantly increase the overall predictability of success in graduate study.

The National Academy of Sciences and the newly formed National Academy of Education are developing a program to promote basic research in the field of education. At its 1969 meeting, held at the University of California at Los Angeles, the Academy of Education explored the psychobiology of learning and memory. Perhaps the future work of these two national academies will further our knowledge and understanding of creativity in science.

DIMENSIONS OF SCHOLARLY DEVELOPMENT

One increasingly important aspect of graduate training is the widening of the young scholar's view of his subject. The accelerating growth of scientific knowledge poses a serious problem for the training of both graduate students and older scientists whose earlier graduate training is now seriously outdated. For instance, many biologists in the field today really need extensive retraining to handle contemporary biological problems. Graduate training must emphasize broadening concepts of science and particularly the interdisciplinary nature of many research frontiers. Biology, for example, can no longer be regarded as a "pure" science. The horizons of molecular biology, psychobiology and ecology require that the young biologist have a much more sophisticated understanding of the physical sciences and mathematics than ever before. Likewise in mathematics there is a growing need for scholars and teachers who can apply mathematical concepts and techniques to problems in the social sciences.

Another important area in graduate training is the relationship between pure and applied research and scholarship. Although these categories are not always clear, some consideration of them will help the graduate student to understand better the nature and structure of his discipline. Exploration of both the pure and applied components of knowledge is especially useful in relating scholarship to teaching. It is not enough to produce better scientists or even better teachers of science. These two tasks are important but they must be accomplished in such a way as to give future faculty members a wider perspective as they confront students in the classroom.

There is also a continuing need for furthering the social awareness of the maturing scientist. Specific activities organized within the Ph.D. program should be developed in pursuit of this goal. For example, such activities might include a seminar on the problems of science and society, or, more specifically, on the topic of science and government. The training of the young scientist should enlarge his effectiveness beyond the narrow confines of his subject. In this respect, the teaching assistantship can be used to expose the student to some of the problems of logistics in the conduct of research, to discussions of sources of information and funding, as well as to questions of public policy with respect to scientific educationand research and other aspects of what one might call the social context of science.

Over the years there has been considerable discussion about the importance of research training for scientists. Yet in most disciplines 90 percent of the literature is produced by 10 percent of the people. Furthermore, little of this research is likely to stand the test of time. Even so, we must continue—and hopefully improve—our efforts to identify young scholars who have promise as researchers. We must make sure that they mature. At the same time we must not neglect teaching. Perhaps we need to question our present allocation of time and resources in the interest of achieving a better balance between teaching and research.

SUPPORT FOR THE DEVELOPING SCHOLAR

Almost all graduate students in the sciences receive financial support as teaching assistants, research assistants, trainees or fellows. During his graduate years, a student may occupy more than one such position. Each provides certain opportunities to extend and enlarge his experiences. Some institutions have a scale of support for graduate assistants which recognizes their increasing experience and effectiveness.

One way to increase the effectiveness of financial support for graduate education would be for federal and state agencies—as well as for the private sources of fellowship and traineeship support—to permit the graduate school to combine funds from all available sources. It would then be possible to budget "support packages" tailored to the financial needs of the individual student. At present, a fellowship student can actually be prevented from teaching during the term of his fellowship and thus is denied supervised teaching experience. At the other extreme, the graduate student who is unable to obtain a fellowship may be forced to become a teaching assistant from the outset of his predoctoral study—to the possible detriment of his progress as a scholar. Graduate schools should be enabled to design programs and provide support so that each graduate student may have a balanced program of study, teaching experience and research suited to his individual needs and interest. This is what is sometimes called the Graduate Combination Fellowship Proposal, which came out of the conference held by the Advisory Council on College Chemistry concerning the appropriate use of junior staff and their role in the university teaching program.[2] Some universities are already pooling nongovernment funds as a first step toward the development of a "support package" program. Unfortunately, most federal grant funds are assigned to specific research or training projects and thus cannot be pooled in this way.

At present, federal support for scientific training is directed primarily toward the training of research scholars or, as in the medical or dental training programs, to enhance the applied skills of professional specialists. Although in recent years the federal government has been very generous in supporting graduate education, major cutbacks are now being made in federal funds. These cutbacks may be temporary, and similar to those which occurred just prior to the Korean War. Hopefully, the federal government will resume its support of scientific research so that the graduate training of research scientists will continue at a level sufficient to meet the nation's specialized manpower needs.

POSTDOCTORAL EDUCATION

The National Research Council has recently completed an extensive study of postdoctoral education, the first—and

[2]Advisory Council on College Chemistry, *A Proposal for the Support of Education and Research in Chemistry*, Teacher Development Committee (Robert Brasted, Chairman) 1967. (AC3-TD-8-a, 7-14-67)

a far more searching—study of postdoctoral education since Berelson's *Graduate Education in the United States* in 1960.[3] In particular, the report outlines the role that postdoctoral students play in the education of graduate students, frequently serving as surrogate mentors in the dissertation phase of graduate education. The postdoctoral student is in a sense the teaching assistant for graduate students. This is good preparation for his future professional role as faculty supervisor of doctoral students.

Especially in the experimental sciences, the postdoctoral experience is becoming a common extension of graduate training. In addition to providing residential postdoctoral study on their own campuses, major graduate departments should offer science faculty members from nearby liberal arts colleges opportunities to participate in research seminars and other activities in order to help them keep current in their discipline. Other possibilities include cooperative access to complex instrumentation, perhaps on a regional basis. Such a program may be an important stimulus both for research activity and instructional experimentation in smaller institutions. Several interinstitutional arrangements of this type have already been established in the field of physics, and the College Science Improvement Program of NSF is especially adapted to the support of this kind of graduate school activity.

Summer research centers operated by major graduate departments provide another way to maintain the competence and scholarly activity of the four-year college teacher. One model for this kind of cooperative effort is the NSF Research Participation Program for College Teachers. Focusing on specialized subdisciplines, these summer research programs give the college teacher an opportunity to meet with other scholars in his own speciality and to work with them to maintain competence and interest in his chosen field.

Universities could also establish regional centers that accept responsibility for maintaining contact not only with their own alumni but with all young scholars at nearby liberal arts colleges who wish to participate in a year-round pro-

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[3] National Research Council, *The Invisible University—Postdoctoral Education in the United States* (Washington, D.C.: National Academy of Sciences, 1969).

gram of colloquia and seminars, as well as special summer activities. Enlarging the competence and encouraging the scholarly activity of the four-year college teacher—especially recent graduates and those about to complete their doctoral study—is an important responsibility and provides the graduate department a significant opportunity both to serve the academic community and to further the scientific enterprise.

The Graduate School and the Developing Teacher

A LARGE proportion of graduate students in all fields of science go on to college or university teaching. Thus the university is not only training physicists or biologists or chemists, it is also training future professors. Mastery of his discipline is the first responsibility of the future professor but mastery of the art of teaching is also important. In the course of sixteen years of schooling, followed by intensive graduate training, the student has encountered many styles of teaching. He has developed pedagogical tastes and values and perhaps even abilities, although this development is unplanned and more or less unconscious. When he enters the classroom as a teaching assistant he has his first opportunity to test his latent skills and to begin to develop his teaching potential.

THE TEACHING ASSISTANTSHIP AND INTERNSHIP

The quality of the graduate assistant's teaching can be influenced through supervision, seminars or other techniques. Well-planned efforts to support the graduate assistant can greatly enhance his classroom performance and thus make the teaching experience more profitable to him and to his students.

Knowledge of how young adults learn will be useful to the teaching assistant. Psychology offers some guidance, and it will pay the beginning teacher to follow it. Therefore internship programs and seminars should provide models which relate to learning theory and the importance of motivation. An understanding of the importance of motivation for learning is particularly valuable to the teacher. Extrinsic rewards such as grades are less likely to induce solid learning than the intrinsic satisfaction which the student gets from mastering a subject and integrating knowledge for himself. To stimulate successfully this kind of learning a teacher has to be sensitive to the changing values and attitudes of different generations of students.

Another problem confronting the teaching assistant is how to organize his discipline for the purpose of teaching it. The process of devising a curriculum can in itself be very instructive for in so doing it becomes apparent that knowledge can be organized and presented in many ways. The task also helps the graduate student to understand better the internal structure of his discipline.

The teaching assistantship program should also involve some kind of organized activity directed toward questions of teaching methodology, including discussion of the curriculum, teaching methods, and classroom evaluation. The evaluation of learning is a task which every teacher must perform. Some acquaintance with the technology of educational measurement will be rewarding both to the young teacher and his students. However, it must be recognized that extensive study of the psychology of learning and educational evaluation is beyond the scope of the teaching assistant program. Future professors should be encouraged to pursue these concerns throughout their teaching careers. Psychologists are aware of the complexity of these problems and are always searching for better means of evaluation and a clearer understanding of the learning process. Much work remains to be done, but even some of the "approximate first answers" to important questions relating to learning and evaluation are helpful guides to the new teacher.

