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SOME THOUGHTS

on the

TRENDS IN ENGINEERING EDUCATION

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I propose to discuss two questions which seem to me to be of vital importance to the future of engineering education and on which there is far from unanimous agreement. These are:

1. Should we teach engineering in the undergraduate engineering curriculum? Another way to state this question is as follows: Should the undergraduate curriculum be strictly a "pre-engineering" one including only studies in the basic sciences, in the humanities and social sciences with no introduction to engineering? This would be analogous to the present system of education for the professions of law and of medicine.

Another possibility is a curriculum that is a compromise between one with engineering in it and a strictly pre-engineering one. This is a curriculum which goes beyond what we usually call the basic sciences and include some of what are commonly called the Engineering Sciences. These include thermodynamics, mechanics of solids and of fluids,transfer and rate processes, electrical sciences, and properties of materials. This type of curriculum has become quite popular in recent years.

2. Should there be two parallel programs of graduate study in engineering, one of which is research-oriented and the other design- or systems-oriented? In discussing these two questions I do not intend to limit their application just to Chemical Engineering, but rather I will direct my remarks toward all branches of Engineering.

Let us proceed to consider question No. 1 first. The question is by no means purely academic. It seems to me that the development of courses in "Engineering Science" and "Engineering Physics" and the like is one definite trend in the direction of displacing courses in engineering with courses that have little if any engineering in them. Mr. John Gardner, President of the Carnegie Corp., wrote as follows in "Goals for Americans":

> "we are beginning to understand that true professional education takes place at the graduate level. Students headed for graduate professional education should spend their years in a liberal arts program, majoring in one of the scientific or scholarly subjects underlying their future profession.
>
> The trend in all professional education is to emphasize the underlying scientific and scholarly fields and to diminish emphasis on "how to do it" courses. In our rapidly changing technology no student can learn specifically how to do his future job."

The American Society of Civil Engineers held a conference on Civil Engineering education in 1960 and adopted several resolutions, one of which reads as follows:

"THEREFORE BE IT RESOLVED, that this conference favors the growth in universities and colleges of a pre-engineering, undergraduate, degree-eligible program for all engineers, emphasizing humanistic-social studies, mathematics, basic and engineering sciences with at least three-quarters of the program interchangeable among the various engineering curricula; to be followed by a professional or graduate civil engineering curriculum based on the pre-engineering program and leading to the first engineering degree awarded only at the completion of the professional or graduate curriculum."

In spite of what some engineering educators would have us believe, engineering is an art and not a science. Of course the engineer uses as much science as he finds applicable to the problem at hand, but I have never met a real engineering problem that could be solved by science alone. I believe it to be true that most of what we call "theory" is oversimplified compared to an actual situation in practice. In other words, all of our theory has limitations when it comes to the applications, and it must inevitably be mixed with empirical knowledge. Until he is called upon to use his theory the student seldom realizes that nature is never quite as simple as our mathematical equations might lead us to believe. Empiricism is still, and I believe always will be, a valuable part of the engineers "stock in trade." It is very necessary in the solution of practical problems simply because our knowledge of fundamentals is still so incomplete. I wonder how many of the decisions made by most engineers are based purely on a mathematical analysis. Relatively few, I suspect, but admittedly more will be so based in the future.

Engineering and science differ profoundly in their goals though the methods and facts employed by scientists and engineers may be almost the same. Engineering problems--and after all the engineer is primarily a problem solver--vary greatly in the extent to which science can be applied in arriving at an acceptable solution. Some require a very sophisticated approach with the latest and most refined tools of mathematics and the physical sciences while others are of such a nature that science is of almost no help and one must fall back on experience and judgement. Even with problems of the first type, considerable art is involved in such steps as analyzing the problem to break it down into more manageable parts, recognizing what techniques are available and applicable to the solution, making the simplifying assumptions that are almost always essential with a complex situation, using judgement in the selection of data and combining all these and other elements to arrive at a satisfactory result.

This is the very essence of engineering and, to me, it is unthinkable that the student of engineering should not be exposed to it early in his career. The earlier in his career that he is introduced to the methodology of engineering, the more likely is he to become really interested in the field and enthusiastic over the opportunities that it offers. Some say "teach the engineering student only the fundamentals and leave the application to on-the-job training or at least to graduate work." This is one of the surest ways I know of to turn the student away from engineering. If he is exposed only to courses in mathematics and science he naturally gets the idea that this is all there is to engineering. Why undertake graduate work in engineering if science is the whole basis of engineering? Not having much conception of the real nature of engineering, he will naturally turn toward advanced courses in math and pure science especially since the various media of publicity make no distinction between the scientist and the engineer and describe most of the great engineering achievements of the past decade or two as wonders of science. Unless we give our students a concept of what professional engineering work is like, we may expect to lose many of them to science. They can only acquire this point of view by doing something in college which at least bears some resemblance to engining.

The student of science is accustomed to thinking of problems as having single, rather precise, answers. This is the type of problem he meets in his courses in math and science. Very few engineering problems are of this type. They have multiple answers and much of the work of the engineer consists in selecting the one best suited for the particular situation. To give the student early in his career a real grasp and understanding of this simple fact, is a potent reason why at least an introduction to real engineering problems should be in the undergraduate curriculum.

