CHEMICAL ENGINEERING EDUCATION

CHEMICAL ENGINEERING DIVISION
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American Society for Engineering Education

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THE PRO AND CON OF GRADUATE ACCREDITATION

by

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For many years professional groups have struggled with the question of accreditation of graduate work. Engineering societies such as ECPD and AIChE have reviewed the problem almost continuously, approaching it gingerly and with mixed feelings. At present accreditation is limited to those curricula which lead to the first professional degree in an engineering field for which there is a recognized society. The curricula are therefore evaluated and accredited as professional programs without raising the whole question of distinguishing a graduate program from an undergraduate one. Accreditation in these few cases has been made necessary primarily due to only one of the many purposes of accreditation, namely the need for registration and licensing of the graduates in the various states.

Before considering the desirability of accreditation of other graduate programs, where these are not the first professional degrees in the field, it would be well to mention the other purposes of accreditation. One of these is to provide information to prospective students or advisors indicating whether or not the program meets some minimum standard. Of greater importance, perhaps, is the use of accreditation or periodic evaluation to encourage improvement in existing programs above minimum standards. In the long run this purpose is probably most important of all, although it need not be accomplished by formal accreditation procedures.

The goals of student counselling and improved education have been attacked in many ways. Internally most universities evaluate suggested new programs, control graduate faculty appointments, and often bring in distinguished scholars from outside the university to give advice on new or even well developed programs. Others have used visiting committees who regularly review the progress of individual departments. One of our sister professions, (chemistry), does not really accredit at any level, but approves undergraduate curricula as a basis of early admission to membership in the American Chemical Society. At the graduate level student counselling is assisted by publishing a directory showing the graduate faculty and important recent publications. Improvement in standards is obtained by periodic published comments on suggested good practice, and by informal discussions with department heads.

Within engineering, at present, an interim policy of ECPD is to proceed with accreditation of graduate programs leading to the first professional degree in the field providing qualified inspectors are available. In such cases accreditation does not indicate approval at the graduate level but merely that the program meets requirements basic to a bachelor's degree. In one specific case, sanitary engineering, accreditation of the M.S. program is proceeding with the advice of the American Sanitary Engineering Intersociety Board. Further accreditation of graduate programs will probably await a study of graduate education by ASEE under the chairmanship of Dean Pettit of Stanford.

In the general field of graduate education, most of the graduate school associations have strongly resisted accreditation above the first professional degree. University administrations and associations of accrediting agencies would in general be loath to encourage this. If it were to be undertaken, areas of jurisdiction would have to be carefully worked out. The whole problem of professional school standards versus graduate school standards would need to be resolved before a professional group undertook the job of accreditation of Ph.D. programs, for instance. This problem might be somewhat less acute at the M.S. or Engineer degree level.

Pro

Many good reasons have been present for many years and many more are developing rapidly to make accreditation at the graduate level desirable, especially in engineering. Pressures from faculty and government are now such as to encourage universities to undertake graduate work in areas where competence is marginal. These pressures are directed particularly to the Ph.D., so schools which would have normally developed slowly through a modest M.S. program, are undertaking Ph.D. work before the staffs are sufficiently developed. Thus as many such centers develop, the usual pattern of selection of graduate school, based on recommendations of professors to universities known by them to be satisfactory for a given student is replaced, at least in part, by independent choice by the student. His protection from an unsatisfactory program is being weakened, and an accreditation procedure would assist him in making a suitable choice.

The strongest case for graduate accreditation in engineering stems from a growing trend toward granting the first professional degree in a special field at the graduate level, or at least with a graduate degree. The first degree may be in engineering science, engineering (general), and may or may not be accreditable by such agencies as ECPD. Here the necessity for accreditation is caused by the problem of registration, and it would appear, also, that the individual technical societies, such as AIChE, would have an interest in accreditation at the first level in such a specialty as chemical engineering. A newer pattern is evolving in which the first accreditable degree in an engineering specialty will be at the Ph.D. or Doctor of Engineering level.

Any profession is interested in ensuring the highest possible standards of education consistent with available raw material and the numbers needed to serve the national needs. Whether accreditation could be really effective at the graduate level is debatable. Certainly, to the extent the curriculum is well organized and consists of a balanced sequence of courses, accreditation is as feasible as it is for undergraduate work. Surely a sharp differentiation should be possible between curricula geared to the average student and those suitable only for the gifted. Here we run into the real problem of differentiating clearly between a professional postgraduate degree, and a truly graduate degree. A decision is necessary regarding the overall control of these two types of programs within the university, and this cannot be done entirely on the basis of the student quality involved. There is a good case for control by the engineering school of programs leading to the master or doctor degree which differ from the ones which are research oriented. A carefully developed program by ECPD might result in a uniform approach to this general problem.

It is more difficult to justify accreditation of the normal research oriented Ph.D. degree unless this is needed for registration purposes. Here the difficulties lie in the personal guidance of a research neophyte by a thesis supervisor. Course work in such a program is of great variety even in a single department. The real problem is that accreditation would need to be based on individual programs and supervisors. A department might have one or two excellent men in research, and as long as the student studied under these, all would be well. A program taken under another man might be wholly inadequate. It would seem that accreditation under these circumstances would require a department to meet very stringent standards in selecting thesis supervisors. This opens up the whole problem of encouraging young staff and presently "mossback" staff to develop sound research capabilities.

The current rapid growth of part-time and of off campus center graduate programs could be cited as further reasons for accreditation at the graduate level. Some of these programs may not be really under faculty control, but serve primarily as a recruiting gimmick for eager employers. Courses may be given by substandard teachers, and research may be largely supervised by company personnel with inadequate standards. An accreditation procedure here might result in the elimination of mediocre programs, and an improvement in the control of standards in the better ones.