Experiment and innovation in training graduate students to become good teachers, as well as further exploration of teaching skills and techniques, must be encouraged. Summer institutes provide an important vehicle for this work and at least two government programs have supported projects in this area: the Education Professions Development Act administered by the U.S. Office of Education, and the College Science Improvement Program (COSIP) of the National Science Foundation. Experimentation and innovation can also be stimulated among the teaching assistants themselves. Furthermore, there should be some form of graduate student participation in planning and evaluating of the undergraduate program. Because of his intermediate status, the graduate assistant can often help undergraduates in ways that senior faculty find difficult or impossible. Thus the teaching assistantship should not be regarded as a source of cheap labor for the instructional staff but as a vital part of the total teaching and learning process.

Finally, the preparation of the graduate student who intends to teach in a college or university should include some exploration of the history and culture of the academic community and the professor's role in the college or university. The academic community, society and the professor will all profit from his better understanding of his calling and its place in the world.

Beyond the teaching assistantship, at the borderline between graduate study and postdoctoral training, is the teaching internship. It is generally characterized by a greater involvement in the planning and development of the course offering than the role usually assigned to a teaching assistant. Such internships are appropriate experiences for advanced graduate students of superior ability as well as for postdoctoral fellows who are interested both in research and teaching. Because of the great demand for college teachers from minority groups special efforts should continue to be made to involve representatives of these groups in internship programs. A university teaching internship is also a very valuable experience for a junior or community college teacher. Young faculty members at neighboring four-year colleges might also find a university teaching internship helpful when their college does not itself afford these opportunities.

SELECTION, TRAINING AND SUPERVISION

Even if there were agreement as to the content of teaching-assistant or internship programs, the question of optimal organization and presentation of this content remains. Appropriate timing and the graduate student's readiness for successive new experiences are important considerations in the development of an effective program.

The value as well as the success of the graduate student's teaching experience depends largely upon the attitude of key members of a graduate faculty toward undergraduate instruction. Appropriate recognition of the teaching function by the graduate faculty is of crucial importance. Some institutions have a graduated support scale for teaching assistants which recognizes increasing experience and effectiveness in the laboratory and in the classroom. Others have adopted a policy of selecting teaching assistants from a broad spectrum of the graduate student population. This policy avoids making the teaching assistantship a consolation prize for those not receiving fellowships. It also avoids concentrating teaching assignments among first-year graduate students, who are often least well equipped to enter the classroom. Furthermore, first-year students themselves need time to adjust to the rigors of graduate study.

The selection of teaching assistants is essentially a matter of matching the student to the job: some individuals are better suited for teaching than others. Selection is essentially a two-stage process. The first step involves screening applications by a member of the department who is familiar with the total curricular program, the personnel needs on the teaching assistantship staff, and the past performance of graduate students who have held teaching appointments in previous years. The final selection should be made by the faculty member who will actually supervise the work of the teaching assistant. This professor also bears major responsibility for helping the teaching assistant understand the goals, objectives and methods of the course in which he will be teaching and its place in the undergraduate curriculum.

The training and supervision of the teaching assistant may be either direct or indirect. At times the principal instructor will actually supervise the teaching assistant in the laboratory or in the classroom by observing, evaluating or correcting his work. Hopefully, these functions will be carried out tactfully so as not to destroy the rapport which the teaching assistant has with his students. Indirect training may include discussion of course outline, assignments, teaching methods, and recent classroom experiences. Some consideration should also be given to student characteristics and attitudes and to appropriate ways of dealing with students in the classroom and the laboratory.

Although the utilization of senior graduate students and postdoctoral fellows as supervisors of teaching assistants may in many instances be desirable, this practice cannot be substituted for the active and interested involvement of senior faculty in the undergraduate teaching program. Their demonstrated belief in the importance of good teaching will do more than anything else to enhance the quality of undergraduate teaching. The availability of a reasonable amount of funds for classroom experimentation and innovation may also assist in producing better teaching.

EVALUATION AND REWARD

Evaluation has two important aspects in the teaching assistantship program. One can evaluate the performance of the teaching assistant himself: Has he mastered the subject matter of his course? Can he communicate it clearly and imaginatively to students? Can he operate effectively in a variety of instructional modes including classroom discussion? Is he able to motivate students to learn? One can also evaluate the achievement of the students in the teaching assistant's classes: Do they perform satisfactorily on achievement tests covering materials in the course? Do they acquire desirable attitudes toward the course, the discipline and the teaching assistant himself? Both of these aspects of evaluation will be useful to the teaching assistant and to the supervising faculty member. Furthermore, both self-evaluation and future recommendations by the faculty will be more effective and realistic if the evaluative function is performed carefully and in some detail. In addition, this process of evaluation will be helpful to the faculty in reviewing the overall effectiveness of the undergraduate program and in selecting graduate students for similar teaching assignments in the future.

The reward system for the teaching assistant is important. As has already been indicated, there is the intrinsic reward of having done an effective job of learning and teaching, as well as its recognition by an appropriate title and a higher salary. If a coherent and flexible program of support for graduate students could be developed, it would help to enhance the status of the teaching assistant as a member of the academic community.

THE NEED TO STUDY EXISTING PROGRAMS

The various position papers prepared for this conference, especially those from the college commissions, discuss in some detail various ideas and programs for the training of teaching assistants and for improving their grasp of the theory and practice of instruction.[1] Although there are differences in detail, all of these reports deal with common problems. They suggest that there are more efforts to encourage better preparation for college teaching than is readily apparent to those who are primarily involved in the problems of their

[1]For example see the paper by John Fowler, Richard West and Kathryn Mervine, "The Preparation of College Physics Teachers," pp. 63 to 81 of this report. Similar material relating to the other science disciplines is available from the appropriate college commission (see List of Participants, p. 93).

own disciplines. Unfortunately, these efforts have not been systematically studied or catalogued. Questionnaire surveys are often of some use but they may not reveal the actual status and content of such programs. At the University of Michigan, for instance, it was found that a favorable attitude toward teacher training resulted in a tendency to "enhance" written reports of current activity, with the result that personal interviews at the department level were required in order to evaluate teaching assistantship programs realistically.[2] No doubt the data which university departments receiving grants for teacher preparation under NDEA Title IV are required to file with the U.S. Office of Education are biased in a similar way. Even so, a study of these USOE data might help identify the scope and location of current efforts to improve the preparation of college teachers. In view of the inadequacy of the present data, further studies of college teacher preparation should be encouraged.

DIFFERING OBJECTIVES IN TEACHER DEVELOPMENT

The tremendous growth of higher education in recent years presents problems both of quantity and quality in the preparation of college science teachers. Some four-year colleges teach only general education courses in science and do not offer science majors or prepare students for graduate work in science. As the number of both colleges and students continues to increase, most of the increment will be in public institutions and notably in the two-year community colleges. Therefore it is important to strengthen science teaching not only in the four-year liberal arts colleges, which differ widely in their objectives, but in junior and community colleges as well. The goals of science programs in these institutions may differ but high standards related to those goals must be encouraged. Superior talent is always scarce. As we face the task of staffing a rapidly increasing number of colleges and courses we must face the fact that not all of tomorrow's college teachers will possess superior talent; indeed many will be mediocre. Improved preparation of college teachers must be directed toward securing the best possible results from

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[2]Frank Koen and Stanford Ericksen, "Analysis of the Specific Features which Characterize the More Successful Programs for the Recruitment and Training of College Teachers," reports such a study. The study itself and a summary (contained in "Memo to the Faculty—No. 21," March 1967) are available from the Center for Research on Learning and Teaching, University of Michigan, Ann Arbor, Michigan.

those whose talent for science may not be of the first rank. Enrichment of their intellectual experience during their graduate school years, as well as better undergraduate preparation, can help to overcome some of these limitations.

It also must be recognized that in any large graduate school there is a wide diversity of student ability and aspiration: teacher-researchers, teacher-nonresearchers, and non-teacher-researchers. It is unrealistic to expect that all students will develop a strong interest in undergraduate teaching. Some will prefer to concentrate on scholarly activity and research, especially during the early years of their career, for many scientists agree that this is the period of greatest research creativity. Later, these research-oriented scholars may become more interested in the problems of teaching. Other students display this interest in teaching from the very beginning. There have been a number of proposals for the development of alternate degree programs at the doctoral level for those students whose primary interest is teaching rather than research. These suggestions have never been greeted with much enthusiasm in the sciences and present attitudes among scientists seem to confirm this view

Furthermore, in many fields the supply of Ph.D. scientists is beginning to catch up with demand and it is unlikely that graduate science departments will invest much time or energy in alternate degree programs at a time when there is a buyer's market for Ph.D.'s. The four-year liberal arts college will continue to seek and will be increasingly able to secure doctorate-level scientists for its faculty.