It is quite generally agreed by those who have given much thought to the subject that design is the characteristic function of the engineer. This means design in its broadest sense---the creation of something new in response to a social need. It takes many forms---the design of a new or improved machine, a better process, a new material, a new combination of various elements into a system designed to yield a product with maximum economy just to mention a few examples. If this is true, it seems inconceivable to me that we should not give the student an opportunity to practice this art early in his career.

I find that many undergraduates feel abused if a problem isn't so clearly stated that the method of solution is almost obvious, or if some data which they feel they need are missing, or if the problem doesn't have a clear cut single answer. But this is precisely the kind of problem he is likely to meet in professional practice and we should prepare him for it. One reason that he resents this type of problem is because in so many of his courses in science he has been conditioned to problems which are precisely stated and which do have unique solutions. The design problem offers a quite different experience and this is why it is so important. It is also important because it can demonstrate to the student of engineering that some of the science and math he has been learning can be put to practical use and this is an important motivating factor.

Let us return for a moment to the question of a pre-engineering course analogous to the pre-medical or pre-law courses. The analogy is not a very good one because of the great difference in these professions. The doctor and the lawyer generally deal directly with the public and their accomplishments are open for all to see and well understand. The situation is quite different in the case of the engineer. He seldom deals directly with the public and his part in an end result is never clear. A college student who has only had an introduction to math and the basic physical sciences can begin to practice the art of engineering in a limited way i.e. at least by his sophomore year. This is probably not true of the law or the medical student. Apparently more maturity is required before one can accomplish anything in a professional way.

I agree that graduate work is becoming more and more important in the study of engineering and that one of the important objectives of the undergraduate course is preparation for graduate work. This is used by some educators as a reason for omitting engineering -- that is, design-- from the undergraduate curriculum. I must insist that an undergraduate course with no engineering in it is hardly good preparation for graduate work in engineering. It may be desirable for a career in research but this is not engineering. Engineers frequently engage in research, and I mean to make a distinction between research and development, but usually for the purpose of developing data or correlations for use in design. When they do this they are acting as scientists rather than engineers and the only essential difference between research by a scientist and that by an engineer is the objective. I think it is an excellent thing for every engineering student to have some research experience if only for the purpose of giving him a real feeling for what is involved in establishing a simple fact. But let's not delude ourselves into thinking that research commonly undertaken by students of engineering, is truly engineering.

I think that engineering educators themselves are partly to blame for the flight of good students away from engineering and into the basic sciences. They themselves have been emphasizing science at the expense of engineering by introducing more and more courses into the curriculum which are mostly science and math with very little engineering even though they often carry engineering labels. Good students can see through this decept- and rightly conclude that if engineering is only a degraded and diluted form of science, why not do it right and become first-class, instead of second-class scientists.

Instead of trying to blur the distinction between the scientist and the engineer and helping to create the impression that the engineer is really only a second-class scientist, I suggest we reverse this trend and take every occasion to emphasize the difference between the two, at the same time showing how each has his own contribution to make and that each depends on the other.

I am strongly urging that we stop squeezing all the engineering out of the curriculum in order to put in more science. I would like to start some elementary design in the first or at least the second year and continue through the undergraduate years and on into the graduate study. Such courses I am convinced, can be made just as interesting and challenging, perhaps more so, than any pure science course. Futhermore they will go a long way toward giving the student an insight into what the practice of engineering involves and, I hope, arousing enthusiasm for the possibilities for service that the profession offers. In addition -- and I am sure this will be considered heresy in some quarters -- my own experience has convinced me that the best way to gain an understanding of scientific principles is to have to apply them to solve a practical problem - in other words, to study engineering.

Unfortunately, I think that some engineering teachers are really more interested in the science content of the courses they teach than they are in the engineering aspects. In fact I have been a little shocked to find that some engineering teachers I know are not really interested in what I, at least, consider to be engineering. One reason for this is simply the plain fact that they have never done any real engineering. I have the feeling that some engineering teachers are not only uninterested in design but actually look down on it as a second-class endeavor not worthy of their best efforts. This is cause for considerable concern when one considers that design is generally recognized as the most characteristic activity of the engineer.

I think we need to attract into the teaching profession more men who have had experience in the practice of engineering and in some cases it should be engineering of a very up-to-date and sophisticated character. Perhaps we can begin by bringing in young engineers with 5-10 years of practical experience on a part-time basis. I would like to see this avenue explored more fully. I would agree that some of the members of the engineering faculty should be scientists rather than engineers but scientists with an interest in application and who are willing to work with engineers. This is becoming increasingly important now that science is developing so rapidly and the science that the engineering student learned in college is likely to become obsolescent in 5 to 10 years. I am concerned, however, with maintaining a good balance between the applied scientists and the engineers on our engineering faculties.