One of the strong reasons for graduate accreditation is the present rather frenzied growth of new graduate programs at a time when engineering enrollments at the undergraduate level are falling. Availability of funds for research, demands of staff for "a pair of hands", and university administrative pressures for "research status" are powerful weapons which may cause a drop in admission standards at the graduate level, a consequent retention of mediocrities in the program, and progressive downgrading of the quality of finished product. Accreditation procedures would not necessarily stop this, but students would be more adequately warned about what they were likely to encounter.

Another strong reason for accreditation, but one that perhaps could be equally well obtained by evaluation or consultation, is the collection of information on real operations in the various graduate centers. This could be made generally available and would assist weak programs to develop into stronger ones. Good ideas would be more rapidly assimilated throughout the country and perhaps the meaning of each degree would be more uniform, hopefully, at a generally higher level.

Con

Many individuals and organizations are firmly against accreditation at the graduate level except where necessitated by registration problems. They argue that accreditation is not workable in such varying programs tailored for the individual student. They argue that accreditation tends to standardize and prevent experiment, and this is particularly undesirable at the graduate level. University presidents already are in rebellion against continuous visitation by various groups and complain that they are losing control of the destiny of their institutions. Almost everyone recognizes the difficulties in accreditation of graduate programs in general, and the immense amount of time that would be consumed by the institutions and the visitors. If it isn't necessary, why do it?

Engineering has a somewhat unique problem in graduate work. Scientists are expected to do research and their graduate programs are tailored to this end. Although formal course work has gradually increased, in essence the "neophy[illegible] studies under one "master" and becomes reasonably proficient in a specia[illegible]

In the past, engineering has largely followed the procedure developed by the scientists, particularly the chemists, without too great questioning. We are now entering an era, however, where post baccalaureate work in engineering encompasses more than the production of research men, and we have "design" oriented programs as well as those which cross over various disciplines in science and engineering.

We no longer are exactly sure what we mean by an engineer and how he differs from the scientist. Is the applied scientist an engineer? Should substantial numbers of engineers be trained to a very high level in design, systems, or decision making in broad sociological problems caused by technology? If so, how should these programs and degrees be differentiated, and what part of the university administration should control? Should our engineering research programs be supervised by the graduate school using one set of standards, and the "engineering" programs remain under the complete control of the engineering school with different standards? We need only to look to the field of education to see the parallel. Would accreditation of all of these programs by an outside agency such as ECPD assist in solving these problems and prevent the development of "high grade" and "low grade" programs within each department?

The strongest argument against graduate accreditation is that in most cases it is not necessary for registration purposes. Most students are relatively mature and should be able to find a graduate program suitable for their needs. No one has yet proved that accreditation results in a general improvement in education that cannot equally well be accomplished by information exchange or private evaluation procedures. The difficulty of accrediting a Ph.D. program tailored to the personal needs of an individual student working largely under the direction of one staff member is clear. Removal of the last area of free experimentation with programs might actually result in poorer rather than better standards. With the necessary close evaluation of individual staff members, it is conceivable that problems of libel would arise, which are now rather unlikely where curricula are reviewed at the undergraduate level.

A strong deterrent to graduate accreditation is the obvious reluctance of most other groups to engage in such work. Our sister science of chemistry has approached this very quietly, but has had success in several areas. For example, the biennial graduate directory is helpful to a student since he can see what professors are present, what their publications are in recent years, etc. Individual consultations with department heads, and periodic publications on "good" graduate practice has no doubt been of assistance to many departments which are developing at the graduate level. For engineering to undertake graduate accreditation it will be necessary to distinguish clearly between "graduate" and "professional post baccalaureate" programs. It would appear desirable for a while to concentrate on the latter, if indeed further accreditation at the graduate level is needed if this is not required for registration purposes.

On Balance

On balance, each of you will decide in your own mind what further steps should be taken in this area by ECPD and AIChE. I can only offer my present feelings in this matter. First, I believe we must recognize our obligation to accredit all satisfactory curricula for a first degree in engineering, regardless of the particular degree offered even up to the Ph.D. or D.Eng. Secondly, I feel that it is probably desirable to accredit all first degrees in a broad engineering field such as those represented by the technical societies affiliated with ECPD even if a prior accredited degree is in "general" engineering or engineering science. An M.S. degree in chemical engineering following an accredited "engineering" degree is an instance of this.

I would postpone consideration of accreditation of interdisciplinary programs or highly specialized fields. Thus an M.S. in "Systems Engineering" or in "Heat Transfer" might be left alone until some technical group is developed of sufficient strength to provide proper guidance for accreditation, and makes a case for the program on a national scale.

I see no present value in accrediting Ph.D. or D.Eng. programs in general. I do believe, however, that procedures such as those used by the American Chemical Society would be useful in assisting departments to markedly improve their programs. In this area information exchange, private consultations with departments or department heads, publication of suggested "good practice" would be more helpful at this time than a full scale involvement with the problems of accreditation and the doubtful results that would ensue for the effort expended.

I believe that much could be done to clarify general understanding of the admission standards and performance characteristics for the various degrees, in very broad terms. For example, if all students are permitted to enroll in a post baccalaureate program leading to a Master of Science degree, this should somehow be distinguished from a program limited to the highly gifted students. If this is not done, we will fall into the trap of granting "graduate" degrees which are not really this and our remaining truly graduate degrees will be downgraded in general estimation by our colleagues in other disciplines.