In the two-year college the situation is different. The rapid growth of community colleges and their special needs for staffing suggest that the Ph.D. is probably not the appropriate credential for the vast majority of two-year college faculty members. There seems to be growing sentiment in the two-year college that the qualified faculty member probably should have 30 to 60 hours of graduate courses which may differ in many cases from those normally prescribed for the Ph.D.[3]

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[3] In chemistry, for instance, the problem of staffing the community colleges has been studied jointly by the Advisory Council on College Chemistry and the American Association of Junior Colleges. A report of a conference held in Dallas, Texas in January 1968, entitled "The Education and Training of Chemistry Teachers for Two-Year Colleges," is available from the Education Office, American Chemical Society, 1155 16th St., N.W., Washington, D.C. 20036.

It appears likely that many graduate departments training scientists at the doctoral level will not concern themselves with the preparation of two-year college teachers. This is notably the situation in mathematics, where adequate training for the two-year college teacher involves work in both pure and applied mathematics. Furthermore, particularly in the two-year colleges, the teacher is confronted by students who possess a wide range of abilities and objectives. This diversity complicates the learning process and requires the teacher to develop great skill in dealing with students. Consequently graduate departments concentrating at the M.S. level should be encouraged to accept major responsibility for the training of two-year college teachers of science. Since teacher education at this level is likely to be done by someone who wants to do it and since a very large number of two-year college teachers are presently trained in schools and colleges of education, it would be desirable for university graduate departments to cooperate with their schools of education in this important endeavor. Academic-year and summer institutes or similar inservice programs can also be devoted to training two-year college teachers.

These divergent patterns of preparation for two-year and four-year college teaching present certain difficulties. As an example, the academic component of many two-year college curriculums is considered as equivalent to that offered in the four-year college and results in the granting of credit applicable toward a B.A. or B.S. degree. A different problem is indicated by the fact that persons preparing for two-year college teaching are usually happy to be relieved of the necessity of completing the doctorate before starting their teaching careers, yet they may resent being shunted into terminal master's degree programs which are inapplicable to doctoral study at some future date.

These and other problems related to the preparation of two-year college teachers deserve the careful attention of science educators.[4]

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[4] Some of the problems related to the preparation of teachers for the two-year college are discussed in a report of a "Conference on Science in the Two-Year College" held in Washington, D.C. June 18-19, 1969. Copies are available free from the Commission on Undergraduate Education in the Biological Sciences, 3900 Wisconsin Ave., N.W., Washington, D.C. 20016.

Postdoctoral Development of College Teachers

THE graduate and early postdoctoral years—including the early teaching years at the liberal arts college—involve experiences specifically aimed at making the young scientist a better teacher. Each institution must endeavor to provide an environment that will encourage continued scholarly interest and activity in the sciences and thus enhance science teaching. Above all, a successful science program in the college depends upon the quality of its science faculty. The liberal arts college must select its young staff members carefully, giving attention to personal qualifications that are specially relevant to its goals and purposes. A successful educational program depends upon effective matching of the candidate's interests and abilities with the aims of the institution.

Unfortunately, the graduate school experience and attitudes expressed by university professors sometimes prejudice the graduate student's willingness to consider undergraduate teaching, especially in a four-year college, as a desirable and worthy career. The strong research emphasis, and occasionally the denigration of undergraduate teaching, in our graduate schools often convinces the new Ph.D. that acceptance of an undergraduate teaching job is tantamount to committing professional suicide. His professors tell him that in the college teaching loads are heavy, research opportunities are scarce and laboratory equipment is inadequate. They have been known to tell him that if he goes to such a place he will never be able to meet the high expectations that his associates, his university and the scientific community have for him. Little or nothing is said about the genuine satisfactions to be derived from creative teaching nor of the real social and scientific importance of high quality undergraduate science education. Universities should reinforce the idea that the four-year college is not an academic Siberia, and should reassure the potential college teacher that opportunities do exist there for scholarly activity and professional growth.

RECRUITMENT AND SELECTION

It is in the above cultural context that the four-year colleges have to attract and recruit a high quality science faculty.

During the past two decades when higher education has expanded rapidly and Ph.D. scientists have been in short supply, effective faculty recruitment has been especially difficult. At present the supply of Ph.D.'s in some fields has begun to catch up with demand. Furthermore, the decreasing availability of research funds, especially from the federal government, has made college teaching more attractive. Thus some four-year colleges are now beginning to find it less difficult to attract well-qualified scientists to their campuses.

Colleges themselves should carefully examine their recruiting practices. For example, it would be desirable to require more complete vitae so as to provide a better picture of the candidate's background and experience, in addition to his graduate school record. In the small college particularly, the evaluation of the candidate should not be the sole responsibility of an individual department. Other faculty members external to the department and administrators who are concerned with the college and its total educational program should help decide who will be invited to join the faculty. Some colleges even find it desirable to ask students to share in evaluating prospective faculty members.

A college's expectations concerning research and scholarly activity should be stated as clearly as possible at the outset of the relationship. There should be a careful and clear articulation between the goals of the college and those of the individual faculty member as a teacher-scholar. A clear understanding of this relationship—both by the college and the faculty member—will improve faculty morale and enhance the educational program of the college.

ENCOURAGING THE YOUNG TEACHER

In recent years there has been greater recognition of the importance of good teaching as one of the criteria for faculty evaluation. Student demands for better teaching have been a significant influence in this regard. Promotion and tenure committees are beginning to recognize and value good teaching. It will be helpful if presidents, deans and department heads articulate their support of good teaching and urge promotion committees to reward this vital activity.

What makes a good teacher has long been debated. It is very difficult to set down concrete objective criteria for teaching excellence. Yet, in a subjective but valid way, it is possible to determine who is a superior teacher and who is a poor teacher. It is much more difficult to distinguish between a merely adequate teacher and a good teacher. Nevertheless, there are means for judging the quality of teaching and of encouraging self-evaluation among young teachers. Such techniques include student evaluation (which is both underestimated as well as sometimes over-rated), discreet help by senior colleagues, and private use of videotapes and other feedback devices for self-evaluation of teaching performance.

Both the university and the college should demonstrate in many ways that they recognize good teaching and will reward the good teacher. Just as universities and colleges support research they also should support instruction through grants for innovative and experimental teaching. It is certainly incumbent upon all institutions to develop criteria for the identification of good teaching, to study how it might be nurtured, and to provide faculty members with released time as well as lead time for course development. Other ways of supporting good teaching include support of summer activities designed to enhance teaching, money for project development, and just plain moral support. Many colleges have found it helpful to establish a mentor relationship between new junior faculty members and senior professors so that, early in his career, the new faculty member can establish good patterns of teaching with the advice and guidance of a superior teacher.[1]

The present practice of assigning heavy teaching loads to the young scholar should be changed. He should have a light load, freedom from administrative duties, and frequent leaves of absence. Tulane University, for instance, makes it possible for young professors to discharge their total annual teaching responsibility during one semester so that they can use the other for full-time research work.

INNOVATION AND DEVELOPMENT IN TEACHING

Although there may be some danger of diverting a young scholar from potentially creative research, the most effective

[1] Two articles in the October 1969 issue of *Liberal Education* deal with faculty development: Richard P. Vaughan, "Teaching the Teachers" (pp. 417-420) and Sherrill Cleland, "Internships are Second Best" (pp. 421-432).

way of improving college teaching might be to give the young teacher, after about three years of experience, a one-semester leave to be spent in a program individually and specifically designed to improve his performance as a teacher. By this time he will have some real questions to ask about teaching and ought to have a chance to reflect and seek answers to them. This semester leave should be spent away from the teacher's own college, and he should pursue a specific, though not inflexible, program which has been discussed and approved in advance in cooperation with his college. He should not only be concerned with techniques for improved teaching in his discipline but he should reflect on his responsibilities as a scholar-teacher and as a member of the college community. He might also explore new approaches to curriculum development, recent advances in the psychology of learning, and some experiences designed to extend his own social awareness. Specific topics for study might include the relationship between the university and society, that of the student and his learning problems, and the increased educational opportunity for minority groups.

As an extension of its already existing science faculty fellowships, the National Science Foundation should be urged to provide increased funding for such programs. Without significant outside funding, universities and colleges might also provide such opportunities through faculty exchange programs. Although this approach poses some difficulties for small colleges having small departments, by careful planning and the rotation of their course offerings most liberal arts colleges can arrange for each department member to have a semester's leave periodically.

Many colleges and universities are showing greater interest in and encouragement of curricular innovation and the development of new approaches to learning and teaching. The University of Minnesota, for instance, makes small grants available to individual professors who wish to innovate or experiment in their own classrooms. Michigan State University has a similar program which also provides the professor with the consultant services of an educational psychologist.