I certainly wouldn't quarrel with the idea that the modern engineer needs as much science as it is possible to acquire and not just superficial knowledge but knowledge in depth. But there is a limit to the amount that the average engineering student can absorb and really understand without being given the opportunity to use some of it in the solution of a practical -- as distinct from a purely artificial -- problem. All through the student's academic career, I think the science and math courses should be paralleled by courses,or at least one course,that offers the opportunity of applying them. At this point I should like to emphasize again that few real engineering problems - and I am using the word "problem" in the broad sense of a situation calling for an action, a question demanding an answer which may or may not be quantitative - can be satisfactorily solved with the tools of science alone. These must usually be combined with empirjcal information and especially with economic balance among various alternatives. The balance may be of a rather crude, semi-quantitative type or it may be of a highly sophisticated character requiring an electronic computer to solve. This points up one of the most important differences between the engineer and the scientist. The former is continually preoccupied with costs and economic balances and the latter almost never is. This makes a profound difference in their attitude and approach to problems.

There are, in my view, four areas that should be included in all engineering curricula. These are:

1. Humanities
2. Basic Science
3. Engineering Science
4. Design

I am not concerned with No. 1 in this discussion. Let us accept without argument that something like 20-25% of the time of the undergraduate course should be devoted to this area. In passing, let me say that I think there is considerable room for improvement in the way in which this time is used, but that is another story.

No. 2 needs no discussion and I will merely say that I think the proportion in the curriculum should lie between 25 and 35 percent.

Area No. 3 builds directly on No. 2 and is essentially an extension of it to develop tools that the engineer can directly use. Perhaps an example or two is needed here to clarify the point. The student learns the basic principles of thermodynamics both in physics and in physical chemistry but anyone who has taught thermodynamics as an engineering science knows how far the student is from being able to use these principles. They need to be amplified and illustrated in many ways before the student can expect to have any facility in their use. This is the reason why engineering teachers give courses in this subject. I should like to choose one other example and this time from the field of chemical engineering. In his physical chemistry course the student learns the basic principles on which the unit operation of distillation depends but here again these need to be supplemented and illustrated in much greater depth before he is in any position to use them in the solution of an engineering problem. This area might occupy from 25 to 35 percent of the curriculum.

I would like to emphasize again that mere knowledge of the "tools of engineering" does not constitute an ability to practice it. Admittedly, the student will do most of his learning about how to apply these tools after he graduates but I firmly believe that he should have some introduction to this art in school. This brings us to a consideration of the fourth area in my list.

This area is the only real engineering part of the curriculum. Without it the course should not carry the label of engineering. It should probably constitute from 15-20% of the curriculum. It should consist of problems or projects for which no single answer exists and which demands some kind of original thinking. In chemical engineering, the only field about which I can speak with any authority, it usually takes the form of a choice between several processes or courses of action, based on an economic criterion. Naturally the problems will initially be very simple and then gradually increase in scope and difficulty.

Admittedly we should not even attempt in the 4-year undergraduate course, and probably not even in the graduate courses, to turn out professional engineers but it does seem to me that we should teach them the engineering approach to problems and try to arouse an interest in professional work. I fear that some of us seem to lose sight of the fact that we are supposed to be educating engineers and not scientists. Whereas work of a truly professional character must be deferred until after graduation we cannot begin too soon to inculcate the habits of thought and the attitudes of the engineer. Some of these are:

1. The willingness to accept a rather vague assignment and to go ahead and define the problem himself.

2. The courage to go ahead and make a decision when the available information on which it has to be based, is quite incomplete.

3. A questioning attitute toward facts and formulae.

4. Recognition that few engineering problems have a single solution and that one needs to learn how to exercise judgement in selecting the best one.

Such attitudes of mind can only be acquired by tackling problems of a type that will call them into play. If they are not acquired early in the student's academic career, contrary habits will be formed which are very difficult to change.

The problem with a single numerical answer has two great advantages for the teacher over the design-type. It is much easier to make up and also easier to judge and grade but it does not help much to develop judgement;in fact it tends to discourage it.

Let me now turn to the other question which I said at the very beginning I intended to discuss. It is not unrelated to the first one. As I see it, the common pattern for graduate work in engineering consists of more textbook-type courses but of course more advanced plus sometimes a brief introduction to research leading to a master's degree and then further research leading to the doctorate. The main objective is to train men for careers in research, or teaching. For this it is well suited and conforms to the general theme I have been developing, which applied to this case simply says that the best way to train men for research is to have them do some research. But I submit that a large proportion of our engineers in industry are not doing research but are engaged in other kinds of professional activity. My point is simply this: that for those students who are more interested in these other activities, for example design, development, production, systems analysis, technical service, etc. another type of graduate education would seem to be more suited to their needs. In other words we need two distinct types of graduate programs, one of which is research-oriented and the other directed more toward professional engineering or design.

The program of the first or research-oriented type would consist of advanced courses in applied mathematics and engineering sciences followed by a research problem. As at present it would be desirable to have two levels of degrees, a master's and a doctor's degree. The main difference between them would be the amount of time spent on research. In the case of the master's degree one could only offer a brief introduction to the technique of doing research and little in the way of results of value could be expected. In the case of the doctor's degree the research would be more thorough and should lead to publishable results.