CURRENT ASPECTS OF GRADUATE CHEMICAL ENGINEERING EDUCATION

The following remarks were presented at the 1963 ASEE Annual Meeting in Philadelphia as part of a panel discussion on "Current Aspects of Graduate Chemical Engineering Education". The session was moderated by R. N. Moddox of Oklahoma State University. The panelists were Alan S. Foust, Dean of Engineering at Lehigh University; Brage Golding, Head of the School of Chemical Engineering at Purdue; Harold S. Mickley, Professor of Chemical Engineering at M.I.T., and David H. Morgan, Director of College Relations for the Dow Chemical Company.

Remarks By Alan S. Foust

In offering my opinion on the present status of graduate education in Chemical Engineering, I will state in advance that I do not offer a panacea for the present situation. In my opinion, graduate education in Chemical Engineering is at the crossroads, with the field flowing across us under very high gradients. It is impossible to say now if the field is linear or non-linear; whether our parameters may be lumped or distributed, or whether the boundry conditions can be describable by linear equations.

In this situation, it is not surprising that we as educators have up to now been unable to optimize this system which is our challenge for delivering today's graduate-trained Chemical Engineers.

Before we proceed very far on this, we must decide how many of these men we are training for research, and how many we are training for design and other true engineering activities.

I hope there is not any universal decision among the alternatives we face in planning our graduate programs of the future. We shall probably continue to need some training in refinements and expansions of the Unit Operations techniques, since it is highly probable that the time devoted to them in the undergraduate program must shrink. Whether or not the old name disappears is inconsequential. The pedagogical advantage of looking at each of these operations in a fundamental framework must not be lost. Some departments will doubtless concentrate on the proper design of catalytic reactors, rather than a simple specification which is usually done now, and will illustrate the integration of this into a total system. Some other departments may wish to concentrate on filling the gap between established and usable knowledge in Chemistry and other basic sciences beyond the amount which is normally taught in the undergraduate years to Chemical Engineers. All of us are going to have to face some nonlinear mathematics which may provide the eventual clue to rigorous modeling of chemical systems in totò.

These assumptions indicate that we are not likely to find much room in the typical Chemical Engineering graduate program for the necessary physics of the solid state and the materials with which we work. Neither will there be time for training men in the intricacies of the electronic gear necessary to tell us how a process is behaving. They will make it even more difficult than at present to stimulate the student who has been trained largely by exposure to existing and thoroughly solved problems for which there is some reasonably definite answer under described boundary conditions toward the creativity necessary in addressing a new situation and exploring beyond the frontiers of the material he has gotten from textbooks. This will be absolutely necessary in the graduate education of the design engineer.

There is serious consideration being given to the question of whether or not the broad subject "Design" can actually be taught. This does not refer to the routine selection and synthesis of known components on the basis of available information and handbook formulae. My concern is in the synthesis of totally new systems, requiring projection beyond available information.

Experience in such a synthesis during a doctoral dissertation will probably raise conflicts with purists who insist on some new information or new concept as constituting the research we normally expect. If we had a degree designation of prestige equal to the Ph.D. awarded to these men who have demonstrated the ability to synthesize available information into a new system, we would probably find it easier to satisfy in graduate school the need of industry for expert designers of sophisticated systems.

So long as the most available money for supporting graduate students is closely held for fundamental research, and as long as the majority of our Chemical Engineering faculties are youngsters who have just completed a similar program of research and have never done any design, a solution will be elusive.

We must search not only for our contribution to stimulating the creative capacity of our graduate students, but we must devise some procedure or label which will retain prestige for design engineers, comparable to the Ph.D. for research engineers.

Remarks By David H. Morgan

In opening my part of the panel today I should like to start with a quotation which really "rocked" me. "In ten years it will be difficult to distinguish between engineering graduates and science graduates." Professors in the audience over 55 may relax in that possibly they might retire before their department evaporates if this statement is true. However, I cannot help but believe that chemical engineering has something unique to offer. Of course, I am assuming that the reason there will be no difference between the engineering and the science graduate, in the thinking of the writer of the above statement, will result from engineering becoming science rather than from science becoming engineering.

While not detracting from the necessity for science we should point out that chemical engineering arose from a need to apply the scientific discoveries to mankind's use. It is this application which has made our country great.

As one who has spent over a quarter of a century in education, I have seen movements, "fads," come and go. The disciples seize the new theory and spread the word--many times without fully understanding the concept--far beyond the original great idea.

Some of you experienced the growth of progressive education in the elementary and secondary education levels during the early thirties. Later some of these theories spread to general education at the college level. The testing movement came in and reached the stage where you could hear one superintendent of schools say to another, "Congratulations, John, I hear that you have installed a testing program!" The purpose of the testing program did not seem important. Methods versus subject matter in teaching has long been a source for speeches and articles.

These movements or fads are introduced merely to show that many times in education, as in other fields, the true purpose or value of a new concept depends on the degree to which a given objective is achieved. At the same time we must remember that there are other valid objectives which may or may not be affected by the new concept.

While I have no quarrel with some programs being developed to meet a specific need for engineering science, I am concerned over the appearance of the move becoming a "fad"--getting on the band wagon--throwing everything out of the window that has been found good, and solid, and productive.

We live in a new world. Engineering design taught today may be outmoded tomorrow. Therefore, the specific thought in engineering may give way to newer concepts, but the specifics are not the objective of education. We are interested in the development of the engineer. If learning the specifics which later became out of date has developed his knowledge of principles and applications of science to engineering, then they have achieved their purpose.

In some of the arguments which I have read on basic science versus engineering, the author seemed to believe that basic science will remain unchanged. This is a fallacy, as we all know, because just as engineering applications will change with advancement in knowledge so has our knowledge changed. I learned a basic fact in chemistry, "The atom is the smallest indivisible body of matter." Nothing could be more basic than that.