Because of the great variability in their size, character, structure, and function it is difficult to generalize about liberal arts colleges. Some, among them Dartmouth and Franklin and Marshall, are well ahead of many universities in development of innovative science programs and inspired science teaching. A few primarily four-year colleges offer the Ph.D. degree in one or two science fields. Some colleges have developed special cooperative arrangements with universities for offering M.S. degrees. The further development of innovative programs and cooperative relationships among colleges or between colleges and universities should be encouraged.

ENCOURAGEMENT OF SCHOLARSHIP AND RESEARCH

The liberal arts college should expect its faculty to pursue their research interests and other scholarly activities. Faculty personnel policies and administrative procedures should encourage a high standard and reward significant achievement in scholarship and research. However, scholarship and research should be defined somewhat more broadly in a liberal arts college than it is in a graduate department. Evaluation of scholarly achievement need not be limited to publication in research journals. Other activities, including special faculty lectures or demonstrations presented to the college community, may testify to significant scholarly achievement.

It is obvious that more internal funding is needed for scholarship and research in the liberal arts college. This funding should include "seed grants" for personnel and facilities to enable young faculty members to get started on a project. Later they may be able to secure external support as the project develops. Even so, no matter how much money is available, one needs the "local spark" that can only come from a person with some ideas and a will to carry them out. Often the so-called "critical mass" which encourages scholarship and research can be achieved in the small college by fostering interdisciplinary and cross-disciplinary efforts. Faculty members in diverse fields, even though each may be the only representative of his discipline on the campus, can often find a common thread of scholarly interest which will bring them together.

Faculty members should be encouraged to secure outside support for research activities. Internal funding that is too generous or too easily attained can lead to dilettantism in research and scholarly work. It may even be desirable to secure *external* critical judgment even when evaluating proposals for *internal* support. One example of effective funding for research in the liberal arts college is the NIH Small Grants Research Program, now in its fifteenth year of operation. This program is an excellent resource for professors in liberal arts colleges. Grants are limited to $5000 a year for work in the behavioral sciences and also in mathematics, chemistry and biology as they relate to behavior. Local industry may be another source not only for research support but for involving members of the community with the interests of the college.

Every college should provide for the enhancement of scholarship and teaching through sabbatical or other academic leave programs. Faculty members should be encouraged to seek out both predoctoral and postdoctoral fellowships. Departments should establish faculty exchange programs with other institutions. Teaching loads, the ever present problem, should be balanced and determined in relationship to other demands made upon the faculty member by his institution and his discipline.

TEACHING AND RESEARCH

In the large university there is room for scientists of diverse professional skills and interests. Some will concentrate on teaching and others on research. Still others will combine the two activities. Small colleges, however, are seldom able to provide for this specialization of function. Teaching and research must go hand-in-hand and a successful liberal arts college teacher must maintain a lively interest in teaching along with his research activity. Another problem involves those few faculty members whose teaching and scholarly performance both deteriorate to the point where they become a serious negative element in the academic environment. Clearly, every possible effort should be made to revive such deadwood both through inservice activities and off-campus opportunities for academic self-renewal. Should these efforts fail, a difficult and delicate problem remains. It may be possible to devise some form of early retirement plan that, with some degree of grace and comfort, will enable such faculty members to give up their teaching responsibilities. Often they too are painfully aware of their inadequacy and welcome the opportunity to leave the classroom when a suitable alternative activity can be found.

Much of what has been said regarding the encouragement of scholarship and research can also be said of teaching:

the articulation of goals, the demand for performance, and the rewarding of performance. It is also true that much education occurs outside the classroom and that students learn a great deal from their peers and their own subculture. Every effort should be made to create within the college, both in and outside the classroom, an atmosphere which reflects its central value—the love of learning. When such an atmosphere is present one can be confident that the college will achieve its educational objectives.

Finally, how can the college administration and the faculty best meet their responsibilities for guiding the educational development of students? It is axiomatic that good teaching requires not only scholarship but the ability to relate meaningfully to students as persons, to understand their needs and interests, and to respect their goals and purposes. Inviting student involvement in all aspects of the educational process, including faculty research and undergraduate teaching, may contribute to mutual understanding and respect. Shared participation and responsibility often result in increased understanding of both the educational process and the rewards of scholarship.

The Preparation of College Physics Teachers*

JOHN M. FOWLER, RICHARD W. WEST and
KATHRYN E. MERVINE, *Commission on College Physics*

INTRODUCTION

> ...the basic pattern of the American Ph.D. is educationally and philosophically sound and is the best terminal education yet devised by any educational system. The strength of this program is, it seems to me, that it produces master knowers in a given discipline and that these master knowers are so produced that, to greater or lesser extent, they are also creative masters of their own discipline.[1]

As physicists, we can comfortably echo this well-founded pride in the American Ph.D. program. Measured on almost any terms, a Ph.D. in physics from a first-rank American university is the soundest certification a physicist can receive.

But physics also shares strongly in the weaknesses of this program. For, while the "mastery" that is pointed to in the opening quotation has led to great successes in both applied and basic research, it does not, apparently, assure excellence in instruction. There are symptoms, such as the decreasing percentage of students electing to major in physics, which are

*This paper is one of several provided by the commissions in advance of the conference as background material. Limitations of space preclude the inclusion of all of these materials and Dr. Fowler's paper has been selected as representative of the contributions of all the commissions to the effectiveness of the conference discussion. Editor.

[1] R. J. Henle, "The Soundness of the American Ph.D. Program," *Improving College Teaching*, Calvin B. T. Lee, ed. (Washington, D.C.: American Council on Education, 1967).

susceptible to documentation. However, there are more subtle evidences of weakness which abound in all the sciences and it is these, one suspects, which have played some role in inspiring the present conference. And, since 62 percent of Ph.D. physicists find themselves called upon to teach at some point in their career,[2] a weakness, even if only suspected, must be examined.

Anyone who has either taught graduate students, or been one, knows only too well that present Ph.D. programs are poorly designed for teacher training. In fact, if one views teaching as a part of the professional duties of a physicist, then he is led to agree with the President's Commission on Higher Education:

> College teaching is the only major learned profession for which there does not exist a well-defined program of preparation directed toward developing the skills which it is essential for the practitioner to possess.[3]

Yet the problem goes deeper, for graduate training is apt to weigh negatively against teaching. In the universities where physics departments are swamped with large numbers of indifferent students in elementary courses, the graduate student carries an important part of the teaching duties. But, he carries these duties as an indentured servant; he is usually given little or no voice in the curricular and pedagogical decisions, and his success or failure, if it is measured at all, frequently has little to do with opening and shutting the gates of judgment through which he must pass to gain the final degree. His only reward is financial, and this reward is so out of keeping with his educational level that it is better left unmentioned.

The recognition that an imbalance exists between the quality of the preparation for research and that for teaching is not newly come upon; the quotation from the President's Commission on Higher Education dates back to 1947. Measured against the demand, the response to the problem of more adequate teacher training seems slight. However, there

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[2] This percentage, reported by the AIP for 1967, probably underestimates the real effect when one considers the teaching duties of even industrial and government physicists.

[3] *Report of the President's Commission on Higher Education*, vol. 4 (1947), page 16.

have been notable individual and profession-wide attempts which deserve our attention.

An outstanding individual effort (led by Professor Harold K. Schilling) was generated at Pennsylvania State College in the early 1950's. This three-part program emphasized the professional side of physics (including teaching) by establishing the practice of an occasional colloquium talk, by considering teaching apprenticeships, and by experimenting with a graduate level seminar on college physics teaching.

We quote from Schilling's description:

> The purpose of this seminar was rather broad. It was predicated on two basic assumptions whose validity not everybody will grant, but which I consider both valid and important. They are:
>
> First, a physics teacher must be more than a physicist. Knowing physics does not itself qualify a man to teach physics. While mastery of subject matter is indispensable for success in teaching, it is not sufficient. Certain personality and character traits are necessary; as are also a thorough acquaintance with and a ready command of the "tricks of the trade." The physics teacher should be a professional in the classroom, not an amateur.
>
> The second assumption is that being a physics teacher involves even more than being an expert classroom teacher. Teachers have important obligations outside the classroom.
>
> Therefore, the objectives of the seminar were announced as follows:
>
> 1. To introduce graduate students in physics who are looking forward to college teaching as a career to the more important contemporary problems of higher education—with special reference to possible contributions physics teachers can make to their solution.
>
> 2. To consider the various functions and obligations of a college teacher in regard to (a) classroom teaching; (b) student counselling; (c) participation in curriculum-building and other institutional affairs; (d) scholarship, research, and other creative work; (e) community life.
>
> It would not seem unreasonable to expect a young man planning to go into college teaching to give some serious thought to the variety of duties he will encounter later. Why should he not learn some-

thing, for instance, about the learning process, about the psychology of youth, and how to advise and guide them? Why should he be allowed to tinker with young minds if he has never bothered to inform himself on how human minds function? And why should he not become informed on educational matters of broad institutional concern even though they may not be directly related to physics? Why shouldn't he have at least a modicum of such professional knowledge and awareness of issues before he takes a job?