In the case of the profession-oriented or design-type of graduate program, the first part of the program would be quite similar to that of the previous type, namely advanced courses in applied math and the engineering sciences, but in place of research the student would undertake one or more projects involving engineering design or planning or analysis of systems with a view of optimization. Again there might well be two degrees corresponding to the two levels of accomplishment.

The names of the degrees for these two parallel programs naturally should be different. For the first type, which is the one commonly offered by most of our universities and institutes of technology, we might retain the present names of Master of Science (MS) and Doctor of Philosophy (Ph.D.). For the second type I would suggest the designations of Master of Engineering (ME) and Doctor of Engineering (DE). Some schools now offer these four degrees but in most if not all of these cases with which I am familiar the difference between the programs leading to the MS and to the ME or those leading to the Ph.D and the DE are quite trivial. I think it is time that we recognize that there are these two different interests among students of engineering and provide these two avenues of training with a real difference between them.

One of the difficult problems involved in administering the second type of graduate program is that of securing competent teachers. They must be men who have had actual design or systems-engineering experience in industry or government. By contract, competent teachers for the research oriented type of programs need never to have worked outside the walls of an academic institution though I am sure they would be better teachers for some experience in industry.

I have discussed two points related to engineering education which are somewhat controversial and have tried to give you one man's thoughts based on many years experience in the field of education and some years of industrial experience. I offer these mainly for the purpose of stimulating discussion and not to "lay down the law" on what should be done. In fact I am going to confess that I still have an open mind on these questions and am as perplexed as anyone about what is our best course.

INTRODUCTION TO COMPUTER TECHNIQUE IN STOICHIOMETRY

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Needs for Computers

Many educators have seen the need for computer technique by the undergraduate chemical engineering student. This need arises from a number of sources. We have observed in recent years the extensive use of computers in such fields as research and development, where they are used for design of experiments to give the best statistical choice, and in many other applications. Computers have also come into wide use in plant design, where they are used for making tedious calculations as required for multicomponent distillations, rating of heat exchangers, optimization of design parameters, numerical solution of differential equations, and various other computations of this sort. We have also seen computers being used in such new engineering disciplines as systems engineering and operations research. Also, wide application is now being made in engineering economic studies.

There are very few engineering offices today which do not make use of computers. Some of the most conservative engineering offices are now acquiring computers, because they see that they are at a competitive disadvantage with those organizations which do use computers.

This has been due to the fact that computation jobs which were unthinkable in engineering a few years ago now have become practical. In minutes or hours, it is often possible with the aid of computers to accomplish calculations which used to take a man several months or years to complete.

Intimate Knowledge Necessary

As regards the knowledge of computers required of the chemical engineering graduate, it is the author's belief that a reasonably intimate knowledge of computers is necessary, if he is to be considered a professional engineer. Many have argued that intimate knowledge of computers is not required because the engineer can depend on professional computer operators and mathematicians to translate his engineering problem to a computer program. At first glance this sounds good. However, many times in actual practice the professional computer operators and mathematicians are too busy to give full attention to a given individual's problems. Then too, communications often break down and the engineer has difficulty in explaining what he is trying to accomplish. If he has an intimate knowledge of the computer, the engineer is much better able to communicate and to visualize his problem.

Moreover, a more intimate knowledge of the machine will give him a much better appreciation of its potentialities. Inexperienced persons are often awed by a computer and will blindly accept the machine answer as absolutely correct. Personal experience wmth a computer, however, will soon impress the operator with the general limitations of these machines. They cannot, for instance, rise to an occasion not provided for in their program. If, in the course of a computation, the machine must subtract two functions which have unexpectedly similar values, most of the significant figures will be lost, and an answer with no physical meaning will be furnished. Only an intimate knowledge of the physical parameters, as well as the machine's limitations, will give the necessary confidence to question a computer result.

Why Stoichiometry ?

Perhaps the first question that may enter our minds would be why pick stoichiometry as a means of introducing the chemical engineering student to computer technique. As a matter of fact many educators propose special early training courses devoted solely to the topic of computers and not interwoven necessarily with other specific academic courses(1). Stoichiometry does lend itself as a medium by which the student can be introduced to computer technique. But it certainly does not rule out other courses for the same purpose.

First of all, stoichiometry is usually one of the first chemical engineering courses a student takes. This is generally given in the second or third year. The conventional stoichiometry course is characterized by incessant drilling in the performance of heat and material balances around chemical plants. The essence of the problem is always the same, but as the course proceeds, the computations become more complicated, tedious, and time consuming. The student may start with the simple conversion from mol composition of a gas to weight composition. Then he may take problems in heat and material balances around a natural gas or coal-fired furnace. Finally, the complexity of the problem may be increased until he is making a balance around something as complicated as a pig iron blast furnace.

In all these exercises the pattern of computation is the same. The only thing that changes is the degree of complexity. A general formula which might be used for all of these problems is:

$$\text{(energy in)} = \text{(energy out)} + \text{(accumulation)}$$

and

$$\text{(mass in)} = \text{(mass out)} + \text{(accumulation)}$$

With the current modern trend in engineering education to include more and more principles in the curriculum at the expense of practice and factual information, it becomes necessary for us to review the treatment of such subjects as stoichiometry, which has been strictly a drill-course. In essence, the only principles which the student has learned in this course is energy and material balance.