One of Dow's summer employees, within a year of completing his dissertation, performed a certain function all summer. In one of his courses the next fall he learned that what he had been doing all summer could not be done. In fact, he missed the question on the final examination because he answered according to what he had been doing and not according to the text and the professor. (On his oral he answered according to the professor!)

I am concerned with the number of requests for money to help develop Ph.D. programs in chemical engineering. Money, if granted, would have to come from perhaps some of you. What will be the effect on your program? Departments represented here will provide the staff. What happens to the department? Present graduate departments have staff, equipment, and research geared to a certain size of operation. The statistics recently crossing my desk show that the number of chemical engineers is decreasing. Do we need more graduate schools, or do we need more beginning students in chemical engineering?

I am concerned over the B.S. and M.S. Programs being geared to the Ph.D. engineering science. Certainly all of these students are not going on for a Ph.D. engineering science degree. I do not favor "dropping off" places in a sieve to separate the true engineering scientists from those without ability, or inclination. What happens to the student in an educational program of this nature? He is not prepared for the work which he could enjoy doing.

Perhaps one way to look at this would be to examine what chemical engineers are doing at the Dow Chemical Company.

All Chemical Engineering	Per Cent	No./1,000
Research	30	300
Production	30	300
Technical Service and Development	10	100
Sales	10	100
Design & Process Engineering	10	100
Non-engineering Management	2	20
Miscellaneous	8	80

Although the number actually exceeds a thousand, it is close enough to give us an understanding of the numbers of individuals involved rather than the per cent. From these figures, it is evident that basic chemical knowledge is desired, but engineering is essential.

Of course, if we take the Ph.D.'s alone, the statistics change markedly.

All Chemical Engineering	Per Cent
Research	76
Production	3
Sales	1
Technical Service and Development	3
Design	5
Non-engineering Management	3
Miscellaneous	9

What do we want? A good grasp for fundamentals, an adequate engineering background to fit into our organization, the ability to think systematically, dedication to the profession so that there is a desire to keep abreast of developments persistence, perseverance, and sustained drive to accomplish solution of technical problems of considerable complexity.

One of the strengths of the chemical engineer has been a balance of business judgment, knowledge of scientific principles, and technical problem-solving ability which has made him valuable to industrial management. Certainly, in fundamental research there is a need for the individual well versed in theory in depth. But, should the purpose of chemical engineering education be to make all schools of this type? Should not certain schools concentrate in certain areas of specific competence? Should a school with outstanding reputation in a certain area (e.g. chemical process engineering) abandon that area to start turning out carbon copies of the latest image of an engineering scientist? Is there sound engineering education thinking behind the move--if made--or is it immediate prestige seeking?

Don't misunderstand me. From the Company's point of view, if you have a super-superior chemical engineering scientist finishing his Ph.D. this summer--industry oriented--then sell him on my Company and send him c.o.d. to us! We can use him, but we still shall have need for many Production, Technical Service and Development, and Sales oriented engineers to make the profit after taxes to pay his salary.

Remarks By Harold S. Mickley

Despite the pessimistic views held by some, we are not here to attend a wake or to discuss the best way to bury engineering. Rather, we are here to explore ways to capitalize on our past accomplishments in order to ensure greater ones in the future. My optimistic attitude is borne out by hard economic facts.

The June 10, 1963 edition of "Chemical and Engineering News" reports starting salaries for college graduates. Technically trained people continue in high demand and of these, Chemical Engineers are among the best paid. The median starting salaries for Chemical Engineers are greater than those for chemists:

Degree	Median Starting Salary	
	Chemist	Chemical Engineer
B.S.	500	560
M.S.	578	645
Ph.D.	825	875

On the other hand, engineering is not without its problems. The report of the President's Science Advisory Committee: ("Meeting Manpower Needs in Science and Technology", Report No. 1, Graduate Training in Engineering, Mathematics, and Physical Sciences, Dec. 12, 1962, Washington, D.C.) states that we have no lack of engineers but we are critically short of engineering leaders. Unstated but certainly implied is dissatisfaction with the technician type work now done by a large fraction of our engineering graduates. In my opinion this minimal skill employment is responsible for the growth of unionism in engineering; a growth, which if unchecked, will dissipate the professional status of the engineer. The advisory committee advocates greatly increasing the number of engineers who go on to graduate work. It points out that engineers are far behind the scientist in the fraction that go on for advanced work:

Discipline	% Ph.D.
Biology	33
Chemistry	25
Physics	17
Mathematics	8
All Engineering	3.5
Chemical Engineering	11

Chemistry alone produces more Ph.D.'s than all of engineering.

It is safe to say that the universities will soon receive Federal support for graduate training in engineering on a scale undreamed of five years ago. Our job is to capitalize on this support.

What is our principal task? I believe it is to nurture Chemical Engineering as a true profession. Our product, the chemical engineer, must satisfy the following criteria of a true professional.

1. He must recognize that he forms one of the bridges between science and the fulfillment of human aspirations.
2. He must assume the responsibility for recognizing and solving a complete problem. Handling the purely technical aspects is not enough; he must take on the political, economic, and social headaches as well.
3. He must have a technical area in which he excels and must be prepared to maintain this excellence by continued self-education throughout his career.

An adequate discussion of possible means to achieve these requisites is not feasible in the limited time available. Consequently, I shall focus on item 3.

The technical area of the chemical engineer is the optimization of composition change. It is a vital, exciting, and growing area. Our position in this area is challenged from two sides by the scientist, principally the chemist, on one hand and by sister engineering disciplines on the other.