3. To study effective procedures and techniques for the formulation and realization of teaching objectives. This includes consideration of (a) how to formulate curricular and course objectives, (b) the value and methodology of the lecture, (c) the recitation or discussion period, and the laboratory, (d) diagnostic and remedial devices, (e) teaching "how to study," and so on.

It is the third objective which absorbed most of the time and effort of the seminar.

4. To develop a professional attitude and consciousness on the part of the prospective college teacher by considering (a) problems of the teaching profession as such, (b) professional organizations, their functions and activities, (c) professional literature, (d) Federal and private agencies promoting the study and improvement of teaching, (e) legal problems, and (f) professional ethics. [4]

What is needed to understand the degree of effectiveness of this program is a follow-up of the teachers it produced. Even lacking this, however, it is interesting that several of the present programs described here rediscover many of Schilling's ideas.

There was also, in the 1950's, a profession-wide look at a piece of the problem—the training of laboratory assistants. Here, the emphasis was not on preparation of graduate students for teaching careers, but rather on improving their service to the department. But the two goals are not entirely exclusive.

[4] Harold K. Schilling, Preparation of College Physics Teachers at the Pennsylvania State College," *American Journal of Physics*, vol. 18 (1950), p. 549.

A Conference on The Training of College Physics Laboratory Assistants was held at Northwestern University in June 1954. The major graduate schools (as measured by numbers of physics graduate students) were represented. It is a good bet that the report of this conference, now out of print, is not well known to the physicists who supervise today's teaching assistants. The report of the Committee on Conclusions, however, set forth a number of suggestions which deserve restatement.

One of the major complaints, voiced by teaching assistants and students alike, is the lack of any clear statement of objectives for the laboratory. Not only must these objectives be set clearly, but a continuous and open dialogue must be maintained between the faculty and teaching assistants to keep them effective. But the Committee also recognized that the interest of the teaching assistant must be captured before any real communication can take place. In fact, next to a clear understanding of the purposes of teaching laboratory, the motivation of the teaching assistant was felt to be the most important factor contributing to good laboratory instruction.

The Committee's recommendations for improving motivation focus on a system of rewards which would couple increased financial recognition of the teaching assistant's role with an accompanying emphasis on his personal involvement in the administration and planning of the laboratory. Specific suggestions include establishing an increasing pay scale which would recognize the teaching assistant's experience and value, enabling teaching assistants to take recitation sections as a reward for superior teaching in laboratory, and giving academic credit for faculty-conducted, teacher-training sessions.

As an added measure to increase the teaching assistant's familiarity with the laboratory environment, the Committee recommends that the week prior to the beginning of classes be used as an orientation period during which the objectives of the course and laboratory can be thoroughly reviewed. Such a review might include discussions of proper teaching methods and the parameters of student-teacher interaction, along with such fundamental considerations as procedures for obtaining supplies and equipment and trial runs of any new or unfamiliar experiments.

The Committee concludes, however, that the best means of insuring fruitful exchange between the teaching assistants and faculty is a weekly staff meeting. Here, consideration of new experiments, details of laboratory operations and administration, and recommendations for improved teaching techniques could be opened to discussion between the senior staff men and their teaching assistants.

The Committee views evaluation of teaching performance as an important ingredient in the success of any teacher-training program. The use of student questionnaires on various phases of the laboratory, along with formal written reports summarizing the recommendations of the faculty superviser, are suggested as evaluative procedures.

Because the advice of an experienced teacher should be an essential part of the learning experience for prospective teachers, the Committee emphasizes the importance of senior staff men having teaching duties in the laboratory. While this requires strong administrative support for the laboratory teaching program, the Committee affirms the necessity of such a provision stating that "the best teaching of teaching assistants is to be had only when they can actually observe an experienced faculty man in practice."[5]

In preparing this paper, we do not have access to questionnaire data on present practices within the profession, but it is our impression that a similar conference, if held in 1969, would turn up the same problems and recommend many of the same corrective measures. Perhaps this conference was before its time. But, the present general and vociferous student dissatisfaction with the quality of teaching is beginning to reach the conscience of the profession. New programs have been brought into existence which have as their aim, not only the improvement of the teaching performance of graduate assistants, but, in some instances at least, the deliberate professional preparation for careers in college teaching.

SOME EXISTING PROGRAMS

The following examples we describe are mainly of two types: graduate programs specifically designed to produce teachers, and seminars which are part of the training of all

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[5] *The Training of College Physics Laboratory Assistants*, proceedings of the Northwestern Conference (Chicago, Illinois: Northwestern University Press, 1954), p. 168.

graduate students. This list of activities is surely not complete, but it should serve to indicate the present variety and will, perhaps, stimulate more creative involvement in similar activities within the physics profession.

A. GRADUATE PROGRAMS

1. Ph.D. Program—University of California, Berkeley

The University of California at Berkeley this year has initiated a new program leading to the Ph.D. in science or mathematics education open to superior students with Masters degrees in one of several science disciplines. Currently sponsored by the Departments of Mathematics, Physics, Botany, Zoology, and Physiology, the program also includes the active participation of several faculty members of the School of Education.

The Berkeley program provides the candidate with the opportunity of attaining competence in his chosen field comparable to that of a regular departmental Ph.D., along with teaching experience, as a teaching fellow or in a similar capacity, and familiarity with modern educational developments through specially designed seminars and courses. In addition, each candidate must complete a research thesis in some area of science education (e.g., experiments in curricular innovation, new educational techniques, technological aids, etc.) under the supervision of a science department faculty member.[6]

2. Ph.D. Program—Kansas State University

A program aimed at providing qualified teachers of physics for the smaller colleges has been initiated this year at Kansas State University. The Physics Department, in conjunction with the College of Education, provides teaching assistantships to qualified candidates and certifies their proficiency in physics upon completion of a minimum of 30 hours of graduate work which includes research in physics. The program, which leads to the Ph.D. degree in education,

[6]Additional information on the "SESAME" (Search for Excellence in Science and Mathematics Education) program can be obtained by writing Professor F. Reif, Chairman, Group in Science and Mathematics Education, 347 Birge Hall, University of California, Berkeley, California 94720.

seeks students with a B.S. or B.A. degree in physics who are inclined toward college teaching careers.

3. *Masters Program — University of Tennessee*

The Master of Arts in College Teaching program (MACT) at the University of Tennessee is designed to produce quality teachers with experience in teaching the general survey courses, traditionally offered during the first two years in both two-year and four-year colleges. Twelve participating departments have structured their individual two-year programs around common requirements which include 60 quarter hours (compared to 45 hours for the conventional M.A. and M.S. degree), a three quarter interdepartmental seminar on college teaching, and six quarters of teacher training and teaching experience. The interdepartmental seminar on college teaching is used as a vehicle for professional career orientation and the introduction of recent innovations in curricular development. In the Physics Department, the six quarter teacher training requirement is implemented by individual students teaching in sections of the introductory course for nonscience majors. One section is operated as a demonstration class for MACT student observation and emulation. These students are also required to participate in a seminar dealing with special problems in the teaching of college physics.

During the two-year period 1966-1968, the program enrolled a total of 65 students and graduated about 20 in June 1968. All but about 20 percent of these graduates went directly into college teaching in two- and four-year colleges. Although contrary to the program's aims, the remainder of the graduates elected to continue on toward the regular Ph.-D. degree. A disproportionately high percentage of these were physics majors.

B. SEMINARS

1. *Teaching Assistant Seminar — University of Maryland*

Enrollment in this one-credit, single-semester seminar on the teaching of college physics has tripled since its inception in the fall of 1968. Sponsored by the University of Maryland Physics and Astronomy Department, with the cooperation of the CCP staff, the seminar draws on faculty participation from the Departments of Physics and Astronomy and Education.

Seminar topics (see Appendix A) have focused on two major areas: the structure of instruction (e.g., the role of lecture, laboratory, examination, etc.) and new instructional materials (e.g., films, computer-assisted instruction, etc.). A conscious attempt has been made to encourage student initiative in the seminar format, and faculty participation has concentrated on stimulating student discussion and providing suggestions of appropriate background reading (see Appendix B). While no formal examinations are given, individual students take partial responsibility for the presentation of at least one of the weekly topics, and each student is required to work on a project of his own selection. Some sample topics for these projects are:

1. Design a diagnostic exam for entering graduate students.

2. Prepare an example (or film or video tape) of the presentation of problem solutions and test it on students.

3. Prepare some remedial material in programmed instruction form.

4. Make some concrete proposals for the inclusion of socially relevant material in the introductory course.

5. Design a laboratory exercise in the "divergent laboratory" style.

6. Prepare a proposal which examines both the present status of recitation sections as a supplement to the lecture, and their relevance to the training of graduate students, and which makes definite recommendations for changes or improvements where needed. For the sake of this exercise, assume the proposal is designed to be presented to a physics faculty.