It was with this view in mind that the author decided to attempt introduction to computer technique in the stoichiometry course. The problems are of such a tedious and repetitious nature that they lend themselves to demonstrating the value of computers.

Tried in the Classroom

The author has had the opportunity on two different occassions to introduce computer technique in a stoichiometry class. A class term consists of ten weeks, in which there are eight contact hours during any one week. Two hours are set aside for lectures, and the other six are set aside as recitation-laboratory periods, wherein the students are allowed to work their problems under teacher supervision. This schedule was very amenable to the introduction to computers, because this extra laboratory time made it possible to teach the basic knowledge of the machine rapidly.

The IBM 650 was chosen as the computer for this course, chiefly because this was the computer with which the author was most familiar. Also, the basic machine language of the IBM 650 is relatively simple, and this type of computer is widely used.

An outline of how this material was presented to the class may be of interest. First of all, the author took the students through the conventional stoichiometry drills for about four of the ten weeks. In this time the degree of complexity was gradually increased up to cases such as oil and coal-fired furnaces. By this time the students also had such problems as equilibrium flash calculations.

At this point the students were given a furnace problem in which they were required to calculate the material balance using purely algebraic symbols and no numbers. This was a break with tradition since engineers are usually discouraged from doing problems by algebraic formulation. Rather, we were taught to go through logical numerical steps so that we could visualize the problem as we went. This also minimized the possibility of ridiculously great numerical errors. It can be understood that this algebraic approach was meant to condition the students for setting up the algorithims by way of computer programming. It was explained to them that the algebraic solution of one of these problems was one extreme, whereas the conventional numerical solution of these problems was another extreme, and that programming them on a computer would be somewhere between.

The students were then allowed one to two weeks for familiarization with an IBM 650. They were given the usual diagram explaining the input, output, the storage drum or memory, the arithmetic unit or accumulator, and all the various other essential components. Their interrelation and functioning were explained. The students were given an explanation of the operation code of the machine. Then they got simple problems in arithmetic with whole numbers, just to demonstrate the functioning of the equipment. This was followed by an introduction to floating decimals, and with this they were able to program simple material balances in which there was no chemical reaction. After this, they were able to make multiple additions and subtractions according to the directions of the streams in and out of the systems studied.

Iteration processes were introduced together with the use of index registers. This allowed the students to calculate, say, temperatures from vapor pressures by trial and error solution of algebraic relationships. Then they were given exercises in coding furnace-type problems with basic machine language. With the basic idea of programming somewhat mastered, the students were then required to use their knowledge of programming vapor pressure-temperature relationships in coding equilibrium flash calculations. These were complicated enough to demonstrate the utility of a computer in this realm. The students could well appreciate this because previously they had done an equilibrium flash calculation by hand and spent considerable time in trial and error calculations.

There was just enough time left in the course to mention such topics as compilers, but the author felt that the students had acquired quite a bit of know-how, appreciation,and competence in the application of computers to chemical engineering calculation.

Students Enthusiastic

The reaction of the students to this program has been one of enthusiasm. Our general feeling is that they take this as something new, exciting, scientific, and to their liking. This program in the stoichiometry course came as a surprise to them and they feel it is going to help them solve problems in the future. Also, the author has noticed that students feel that they have benefited from the course as regards training. They believe that they need this subject, that it is going to be useful to them, and that it is going to give them a more mature viewpoint toward the solving of problems.

This situation is further intensified by the fact that our students are on co-operative education and spend alternate 10-week periods working in industry and working in the classroom. Many of these co-operative students have been exposed to computers in their industrial work and have a mature appreciation of the need for computers. In a couple of cases the author has found students who try to teach him about the computer. These students had been actually working on programming or in some capacity related to the utilization of computers. In the case of many of these co-op students they know what they need in their engineering training. They cannot be fooled. They have been out in the world; they have seen what are being used as the basic tools of the engineers around them.

Teaching with Compilers Alone

Intimately involved in this discussion is the question as to whether machine language should be taught to the students or simply compilers, such as MAD, GAT, or FORTRAN. The author's opinion is in favor of teaching basic machine language to the student if time permits. It is felt that in this instance, time is not a problem. In the case of the IBM 650, the machine language is relatively simple. It does not take more than a week or two to familiarize the student with it. But compilers would have been covered more thoroughly had there been enough time. However, it was felt that machine language was more important for the student to learn, because it is more basic. Once the machine language is understood, and the student has a working knowledge of it, he can easily pick up the use of a compiler, but the converse is not true.

Also it is felt that the student should be as close to the machine as practicable, and learning the basic machine language first is one way of attaining this objective. This more intimate knowledge of the machine, as mentioned before, helps in the liaison between the engineer and computer personnel. If the practicing engineer's program written with a compiler does not work, he may then need an intimate knowledge of machine language for the debugging step.

Also it is believed that a knowledge of the basic machine language gives the student a better appreciation of the machine's possibilities in purely logical programs rather than algebraic computation programs.