The Challenge of the Scientist

The main challenge which the scientist poses is: "Is a University education devoted exclusively to science a superior training for a man who intends to function as an engineer?" The key words are function as an engineer for there is no cause for alarm if he functions as a scientist. There should be no gnashing of teeth if an industrial scientist makes a basic discovery, as engineers we should cheer since this is the wheat from which we fashion our bread. When, however, the scientists by education show signs, as they now do, of carrying a basic discovery into the production stage more rapidly and more effectively than the engineer by education it is time to sound the alarm.

I think that the rapid evolution of new technology of increasing complexity has created a situation where the scientist now has some definite advantages. These advantages principally reside in the ability to size up a new situation faster and explore it in more depth. They are derived from

1.) A better grasp of basic laws and phenomena.
2.) A greater familiarity and experience with prediction methods.

There are some important disadvantages which show up when a scientist starts to practice engineering.

1.) He avoids incompletely understood techniques.
2.) He tends to carry analysis and research past the economic optimum.
3.) He is not accustomed to thinking in terms of synthesis of the whole in contrast to analysis of individual segments.

It is perhaps trite to say that we should seek to incorporate the advantages of scientific training into engineering education without adding its disadvantages but I think we can do a better job than at present.

The Challenge of other Engineering Disciplines

Most other engineering disciplines are based on physics. They present a challenge because in some respects they are better qualified than chemical engineers to treat the problems of composition change.

The changes in physics-based engineering education directly reflect the changed directions taken by the technology which they take to be their special areas. This technology has emphasized the importance of attention to fundamentals and deflated the position of specialized knowhow. They have been frankly concerned with the skill with which the scientist has handled problems in their areas. The result has been a realignment of their educational philosophy with renewed attention to basic science. They are now doing what the chemical engineer has always felt to be essential, but using as a base physics rather than chemistry. The results are somewhat different however. In many ways physics is a tidier science than chemistry and the phenomena of interest to the engineer are more susceptible to analysis. Further, the mathematical description and analytical approach to apparently different phenomena turn out to be closely related and the results of intensive work in one area are readily applied to another. For example, the electrical engineer is well prepared to attack problems involving potential flow of any kind (fluid, heat, mass) and to carry on with fluctuating phenomena (i.e., turbulence) because of the effort which he has made to analyze and understand similar phenomena in electromagnetism.

The other engineering disciplines have begun to devote considerable effort to formalizing the synthesis of systems and have made considerable progress.

What significance do these changes in the educational approach of the other engineering disciplines have for chemical engineers? It seems to me that in certain overlapping activities we are currently being pushed hard; for example:

1. The other disciplines are attacking momentum, heat, and mass transfer in an intensive and fundamental manner.
2. In operations carried out under extreme conditions with or without interacting fields, the interests of the other disciplines in such things as plasma jets, extremely high speed flight, deformations under very high stress, etc. has led them to undertake work of an advanced character. Further, much of this work involves chemical reactions which they have taken in stride.
3. It is known that semi-conductors are closely related to chemical reaction catalysts. The solid-state work of the electrical engineer and metallurgist is carrying him further into the fundamentals of catalysis.
4. In systems synthesis, the pace is accelerating.

The above and similar circumstances represent challenges to the chemical engineer to look to his own laurels and to make certain that he is truly operating at maximum effectiveness.

It is with these opportunities and challenges to the profession of Chemical Engineering in mind that I suggest the following objectives for the technical part of his University Education. How this accomplishment is split between graduate and undergraduate years will vary from institution to institution.

1. A broad but penetrating exposure to the areas of both fundamental and applied technology. Much of what is traditional in Chemical Engineering education belongs in here but it needs redoing.

2. More depth in chemistry but with emphasis on understanding and application rather than on manipulative technique. Wet analytical chemistry is not our dish. Emphasis structure and synthesis approached from quantum ideas at the atomic scale; how does one tailor-make molecules? Formulate and use the connections between the molecular and continuum approaches to the behavior of matter. Give increased attention to interphase phenomena adsorption, liquid/liquid equilibria, etc. because their applications are so important. Investigate non-equilibrium phenomena: kinetics, interaction with electromagnetic and high energy particle fields, extreme temperatures.

The subjects which in combination provide this depth in chemistry will not all be given by the chemistry faculty. Physics and other engineering disciplines may well offer more suitable material; the chemical engineering faculties will need to develop programs of their own.

3. Depth in a field theory discipline: continuum mechanics (which includes fluid mechanics) or electromagnetic theory. A real understanding in depth in one of these areas is readily used as a springboard to real understanding in a related one. Everywhere we turn we find old and new applications of field phenomena.

4. A meaningful experience in synthesis and design. This is fundamental to engineering and very difficult to accomplish. We have not done well here. "Plant design" etc. is in the right direction but too artificial and contrived. We need a no-holds-barred experience which includes laboratory experiment, economics, politics, and technical theory. Industry can be of great help here and I think we should seek new ways of drawing on their ideas and experience. In my own institution I have seen the project oriented Instrumentation Laboratory (Guidance System) and Lincoln Laboratory (Radar Systems) used as superb training grounds for engineers. These laboratories operate at high levels of technical competence with real hardware to produce under pressure of deadline, budgets, contract negotiations, etc. Men trained in this way, on moving into industry, become project managers and ultimately top management people. We in Chemical Engineering ought to be able to do something like this if we really set our minds to it.

Finally, we should reassess our Ph.D. program. There is a real need for competence in areas outside of research and development. The present format of the Ph.D. degree, entailing several years effort on a single research problem, is borrowed from antiquity. Although well suited for training for a career in research, I have serious doubts as to its efficiency for training men for other jobs in engineering. A shortened research interval, perhaps oriented more toward a project-type problem, might be far better. The introduction of another educational path requires a break with tradition but to be an engineer one must pioneer.