2. *Teaching Assistant Seminar — University of Minnesota*

Lectures and informal discussions of course and curricular techniques and materials for undergraduate physics instruction form the basis of this one-credit-per-quarter, three quarter graduate physics seminar on "Problems of Physics Teaching and Higher Education." The first quarter is devoted to providing an overview of the main problem areas, and the techniques and materials for physics teaching, while the second and third quarters focus on faculty-guided projects, e.g., developing or investigating an instructional "unit": a lecture demonstration, a laboratory experiment, or a video tape presentation. The project might also be the development of a laboratory approach suited to a particular kind of student. In some instances, groups of undergraduate students are used in trial studies of these projects.

The seminar, which has been developed under the guidance of Peter Roll, is now in its third year. It is designed to attract the first-year graduate teaching assistant and those students who plan to go into college or university teaching. A partial list of some topics of discussion appears in Appendix C.

C. *OTHER PROGRAMS*

The sampling of programs presented here is certainly not all-inclusive; there are surely many others. The Department of Physics at the University of Michigan has been undertaking a program to improve teaching which is sponsored by the Danforth Foundation. While a report of that program could not be obtained for this report, it is known to consist primarily of video tape studies of graduate student laboratory teaching

The State University of New York at Stony Brook has also used video tape to study lecture techniques and to produce microteaching examples for discussion by faculty and graduate students. The faculty is presently considering proposing that the award of a Ph.D. include "certification" that the graduate student is competent in instruction. They are engaged in the design of a program, course or courses, apprenticeship in laboratory, lecture, etc., and student projects which will make this "certification" meaningful.

The American Institute of Physics is currently conducting a survey of programs for graduate training among the physics departments. A follow-up of this survey will lead to a more complete description of the present response of the physics profession to the need for more emphasis on teacher training.

STEPS TOWARD IMPROVEMENT

There are several graded steps which should be taken if the Ph.D. program is to incorporate more directed experience with teaching and instruction.

The first of these steps, recognition of the problem, has been taken by this and other conferences. It has yet to be taken by the profession as a whole. The final report of this conference should supply the necessary evidence to stimulate profession-wide response.

But other changes must be brought about in the graduate ecology. As long as the teaching component of professional activity is put aside as idiosyncratic, as an art not amenable to scientific improvement and judgment, then most graduate students will join their professors in relegating it to a low priority.[7] As Arrowsmith has said:

> At present the universities are as uncongenial to teaching as the Mojave Desert to a clutch of Druid priests. If you want to restore a Druid priesthood, you cannot do it by offering prizes for Druid-of-the-year. If you want Druids, you must grow forests. There is no other way of setting about it.[8]

If this change in ecology occurs, it will not be hard to find the program components. One such set of suggestions is to be found in the article, "Teaching College Science Teachers to Teach," by Charles Süsskind:

> Here are some of the elements, listed in the probable order of frequency of occurrence:
>
> (1) Supervision of laboratory instruction. In the majority of colleges, a senior faculty member is in charge of the laboratory, and is frequently present during at least part of the laboratory period.
>
> (2) Regularly scheduled conferences between graduate assistants and senior faculty members. Such conferences, whether formal or informal, provide an excellent opportunity for the prospective teacher to ask questions about the techniques and methods of his chosen profession, subject only to the senior man's ability and willingness to give the answers.
>
> (3) Supervision of recitation periods and of classroom instruction. This element is found more rarely; its

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[7]The realistic manner in which physics graduate students give priority to their teaching duties is interestingly conveyed by the special issue on the graduate student of *Physics Today* (March 1969).

[8]William Arrowsmith, "The Future of Teaching," *Improving College Teaching*, Calvin B. T. Lee, ed. Washington, D.C.: American Council on Education, (1967).

absence is in most cases due to indolence, but often also to genuinely felt distaste (largely unjustified) of anything that smacks of interference with academic freedom. Needless to say, the presence of a senior faculty member in the classroom is sure to affect the performance of the lecturer under scrutiny—either adversely or beneficially—and the monitor must learn to allow for the perturbation that he causes merely by being there. A frank critique after the lecture cannot prove to be anything but helpful, especially if the advice is administered tactfully and mingled with praise; nothing will perk up a beginner like a pat on the back.

(4) A teaching seminar, for the discussion of teaching methods and allied topics. Only a handful of colleges have anything like it; where such a scheme exists, it depends almost entirely on the initiative and enthusiasm of the younger faculty members, who must take time out from research and from teaching and other duties to participate. Nevertheless, this is a very useful method of introducing the importance of the subject to future teachers, and of making them learn something about their profession.

(5) A formal course, with provisions for presentation before a group for criticism, and for discussion of the theory and practice of teaching.... It is the writer's firm conviction that this is the most effective way to improve the teaching skills of the large body of new instructors who are turned loose on our college population each year.

The foregoing schemes might be considered as forming a five-step ladder, with each successive step encompassing most of the features of the step below. To develop the teaching abilities of future professors, every institution engaged in graduate instruction should strive to climb this ladder step by step. The more vigorous might even find it possible to take it two steps at a time.[9]

These are not new ideas—the article dates back to 1957—but their broad application in physics would be new.

Jencks and Riesman, in their perceptive study "The Academic Revolution," expand on the suggestion that the teaching duties of the graduate student could be the take-off point for a more thorough "clinical training program":

Many undergraduate courses at large universities are taught by one or two senior faculty and a group of graduate assistants. The issues raised in these courses are—or

[9]Charles Süsskind, "Teaching College Science Teachers to Teach," *American Journal of Physics*, vol. 25 (1957), p. 201.

should be—of fundamental importance to graduate students as well as undergraduates. Yet we know no university where the staff of such courses habitually meets together, discusses the intellectual questions being raised, and initiates research in areas where it would be helpful. (Chicago is the closest approximation.) A serious effort along these lines would probably require constituting the staff of big undergraduate courses as a graduate seminar, having the participants meet weekly to discuss the books they were reading with undergraduates, asking them to prepare seminar papers that would also be delivered as course lectures, and discussing individual lectures given in the course in both substantive and pedagogic terms.

This scheme also suggests a possible device for avoiding incompetent amateurism in teaching and developing pedagogic colleagueship. Staff-taught courses that held regular meetings to discuss the intellectual substance of a course could also discuss and evaluate its effect on the students. A staff is by definition a potential colleague group with common problems, common experience, and perhaps even a common objective. If professors are sufficiently secure so that they can elicit and encourage criticism of their performance, and if the graduate students are open enough and interested enough to visit one another's classes, the beginnings of a clinical training program are in hand. These possibilities have been explored on a number of campuses, notably Chicago, and the second author teaches a course at Harvard that tries to achieve this sort of critical perspective on itself. Although there is no quantitative evidence that the staff members of this course are better teachers at the end than the beginning, most of them believe they are.

For one thing, they are encouraged to become more aware of the variety of students they face even in a highly selective college, and this itself is apt to make their teaching more interesting as well as more taxing. Then too, some of the most conscientious come to realize that their tacit hope of reaching every student is an unwarranted demand on both themselves and the students, not all of whom are capable of learning from any particular teacher at a particular moment in their lives. At the same time, staff members seem to become more aware of the often cruel effect they can quite unintentionally have on the more vulnerable students. Since most still think of themselves as inoffensive neophytes, struggling to cope with their own senior professors, the idea that they have power often comes as a shock.

> Innovations of this kind are extremely time-consuming and tiring. A course of the sort we have just described, which combined a graduate seminar with an undergraduate course composed partly of lectures and partly of small-group meetings, and in which the staff also made an effort to supervise one another's pedagogic efforts and discuss the effectiveness of books, lectures, and the like, would be virtually a full-time job for all concerned. This does not mean it is impractical: the cost of such a system need be no greater than the present system, and the yield per dollar might be considerably better. But such an effort can be sustained only if the faculty as a whole believes in its importance, and if it has a real conviction that the present less taxing system is failing so badly that it cannot be allowed to continue. Only a minority has had such feelings for the past two generations.[10]

They also suggest that some postdoctoral "interns" would probably want to associate themselves with such staff efforts, with advantage to the host department and to their own later teaching. Pilot "intern" programs have been established by the Danforth Foundation and the Sloan Foundation.

We have tried to gather together in this report a brief history of earlier efforts to include preparation for college teaching in graduate physics training, a summary of some present programs, and some provocative suggestions for future programs. But suggestions for programs are far from being enough; the existing programs, or those described in the section titled "Steps Toward Improvement," are not likely to have any more influence than the Pennsylvania State program, and the Northwestern Conference mentioned earlier, or the more recent "The Graduate Student as Teacher."[11] What is needed is a change in the over-all attitude of the physics faculty member. He must balance the importance of this facet of career training with that of research preparation and allot it priority. He must release some graduate student time to these other uses; he must be prepared to evaluate, in a sense, certify, the ability to instruct along with the ability to inquire. He must be the one to say, "these things should happen." Then they will.