Need for Experimental Knowledge

Tied in with this topic is the question of the need by the student for experimental knowledge of the computer. Is it sufficient that he be taught how to write programs in the classroom, or should he actually be able to get near the machine, and actually feed input information to the machine by pushing the proper buttons and sitting at the console, and actually operating the machine? Does he need to do all this? Well, it is the difference between experimental knowledge and abstract knowledge. When the student actually puts numbers in and gets numbers out of the computer, his knowledge and appreciation take on a new dimension. He gets a greater feel for the machine. To learn to write programs without getting familiar with the physical operation of the machine would be like a man studying the rules of football without ever having played the game or seen it played. Even though the student may never expect to become a professional computer operator. it is felt that he should get some minimum familiarization with the machine.

With this attitude it became necessary for the author to seek some means by which the student could gain this experimental knowledge. There was a Burroughs computer available on the premises of this institution not similar enough to the IBM 650 to use for experi-demonstration. Therefore, the author arranged for the local IBM sales office to give lecture demonstrations of the IBM 650 at local computation offices. During one term the facilities of the Chrysler Corporation were made available to us, whereby an IBM lecturer would use one of Chrysler's IBM 650's to give a lecture demonstration in the use of the machine. In the other term, the facilities of the Michigan Bell Telephone Company were used. The author believes that this is not the ideal way of doing it. However, this inter-cooperation with local industry has a beneficial effect on the students, on the educational institutions, and on the industrial concerns themselves. The author is very much in favor of inter-cooperation between industry and educational institutions in enterprises of this kind.

Value of Mental Training

It is believed the students not only benefit from this training because of the increasing widespread use of computers in industry, but also there is a certain inherent mental training that goes along with the indoctrination which the student receives. It introduces the student to a whole new philosophy of approach to problems. Most of us have been accustomed to attacking numerical computations by a kind of pragmatic, feel-as-you-go approach. When most people make complicated calculations, they find it hard to keep track of where they came from and where they are going. We tend to "muddle through" in our calculations. Now, with the introduction of the concept of writing flow sheets to represent a computation we have to think out the problem attack with logical exactitude. This opens up a whole new horizon in the general philosophy of problem solving. This particular contribution of computer technique to the education of engineers is of itself well worthwhile.

Future Work Planned

In future stoichiometry classes the author hopes to continue this work, which is necessarily of an experimental nature. One significant difference in the coming year is that we hope to switch from the IBM 650 to the IBM 1620, chiefly because the 1620 replaces the 650, but also, this institution has acquired an IBM 1620 which will be available for use. Whether the increased complexity of the IBM 1620 will force an abandoment of basic machine language is yet to be determined. We hope to assign a limited number of problems, which the student can actually solve on the machine. The IBM 1620 is part of the equipment in our newly formed computer center. This will guarantee that competent computer personnel will be available to assist various teachers who wish to introduce the use of computers into their course work.

Serious study is also under way by various segments of the faculty to provide introduction to computers at the freshman or sophomore level. One possibility is to give the students a course under a computer center mathematician, but because of the squeeze on the engineering curriculum this would probably have to be a one-semester-hour course. Also, the Engineering Graphics department is making an effort to introduce freshman and sophomores to computers during their regularly scheduled engineering graphics courses. They are covering the use of the analog, as well as digital, computers. Such steps as these, it is hoped, will eliminate the need for basic computer instruction in stoichiometry and allow time for study of more advanced problems.

Other Courses

We hope that we will be able to integrate the use of computers, analog, as well as digital, in all courses where applicable computations are involved. It is a tool which can be applied to other diciplines and more difficult calculations that will come along in the later courses. This is in keeping with the findings of Dr. Katz and co-workers in the computer project at the University of Michigan(1).

(1) Katz, D. L. , Organick, E. I., "Use of Computers in Engineering Undergraduate Teaching," Journal of Engineering Education, Vol. 51, no. 3, pp. 183-205, December 1960.

THE ROLE OF HUMANITIES AND SOCIAL SCIENCES IN CHEMICAL ENGINEERING CURRICULA

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Introduction

It is now clear that we are living and may continue to live for decades in an era of continuing peril in which our culture or way of life, democracy, freedom, and many other human values we hold precious, face the real possibility of rapid destruction or of slow, insidious erosion. The ominous inner threats of complacency, ignorance, anti-intellectualism, purposelessness or despair, materialism, conformity, and immoral, selfish, irrational and irresponsible behavior coupled with the external threat of world communism, unchanging, "single-minded," and pathological in its dedication, yet devious and strategic in its methods, require an immensely greater commitment of our intellectual and material resources to meet the challenge than most seem now prepared to make. Freedom is being lost not because it cannot be defended or because we cannot defend it, but because we are not defending it effectively. It seems axiomatic that the outcome of this struggle will depend on the "balance of (1) human commitment and (2) disciplined creative intelligence brought to bear." [1] These are matters of education and suggest a serious re-examination of educational objectives, methods, and processes in the home, public schools, and universities.

I believe universities in our culture have been achieving increasing effectiveness in developing intellectual capacity -- power in clear, critical, creative thinking and in technological or scientific and engineering competence. However, many of our students are not adequately challenged and there still remains much sub-university activity in many university programs. Too many programs are information or technique-centered. Also much has to be learned in the art and science of encouraging creativity.