SHOULD INDUSTRY ASSIST GRADUATE EDUCATION?

The following prepared remarks inaugurated a panel discussion at the 1963 ASEE Annual Meeting. John K. Wolfe of the General Electric Company presided. Members of the panel included George M. Buckingham, Executive Secretary of the Esso Education Foundation;Glenn W. Giddings, Consultant in Educational Relations for the General Electric Company; and C. J. Metz, Trustee and Secretary of the Union Carbide Educational Fund.

Remarks By George M. Buckingham

Education evolves from and feeds upon scholarly study. However, education lives only if it succeeds in motivating young minds to seek the best available learning experience and concurrently works very hard to make the best learning available to the largest number of minds capable of profiting from the experience.

Since all education involves teachers, since some learning is best carried on by individual research, and since we are talking of corporate financial assistance, I have chosen for this brief presentation the title "Educators, Researchers and Shareholders."

In my opinion each corporation management should thoroughly thrash out the reasons why it should consider financially supporting education, before any programs are adopted.

I am sure that many of you own stock in various enterprises and for just a moment I would ask you to look at industry contributions, not as educators or researchers, but as shareholders. A corporation may contribute to institutions such as colleges, hospitals and United Funds as much as 5% of its net taxable income and take an allowable tax deduction under Internal Revenue Service regulations. Since the corporate tax rate gets up to 52% very quickly, since the average business percentage of contributing is less than one per cent of net income before taxes, and since less than half of that flows to educational institutions, it is fairly obvious we are talking of only pennies or less per share. While we know from experience that the majority of shareholders agree with the proposition in general, we also know we must be prepared at all times to give an accounting of our stewardship to the owners of the business. It is for this reason that I believe each management ought to determine whether it should assist education with corporate funds and, if so, what it intends to accomplish by those expenditures.

Justification may be based on a sincere desire to put money to work in an area where it will benefit society and hence benefit the company and its owners, on the premise a business can exist only as long as the society which it serves and of which it is a part permits it to exist. On the other hand, justification may be much closer to a quid pro quo situation, such as establishing close ties with departments that are good sources of topflight manpower for the corporation or a wish to advance a discipline or disciplines closely associated with the business.

One does not have to examine these three rationales for long to see there is no pat answer as to why a corporation considers investing in education at one level or another or in one phase or another.

As Executive Secretary of the Esso Education Foundation, which is interested in the whole spectrum of higher education, I sense some real differences in the present situation as regards undergraduate and graduate areas. When we make a grant to an outstanding liberal arts college, we can be pretty sure it is going to be used primarily to educate those who are probably going to lead future generations. I am not quite so sure we can always be as certain of this when we make funds available at the graduate level.

Before getting on with the reasons for the uncertainty, let me state unequivocally that I most assuredly have no desire to alienate anyone and hope not to do so. If, however, the point to be made is valid, it is a risk seemingly worth taking.

There are just enough cases of smoke to indicate that there are some fires fed by private and public funds intended for graduate training apparently being diverted to personal faculty research and publications; with the result that seemingly playing second fiddle is the education of those upon whom education itself, as well as government, society, labor, and industry,must depend for future leadership.

I am not about to take a stand on the "right" teaching load per professor, nor on teaching methods, nor on the university ideal of being the cradle of new ideas and breakthroughs in knowledge. But, gentlemen, I will take a stand on the importance of every faculty member assuming the responsibility of seeing to it that his masters and doctoral candidates, and post doctorals too, acquire the best possible training to prepare them for becoming the outstandingly competent teachers researchers, administrators and leaders of the future. If university faculties can convince industry that they are bending their energies in this direction, instead of seeking funds to do research for the sake of research, I think they will wind up with a valid claim on industry, which industry will stand ready, willing and able to pay.

In other words, I think industry should certainly invest corporate funds in graduate education, but only under conditions and for purposes that are compatible with the objectives which the company has previously selected as being worthy of achievement and that are mutually satisfactory to both the donor and donee.

Remarks By C. J. Metz

"Is the pattern of corporate support of graduate education changing?" To get the best possible answer to this question, I decided to survey my friends in 25 major corporations including the leading chemical and oil companies. All are known to be knowledgeable in their approach to educational support. All are interested in chemical engineering and chemical engineers. I am grateful for their help.

Because of the diversity of their programs, I encountered some difficulty summarizing the information provided. However, it shows rather clearly that the pattern of corporate support at the graduate level, the oldest form of assistance with most companies, is changing.

In the next 10 minutes I should like to discuss how the current practices of these companies evolved and make some predictions regarding future trends.

ORIGINAL PROGRAMS:

The first company to embark on a formal program in support of graduate education did so in 1918. Others followed suit during the next four decades with the largest number starting in the 40's.

During this period the most popular forms of support were fellowships and research grants, particularly in science and engineering.

The expenditure of company-earned dollars was justified for a number of reasons. The principal ones were:

1) A recognition that graduate education is necessary in maintaining strong faculties at the collegiate level.
2) To help ease the shortage of professionally trained people.
3) To expand knowledge.
4) A feeling of responsibility for support of academic work in technical fields closely related to a company's interests.
5) The desire for closer relations with academic leaders in these fields.

RECENT AND CURRENT PRACTICES:

Corporate support at the graduate level has gained tremendously over the years, and I believe the reasons for giving have remained about the same.

More recently, during the past three or four years, there has been a noticeable shift in the type of graduate assistance. In some cases the changes have been gradual and in others quite abrupt. More than half the companies surveyed have shifted partially or completely from standard fellowships to more flexibly administered departmental grants which can be used by the recipients as they choose.

In some cases existing grant arrangements have been made more general and one company has converted its graduate research grants to unrestricted grants to universities.