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[10] Christopher Jencks and David Riesman, *The Academic Revolution* (Garden City, N.Y.: Doubleday and Co., 1968), pp. 534-535.

[11] Vincent Nowlis, Kenneth E. Clark, and Miriam Rock, eds., *The Graduate Student as Teacher* (Washington, D.C.: American Council on Education, 1968).

Appendix A

LIST OF WEEKLY SEMINAR TOPICS

Seminar on the Teaching of College Physics
University of Maryland

The Objectives of the Elementary Course
The Physics Major Curriculum
The Lecture in Physics Teaching
The Laboratory and its Problems
Some New Laboratory Formats
The Role of Recitation and Problem Solving
A New Self-Study Physics Course at MIT
The Uses of the Computer in Instruction
The Graduate Student as Teacher
(Recitation and Laboratory)
Films in Physics Teaching
Examination Writing
Reports of Student Projects

Appendix B

READING LIST

Seminar on the Teaching of College Physics
University of Maryland

I. General

1. *New Developments in Teaching,* W. J. McKeachie, Bureau of Higher Education Research, USOE (1966).

2. *Handbook of Research in Teaching,* N. L. Gage, editor, Rand McNally Co., Chicago (1963).

3. *The Conditions of Learning,* Robert Gagné, Holt, Rinehart and Winston (1965).

4. *Toward a Theory of Instruction,* Bruner, Belknap Press of Harvard University (1966).

5. "From Graduate Assistant to Teacher: Can Seminars Help?", Commission on Undergraduate Education in the Biological Sciences (CUEBS) News, Vol. V, #1, October (1968).

II. Goals and Objectives

1. "Report of the Carleton Conference," Am. J. Phys. *25,* 417 (1957).

2. "Conference on the Improvement of College Physics Courses," Am. J. Phys. *28*, 368 (1960).

3. *Constructing Behavioral Objectives*, H. Walbesser, Bureau of Educational Research and Field Services, College of Education, University of Maryland (1968).

III. The Introductory Laboratory

1. "Report of the Conference on the Training of College Physics Laboratory Assistants," Northwestern University (1954).

2. "Laboratory Instruction in General College Physics," Report of the Conference at the University of Connecticut, Storrs, Conn., Am. J. Phys. 25, 436 (1957).

3. "The Role of Experimental Work," Walter Michels, Am. J. Phys. *30*, 162 (1962).

4. "On Physics Project Laboratories," John King, Am. J. Phys. *34*, 1058 (1966).

5. "Presenting Experimental Physics to Undergraduates," John King, CCP *Newsletter* #16.

6. "The Divergent Laboratory," J. W. George Ivany and Malcolm R. Parlett, Am. J. Phys. *36*, 1072 (1968) Part 2. "The Instrumented Laboratory," J. A. Soules, Am. J. Phys. *36*, 1068 (1968) Part 2.

7. "Toward a New Lab Style," Report on the CCP Summer Workshop on Introductory Laboratory, CCP *Newsletter* #17.

8. "Experimental Outcomes of Laboratory Instruction in Elementary College Physics," H. Kruglak, Am. J. Phys. *20*, 136 (1952).

9. "Research on Teaching Science," Fletcher G. Watson, in *Handbook of Research in Teaching*, N. L. Gage, editor, Rand McNally Co., Chicago (1963), pp. 1041-1044.

IV. Lecture

1. "The Lecture," Memo to the Faculty #30 (1968), Center for Research in Learning and Teaching, University of Michigan.

2. "The Art of Talking About Science," Sir Lawrence Bragg, Science *154* (1966).

3. "Analysis and Investigation of Teaching Methods," N. E. Wallen and R. M. W. Travers, in *Handbook of Research in Teaching*, N. L. Gage, editor, Rand McNally Co., Chicago (1963), pp. 481-483.

4. "Research on Teaching at the College and University Level," W. J. McKeachie, in *Handbook of Research in Teaching*, N. L. Gage, editor, Rand McNally Co., Chicago (1963), pp. 1125-1132.

V. Examinations

1. "Testing Cognitive Ability and Achievement," Benjamin S. Bloom, in *Handbook of Research in Teaching*, N. L. Gage, editor, Rand McNally Co., Chicago (1963) pp. 389-395.

2. *Science Teaching and Testing*, Leo Nedelsky, Harcourt, Brace and World, New York (1965).

3. "Learning for Mastery," Benjamin S. Bloom, Evaluation Comment, Vol. 1, No. 2, (May 1968). To be published as a chapter in Bloom, Hastings, Madaus: *Formative and Summative Evaluation of Student Learning*, McGraw-Hill.

4. "On Maximizing the Information Obtained from Science Examinations, Written and Oral," John R. Platt, Amer. J. Phys. *29*, 111 (1961).

5. "Writing Test Exercises in the Natural Sciences," Leo Nedelsky, Amer. J. Phys. *26*, 469 (1958).

6. "Design of Examinations and Interpretation of Grades," M. W. P. Strandberg, Amer. J. Phys. 26, 555 (1958).

VI. Film and Other Visual Aids

1. "Production and Use of Single Concept Films in Physics Teaching," Report of the Conference on the Use of Single Concept Film in College Physics, held at Rensselaer Polytechnic Institute, Troy, N. Y., December 1966 and published by the CCP.

2. "Modern Teaching Aids for College Chemistry," Advisory Council on College Chemistry, Department of Chemistry, Stanford University, Stanford, Calif. 94305.

3. "Research on Teaching Science," Fletcher G. Watson, in *Handbook of Research in Teaching*, N. L. Gage, editor, Rand McNally Co., Chicago (1963), pp. 1044-1052.

4. "Research on Teaching at the College and University Level," W. J. McKeachie, in *Handbook of Research in Teaching*, N. L. Gage, editor, Rand McNally Co., Chicago (1963), pp. 1148-1154.

VII. Computers

1. "The Computer in Physics Instruction," Report of the Conference on the Uses of the Computer in Undergraduate

Physics Instruction, held at the University of California, Irvine, Calif., November 1965 and published by the CCP.

2. "Introductory Computer-Based Mechanics," Alfred M. Bork, Arthur W. Luehrmann, and John Robson, published by the CCP.

Appendix C

PARTIAL LIST OF TOPICS FOR DISCUSSION

Seminar on the Problems of Physics Teaching and Higher Education, University of Minnesota

(1) Physics courses and curricula, for various kinds of students (engineers and scientists, biological science students, high school and elementary school teachers, the general public) and at various levels (introductory, intermediate, advanced).

(2) Techniques of teaching physics, their relative effectiveness and importance for different kinds of students, and the problems associated with them. (Lecture, laboratory, class discussion, conference and tutoring, homework and home study, examinations.)

(3) Materials and new technologies for physics teaching—ways to evaluate, construct, buy, and use them. (Textbooks, films, closed circuit TV, video tape recording, laboratory and demonstration equipment, computers, programmed instruction.)

(4) Do psychologists and professional educators have anything to offer the college physics teacher?

(5) Institutional and student efforts to improve physics instruction, and teaching in general. (Plans at the University of Minnesota, the Free University, the Muscatine Report at Berkeley, activities at other universities, interinstitutional cooperation.)

(6) National organizations which support and encourage the improvement of physics instruction; sources of funds for such research and development activities. (Professional physics organizations [AIP, AAPT, CCP]; AAAS, NSTA, college science commissions; government agencies [NSF, OE]; private foundations.)

(7) The general problems and organization of higher education, especially as they relate to physics teaching and research. (Public and private universities and colleges, junior colleges; the potential impact of junior colleges; the effects of elementary and secondary science education on higher education and vice versa.)

(8) The literature of physics teaching and higher education—how to find out what is going on. (Professional journals, newsletters of previously mentioned organizations, government publications and announcements, technical and trade magazines, general magazines, the daily press.)

Putting Our Own House in Order*

REMARKS ON BETTER TEACHER TRAINING THROUGH BETTER GRADUATE RESEARCH

NEILL MEGAW, *University of Texas at Austin*

MOST of us have had enough by now of the old debate: training for research vs. training for teaching. There is a real problem here still, and one of crucial importance; but this tired formulation of the problem as a kind of civil war between disciplinary Puritans and Cavaliers has not helped us to improve matters very much. Even if we concede that specialized research can indeed provide "depth," and that training for teaching the 18-year-old can indeed help the novice teacher to achieve greater rapport with his students, there is little profit or fun in debating the merits of one necessary cause as against another necessary cause. Nor is it clear that we should concede so much, since the "depth" and rapport have a way of coming unstuck when the graduate actually begins teaching. A young Ph.D. deeply versed in the plays of Bulwer-Lytton may have spent so much time on that particular "depth" that he is shallow to the point of incompetence when teaching Donne or Samuel Beckett in the sophomore survey. I am sure that similar situations can be drawn from the natural sciences. And as for that generalized rapport, what happens when the new teacher and his student, arms linked, walk together into water over both their heads? All of this is old stuff now to most of us and it might be wiser to escape the old dilemma, or false dilemma, and consider other approaches to the improvement of our graduate programs.