Although there is much room for improved performance in the development of disciplined creative intelligence, our most serious and conspicuous shortcoming or weakness is insufficient effectiveness in developing human commitment to greatness in discovery, engineering and other service to human well-being and progress. There are still too many intellectually able individuals who are not preparing themselves by appropriate formal education and otherwise for the highly creative contributions to society of which they are potentially capable. Furthermore, too few of those who complete suitable baccalaureate or graduate degree programs are deeply committed to great causes.

Human commitment is a consequence of human values, one of the principal concerns of the humanities and social sciences, and these we have not so successfully or, at least, not so wisely influenced.

In discussing values, we may refer to the conditions or activities which we feel affect our well-being [2] or to the intensity of feeling in consequence of our evaluation of the impact of a condition or activity on our well-being.

Values vary from the highly positive sought by the individual to the negative avoided by the individual. Values are developed by experience or the individual's interpretation of experience. They do not necessarily conform to reality. But, most important to this discussion, our values do govern our behavior. Values have been referred to as our ultimate concerns, the real determiners of our action. The values of concern in this discussion are those contributive to greater self-relization and personal well-being and to the progress of man such as knowledge, understanding, discovery, self-mastery, integrity, morality, excellence, service to great causes, progress of mankind, and freedom.

It is customary in our democratic universities to provide a comprehensive environment for the free, unprescribed development of values by each student. The objective is to provide the student with a rich broad experience in scholarly examination and evaluation of the answers to vital issues of the past and the present, from which it is intended he will acquire wisdom and personal values and perhaps perceive new values more supportive of fuller individual and general human realization. Ultimate values appear to be difficult for man to agree upon and universities are reluctant to inculcate human values. However, universities do implicitly or explicitly support to varying degrees, values such as integrity, knowledge, scholarship, understanding, discovery, and morality. I believe most feel

> (1) that among its responsibilities the American college should include a conscious concern for the character of its students; (2) that it is not desirable to separate the training of the intellect from values which impinge on the life and thought of the student; (3) that basic convictions and values are formed in the early years and primarily in the home, but the college can modify convictions and values both for good and for ill.[3]

Values supporting character and service to great causes automatically generate drive to achieve intellectual excellence, including engineering excellence. It seems, at present, most urgent to adopt values we perceive most valid and pertinent to preservation of freedom, those supportive of character and commitment to human progress and to encourage explicitly their development with all the energy and intelligence we can bring to bear in order to preserve the very freedom to adopt ultimate or more meaningful human values as we may discern them.

Human values are a major concern of humanities-social science programs which are designed to provide a broad stimulating environment for the development of values supportive of the well-being and progress of mankind.

The subject matter commonly included in the humanities concerns the arts--music, painting and other fine arts, literature, language arts, logic, history and philosophy. The social sciences include economics, political science, and the behavioral sciences--psychology, anthropology, and sociology.

In the past (and, at present, to a certain extent) many practicing engineers and some professors of engineering have not been convinced that the humanities-social science programs should constitute an important part of the undergraduate engineering program. A more generally favorable attitude appears to be developing, presumably in consequence of an increasing awareness of

1. the sobering impact of technology on society,
2. the increasing responsibility placed on engineers for leadership,
3. the direct contribution of humanities-social science programs to engineering excellence; development of capacity to understand and deal effectively with others, deeper dedication, improved engineering design (design for safety, compatibility with desirable human response, etc.[3a]
4. the experience in observing the healthy impact of effective humanities-social science programs on engineering students,
5. the obvious urgent need for more responsible citizenship and greater commitment to noble human values.

Technology, Engine of Social Change: Technology (science and engineering) is commonly considered the "engine" of social change. The profound influence which the products of technological advances, for example increased lifespan (especially in underdeveloped countries), the automobile, jet aircraft, radio and television, rockets and nuclear weapons have had and will continue to exert on our social, economic and political activities and organization is evident and has been widely discussed.

In general, technological advances provide stimulus and opportunity for advances of mankind to enriched, more meaningful human living by providing, for example, means (devices, time, etc.) for new and broader human experience, for more education, for creative individual and group activity contributive to improved social, economic and political or cultural conditions, increased time, energy and facilities for research into the fundamental nature of man, other forms of life and the physical universe and for other means for more meaningful living. Our values have not been motivating to take full advantage of these opportunities for human progress in knowledge, understanding, and creative living.

For the first time in history a society, through technological progress, has achieved for the great majority of its people relief from excessive physical toil and, at the same time, satisfaction of the basic material human needs -- food, clothing, shelter--and in addition, undreamed of uncommitted time and means for pursuance of his other values.

Unfortunately material success has encouraged values incompatible with great human living and progress. All are witness to the effect of material opulence on human values. The variety and abundance of material things and frivolous entertainment available to all have developed these as the major values for many, and time and means are too often employed in self-indulgence rather than in contributions to individual growth and general human progress.