Other variations in the pattern are provided by a small number of companies which have diverted fellowship support dollars to other uses, such as professorships, undergraduate scholarships, the purchase of instructional and research equipment, and support of the company's own employees in their graduate studies.

I believe there are two basic reasons for these changes in graduate support:

First, the ever-increasing number and size of fellowships and grants available from other sources, particularly from the various departments and agencies of the federal government. Some companies felt that the impact of their previous arrangements with the universities had been lessened and that their standard fellowship and grant arrangements were losing out in competition with their own tax dollars which are being administered more generously by the government.

Secondly, flexible or unrestricted departmental grants are more acceptable to the recipients. They supplement more effectively the designated grants from other sources.

This brings us up to the present.

FUTURE:

Now, looking to the future, the companies surveyed were asked if they contemplated any changes in the scope or character of their graduate support programs.

Company responses to this query fall into two categories - those who have already attempted to "come to grips" with the problem and have recently revamped their programs, and those "still on the fence".

As previously indicated, the companies in the first group have already shifted the emphasis of their support from fellowships to grants and, in some cases, to other areas of need. They plan to gear their programs to changing business conditions, changing needs of education and other circumstances; but have no plans for major changes in the immediate future.

The second group is comprised of companies still seeking their own solutions. They, too, are overwhelmed by the proliferation of graduate support opportunities and frequently refer to the programs sponsored by NASA, NSF, NIH, etc. They are uncertain regarding their role in support at the graduate level.

It is my opinion that this group will work out solutions to the problem on an individual basis. In all probability, steps taken will be diversified but, in the main, they will follow the pattern established by the companies which have rearranged their types of assistance in the past three or four years.

CONCLUSIONS:

In conclusion - as an amateur crystal-ball-gazer, I would like to make several observations regarding the future of corporate support at the graduate level:

1) I don't envision a wholesale withdrawal of corporate support in the near future. The present total is substantial - it may increase in total dollars - but as corporate support to higher education in all forms continues upward, the percentage of the total which goes to graduate education may decline.

2) Graduate assistance will become more selective, more closely related to the business of the donor. Companies will examine more thoroughly the university programs and the other sources of income at each institution with which they deal. Administrators of company programs, like myself, are finding it increasingly difficult to justify the expenditure of company dollars in the present atmosphere of uncertainty and change.

3) Some of the dollars previously spent on fellowships and grants at the graduate level may be assigned to other areas of need. In addition to professorships, unrestricted grants to universities, undergraduate scholarships, equipment purchases and other donations, and the support of company employees in their graduate studies - all previously mentioned - there are indications that some of these dollars may flow to plant-town colleges, urban universities, undergraduate programs at liberal arts colleges, and other special areas such as business, economics, and medical education.

If these changes occur, as predicted, and graduate education loses some direct support from companies, I am sure you will agree that it stands to gain, at least indirectly, from the dollars spent in the other areas of need.

To paraphrase a statement attributed to the former head of General Motors while serving as Secretary of Defense -- "What's good for general education is good for graduate education" -- or perhaps I should say --"To assist higher education in general is to assist graduate education."

Remarks By Glenn W. Giddings

Most persons would probably give a quick affirmative answer to the question, "Should Industry Assist Graduate Education?" It might come as a surprise, as indeed it did to me, to find that a strong case can be made for the negative.

In opening the discussion on the question of assisting graduate education, I think it might be helpful to try to view it in a larger context. Support to graduate education cannot be isolated; it is a part of the larger problem of support to education. And further, although we all recognize the interdependence of education and industry, a still broader question may appropriately be asked, "Does industry have responsibility to education?". Or, to put it even more strongly, "Is Industry obligated to assist education?". This question, in turn, is part of a still larger problem, "Does business have social responsibilities?". What is the business of business?

Theodore Levitt of Harvard University, writing in the Harvard Business Review, has this to say, "In the end, business has only two responsibilities -- to obey the elementary canons of every-day, face-to-face civility (honesty, good faith, etc.) and to seek material gain."[1] Milton Freedman, Economist of the University of Chicago, has declared, "If anything is certain to destroy our free society, to undermine its very foundations, it would be a widespread acceptance by management of some social responsibilities in some sense other than to make as much money as possible. . ."[2] And consider this further testimony from Kelso and Adler on the responsibilities of management. In The Capitalist Manifesto these authors conclude that ultimate control of a corporation "should rest with those who own it, not with those who merely run it. . . For the management of a corporate enterprise to dispose of what rightfully belongs to its stockholders without their free, present and affirmatively expressed consent is despotism, and it remains despotism no matter how benevolent or wise management is in acting for what it thinks to be the 'best interests' of its stockholders."[3]

These negative pronouncements have all been made within the past five years. In sum, they sound a cautionary note, and provide food for considerable thought on what the social responsibilities of business actually are. The predominance of current opinion, however, is positive, that is, that industry does indeed have social responsibilities, including an obligation to assist in supporting education.

The famous A. P. Smith Case in New Jersey a decade ago has been widely taken as precedent.[4] In that case, as you may recall, the A. P. Smith Company sought approval in the courts for an unrestricted gift of $1,500 to Princeton University, to which the stockholders had objected. Judge Stein of the Superior Court of New Jersey found in favor of the Company. His decision was upheld by the Supreme Court of New Jersey, which held, in effect, that a corporation has social responsibilities, including not only the right but the duty to assist education as being in the common good. An appeal to the Supreme Court of the United States was dismissed, "for the want of a substantial Federal question.".

Judge Stein's decision in the Smith Case, although not tested outside of the New Jersey courts, has undoubtedly been a factor in increasing industrial support to education. It has come to be felt that it is no longer necessary to have a specific quid pro quo, some demonstrable direct benefit to the corporation that may be used in justification of each gift of the stockholders' money.