I would like to take another tack, therefore, in talking with those who are defenders of the research emphasis in graduate studies. Because of the long history of warfare against the "educationists," discussions of improved teacher training have tended to center on such reforms as the introduction of courses in teaching of 18-year-olds, or courses on the work-

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*The following paper was made available in advance of the conference as background material. It is presented here as representative of the contributions of the commissions to the effectiveness of the conference discussion. Editor.

ings of the American college, or courses in educational philosophy, or sometimes, more recently, courses or special programs of interdisciplinary study. These may be good ideas—I would be inclined to support them, myself—but I would like to suggest that for the moment we forget them completely and turn instead to the question of whether there are substantial improvements in the preparation of our graduate students for teaching which can be carried out within the traditional boundaries of the discipline and with the traditional emphasis on solid training and research.

One thing that few experienced faculty members would deny, whether of the conservative or liberal persuasion in respect to research and disciplinary boundaries, is that the new Ph.D.'s first teaching assignment nearly always involves demands that couldn't possibly have been foreseen back in graduate school the year before. Some of these demands, moreover, may even be within the new teacher's supposed area of general competence. The beginner can turn for help to senior colleagues, of course, but this is sometimes a little embarrassing; and in any case the real difficulty is in knowing just what the questions are that should be asked. Typically, therefore, the new teacher turns instead to the library—only to discover that he has not the faintest idea of how to use it to think with. His graduate program trained him to disregard the 99.9 percent of the library that was irrelevant to his very special doctoral research needs. Indeed, the whole point was to move swiftly and silently, Indian-footed, through the dense undergrowth of material peripheral to one's own very limited hunting ground, and then to work it for all it was worth, studiously ignoring everything else. Whose fault is it, then, that these sad epiphanies occur—the novice teachers turning to the library, seeing it as an immense repository of answers to questions that they need to ask, and then realizing that they do not know how to operate the switchboard? Is it the fault of the "educationists"? Or is it the fault of the discipline and research-minded graduate faculty?

You will see my drift by now, I am sure. I would not recommend that every disciplinary program have added to it a course in library science. Indeed, that would be another way of evading the problem. I would recommend instead that in each graduate program—whatever the specific discipline—every student be challenged with a number of radically different kinds of research problems, at least some of which should involve his own definition of the problems to begin with. I would accuse the traditional graduate program of failing to train its students for teaching, not through burdening them with too much research, but with far too little, and that all of one kind. The typical beginning teacher is almost beyond belief an incompetent researcher in his own discipline, if research ability is defined, as it should be, in terms of trained resourcefulness.

To take another approach, let us suppose that the defenders of the disciplinary and research emphases are correct in arguing that the best preparation for teaching is in a thorough mastery of the subject. Are we not beginning to define mastery in somewhat changed terms in recent years? The older terms, of course, were "breadth" and "depth." In recent years, however, we have seen the gradual emergence in higher education of a third term, something like "design" or "form." One has only to look at the burgeoning of environmental programs, of problem-centered courses, of ecological studies ("ecology" has become faddish), and of field study centers and "experiential" education. What these new things have in common, besides an emphasis on relevance and social justice, is that they focus on complex problems having intimately interconnected subsystems. Solution of these problems depends on the selection of a finite number of disciplines—not all that *might* be considered, but only those most relevant—and then on the effective combination of the chosen disciplines. The student operates as a modern, "ecological" equivalent of Renaissance man: he doesn't know everything, but he knows what he needs to know, and has some idea of where to go for help. Each real-life problem suggests a different gestalt of disciplines.

Does this emerging new requirement for mastery in general studies also apply to specialized graduate studies within a given discipline? If so, what changes in our graduate programs are most clearly indicated? To answer these questions in reverse order, I would suggest that the moral for graduate programs is not the familiar one, that we introduce more interdisciplinary work, even though this is perhaps also indicated, perhaps very much indicated. The answer to the prior question will give us a more promising lead. Is it not the case that every graduate "discipline" is in fact a confederation or consortium of subdisciplines? And is it not the case that thes loosely or closely related subdisciplines are differentiated strikingly in their objectives, standards of proof or success, their principles of defining appropriate subject matter, their methods for conducting investigations, and even their vocabulary? And is it not true that no one, not even the most impressive master scholars within the discipline, can hope to attain a comprehensive grasp of all these subspecialties? If all these points are granted, the moral would seem to be not just more interdisciplinary work, but also, and more centrally, more experience in selecting and combining appropriate specialties within the discipline. If you will excuse the barbarism, we need more "intersubdisciplinary" study at the graduate level. I suggest that it is intolerable that a doctoral candidate can be certified as satisfying all degree requirements without having worked first through a series of radically different problems, arranged in order of increasing complexity and challenge, requiring for their solution the selection and effective employment of different combinations of subdisciplines, at least some of which are quite unfamiliar to the graduate student at the time of confronting these problems.

To sum up so far, whether one thinks of the novice teacher as someone who ought to be prepared as well as possible for the unexpected demands of a new position, or as a trained specialist who should simply be given as much mastery of the discipline as we can provide, I suggest that he has been poorly served in his own field of specialization by the graduate program as we know it now.

Thus far my proposals for reform have derived from the plight of the beginning teacher—his need for resourcefulness, his need for versatility. What about changes in the demands of undergraduate students, though? One kind of change I have already mentioned, and its implications for interdisciplinary and disciplinary reforms of graduate programs. Another kind of change, visible in the field study and ecological programs already mentioned and also in the relatively recent growth in honors programs, undergraduate research, and lower division tutorials—as well as in the gradual erosion of conventional grading or credit-hour accounting systems—centers around the new phenomenon of *mass* independent study.

The older view of independent study is fading rapidly: the view that it represented a concessive relaxation of normal requirements for specially gifted students so that they could study exotica under tutorial guidance and produce long papers. The more recent view seems to be that, in spite of the paradoxical element in such a formulation, independence is something that everyone needs training in: drilling in independence must be obligatory, for the C-student as well as for the A+ student. Baby steps first, then larger, normal strides, then giant steps if possible. And since this cannot be managed economically on a tutorial one-to-one faculty-student basis, it must somehow be managed in large student groups with the teacher teaching at one remove, guiding or encouraging from a carefully chosen middle distance.

What are the implications here, for our graduate programs? For this observer, at least, there are two very obvious implications. The first of these simply reinforces what has already been suggested by other considerations, namely, that our graduate students must be both more resourceful and more versatile within their own disciplines, and that new graduate projects should be introduced to make them so. The second is that our graduate students should have some first-hand—and hopefully first-rate—personal experience of group independent research in graduate school. Most graduate "seminars" are simply lecture or discussion courses of smaller than usual size. Those which do involve genuine independent study are often little more than parallel play at an advanced age—a round robin of separate individual presentations. These may or may not be clustered around some central subject or concern; if so, it is probably the teacher who has defined that central locus of interest.

I would suggest that if our graduate students are to be prepared for this emergent kind of teaching-at-one-remove—something in between pure control and pure colleagueship—we need to devise a new form of group-research seminar in graduate school. Here the students would first exchange ideas about the formulation of a challenging problem, then discuss the different major aspects of the problem and alternative ways of approaching these different parts of the whole. They would then distribute individual responsibilities, establishing suitable checks and balances, and so would gradually begin to work on the main body of the investigation as a team, keeping each other abreast of individual findings which might require special subsidiary investigations or even some redefinition of the central problem or the introduction of new special investigations. Finally they would move on to final attempt at synthesis and to the formulation of majority and minority views—as well as to a cooperative analysis and evaluation of the whole group-research experience. This would be both good graduate training in the discipline and good preparation for teaching: students would learn new approaches and the sweet uses of diversity – both for themselves as specialists and for their students as generalists – and then would be doing so within the bounds of the specific discipline.

You will see the burden of these remarks. I am by no means against adding to the graduate program courses in teaching 18-year-olds, or courses in the history and present state of the American college, or in interdisciplinary studies. But I feel irritated when talk of adding these "outside" courses is allowed to obscure the dereliction of duty of our separate academic disciplines in graduate studies. Only too often the gestures in these other directions have enabled us to blink the fact that within each discipline we could be doing a far better job of preparing our graduate students for teaching. Here we could act swiftly and effectively, without administrative complications and without protracted negotiations or compromises with other departments or divisions. Here we, in the disciplinary in-group sense, could help our students now. So far, we have not, and I think it is time we should.

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