This practice of giving without a specific quid pro quo is a relatively new factor in corporate support to education. In a book on Corporation Giving, that was published by F. Emerson Andrews of the Russell Sage Foundation at just about the time the A. P. Smith Case arose, the author makes this comment, "Corporation giving, however, is not based on pure altruism. . . Enlightened selfishness is a legal requirement." The author proceeds, "Much corporation giving undoubtedly proceeds from mixed motives. It is done in behalf of a soulless entity, with selfish advantage obligatory, but by persons whose hearts sometimes outvote their heads."[5] This is a very good statement, for until fairly recently, many appeals for corporate contributions were made on an emotional and personal basis, and giving was capricious.

Recently there has been a marked change. Many companies have established separate components for developing policies and practices of giving, and some have established their own educational foundations. But there is one thing that must not be lost sight of -- the money that corporations give in support of education is still business dollars. If it were not given to education, it might be used for the direct benefit of either the stockholders through increased dividends, or of the customers through lower prices. When diverted to support of education, the objective should be to support the long-range interests of the business.

John A. Pollard, Vice President of the Council for Financial Aid to Education, has put the case well. In an article in the Harvard Business Review, he says, "Now, management sees clearly that support of education in its many forms is not just philanthropy; it is also an investment that benefits the corporation --

1. By stimulating the growth of new knowledge and making possible a wider dissemination of present learning.

2. By recognizing that an adequate supply of educated manpower results from good teaching under favorable circumstances.

3. By fostering a social, economic and political climate in which the company can continue to progress."[6]

Let us return now to the specifics of our question: What are the obligations of industry to assist graduate education? I should like to mention two areas in which I think industry has a pretty well defined obligation to assist in supporting graduate education.

One of them is the preparation of teachers, college teachers particularly. The supply of adequately qualified faculty members seems likely to be the greatest bottleneck in American higher education during the next decade. Industry, in considering its dependence upon a continuing supply of educated manpower, might well take careful thought as to how it can assist graduate education in the production of teachers.

Another area in which, it seems to me, neither industry nor education has made a full assessment of the needs, is the whole field of what has become known as continuing education. Whose job is it to bring up to date and keep up to date the many thousands of college graduates that populate industrial laboratories? Is it the job of the man himself? Certainly, in part. Is it the job of the educational institution that once helped him to learn, but perhaps did not help him sufficiently in learning how to keep on learning? . . . Should education give any "in-service warranty" with its product? Or is it the job of the employer to sense inadequacies or imbalances in the background of employees engaged in practicing changing technologies, and to pay for correcting them? Certainly, at least in part.

The magnitude of the problem of continuing education has not yet, I believe, been fully sensed, and both industry and education must be prepared to participate in a careful assessment of the needs in this area and how to fill them.

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INDUSTRIES' VIEWS OF CURRENT CHEMICAL ENGINEERING EDUCATION

by

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In preparation for a paper presented at the Philadelphia meeting of ASEE, an extensive survey was undertaken in order to determine the industrial attitude toward current chemical engineering education. The result is a monumental 161-page report which has been distributed to all collegiate chemical engineering departments in the United States.

Results of the survey were summarized at the Philadelphia ASEE meeting, and the conclusions certainly will give chemical engineering educators food for thought. A few of the salient conclusions are quoted in the following paragraphs.

"There was a strong plea from industry for more chemical engineering and less engineering science. Industry does not expect a scientist when he hires an engineer. The engineer must have utilization and not knowledge as his goal."

"Industry is less displeased with undergraduate training than with graduate training, even though some schools are neglecting undergraduate activities in order to emphasize graduate work, too often of a research or pure-science flavor. Worse than this, good B.S. engineers interested in industrial careers in operations, management, and engineering are directed into graduate work simply because they are highly capable students. Industry has no objections to research-oriented graduate work for men headed for research or teaching. But it doesn't like a situation where all available B.S. men for industry are mediocre or poor students while the best students are enticed into doing graduate work in which they might not happen to be particularly interested. The problem is further aggravated when industry hires Ph.D.'s groomed in research, to do B.S. work in operations. Neither the man nor the company will be happy with this type of arrangement. And I won't even get into the problem that this causes with salary administration."

"Some comments from industry refer to the possibilities of graduate work leading to a Doctor of Engineering degree. This degree would differ in its objectives from the Ph.D. degree and proficiency in research alone would not qualify a man for it. What is really being said here is that extra schooling can be used to good advantage if it is used to reinforce the basic training of the first four years. Broadening the student, counselling him, and exposing him to the types of complex multi-answer problems that he will encounter in industry appeals to many of the industry people. Many companies have had good experience with M.S. graduates whose training was geared to industrial work. Likewise, industry has need for Ph.D.'s for research work or highly specialized engineering work, as well as Doctors of Engineering for design, operations, and management functions. The big problem is to get the proper types of individuals into the correct type of program under the proper group of teachers."

"One of the things that is so distressing to technical people in industry who are employing new engineers is the fact that so many of these new men come to work without being aware of the fact that good writing and good speaking are very important requirements vital to their success in their professional careers."

"Industry comments on improvement of chemical engineering faculties followed a definite pattern. One of the biggest objections is that too few faculty members have had industrial experience or are able to fully appreciate the situations with which the student will be confronted after he gets into industrial work. There is a feeling that industry could help with this problem by improving liaison between faculty and industry, by having members of industry visit the schools and talk with the students, and by having faculty members actually work in industry on going problems."

Copies of the complete report may be obtained by writing M. W. Mayer, Esso Research and Engineering Company, P.O. Box 209, Madison, New Jersey.