In the minds of too many, material wealth is success. Luxurious homes, automobiles, clothing and capacity for self-indulgence and consumption of material goods have gained highregard or value. Consider the large proportion of our national effort or energy now devoted to luxury in transportation, homes, food, and clothing and to frivolous or trivial entertainment; and on the other hand, consider what might be accomplished by devotion of much of this effort to research into the nature of man, life and the physical universe, and other endeavor contributive to human progress. Material wealth, which frequently accompanies great contribution to human progress, has become the ultimate concern or the motivating value of too many in place of greatness itself.

With technological advance, a large portion of our society has lost identification with the product of their efforts, pride in its excellence and meaning in the job. The job has become merely a means for off-the-job satisfaction of needs, too many of which are basically trivial. Unfortunately, a large percentage of the graduates from engineering programs appear to have this concept of work rather than as an opportunity for dedicated creative service. The causes of the latter development should be of grave concern to engineers and their employers.

With respect to the future for example, the impact of automation and concomitant elevation of job competence to the point where a large segment of our society may not have the required capacity for effective technological service, may require major economic and social adjustment. The trend to "town-meeting" government in effect, through television public debate and the growing possibility of a return to "town-meeting" government in fact with personal living room voting machine identification, radio transmission of votes and machine tabulation, make preparation for greater individual responsibility in government an urgent social and political problem. Great political, social, or economic sophistication was not usually required to cope with local community "medicine men" of the past. The national master television "medicine men" in our present-day living rooms influencing our values and opinions is another matter.

Pages could be devoted to speculating on what the future holds. One thing is certain, barring human disaster, technological discovery and development will be greater and more dramatic than any now foreseen and the accompanying social and economic changes may be equally dramatic and profound. With wise preparation and guidance, the future of mankind can be great.

Chemical Engineers in Executive Function: An increasingly larger percentage of technological decisions which effect so profoundly our economy and social structure are being made by engineers. An ECPD publication indicates that 34 per cent of all engineers acquire high executive responsibility and that 40 per cent of all executives are engineers.[4]. A few years ago, half of the vice-presidents and over twelve board members of Standard Oil of New Jersey and 90 per cent of Union Carbide top executives were reported to have engineering training. Of the seven top Atlas officers, three were engineers, three were chemists, and one was a lawyer [5]. Howard S. Bunn, a chemical engineer who became president of Union Carbide in 1958 and vice-chairman of the board in 1960, reports that in mid-1960, 46 per cent of the chemical engineers employed by this company had management responsibilities [6]. At present, (1962) the presidents of the Standard Oil Company of California, the American Oil Company and the du Pont Company are graduates of chemical engineering programs to name a few.

Chemical engineers, in consequence of uniquely broad and fundamental learning in both science and engineering, the key role played in a large percentage of technological advances, and capacity for understanding most technological developments, are uniquely qualified to interpret science and engineering to their fellow citizens, appraise them of the nature and material implications of technological developments, and serve as competent and wise counselors in a technological age. Also, on the average, the chemical engineer has unusual intellectual capacity, and modern chemical engineering education is fashioned to develop power in clear critical thinking in analysis and synthesis, thus making the chemical engineer potentially a very effective and much-needed member and leader in modern society.

> The engineer is a responsible professional man, whose every professional act has human and social consequences.

> Whether he is aware of it or not, he is instrumental in the creation of a new society and a new economic order, as well as a new physical environment. One result of his professional accomplishments is that he is being called upon to accept an increasingly responsible role as a leader in his community.
>
> To meet his growing responsibilities and to realize his capacities as a human being, the engineer needs both professional competence and a broad understanding of himself and of the world in which he lives [7].

It would seem obvious that engineers as responsible, effective citizens, as professional engineers, and especially as executives who make major decisions affecting our society, need the best possible preparation in knowledge and understanding of mankind, his potential and aspirations and factors contributing to personal well-being and the progress of man, and values consistent with these.

The chemical engineer both as a responsible and respected citizen and as a creator of technological change deserves the best possible education to dedicatedly and competently include or integrate social as well as technological factors into designs and all other decision making.

Objectives of Humanities-Social Science Programs

The philosophies of most university general education programs are related to the Socratic theme "the unexamined life is not worth living." or better, "the examined life is worth living."

> In the four years of continuing enlightenment, every course, every professor, every campus activity should make a contribution in its own fashion and degree to the examined life which now is worth human living. The result may be the beginning answer not merely to Who is man? but to Who am I? The educated student emerges with a sense of what it really means to be a human being [8].

In general, the objective of all humanities-social science programs is to prepare the student for enriched, purposeful living which will contribute a maximum to the well-being and advancement of the individual and of mankind. Such living is dependent on (1) knowledge, a thirst for knowledge, and ability to acquire or ferret out pertinent facts and principles; (2) power in clear, critical, imaginative thinking (analysis and synthesis) to deduce meanings, vital principles, and arrive at sound conclusions and decisions from the facts and principles; and (3) values motivating or committing to living in accord with the implications of the facts and principles and in the interest of the advancement of mankind. The objective as suggested here includes the development of wisdom, attitudes, and values contributing to the noblest character defined as

> ...intelligent direction and purposeful control of conduct by definite moral principles. Thus, character is found in action based on principles rather than pressure or expediency. In this sense, character is reflected in the conversion of commitments into consistent application to the complex and varied

activities of life. The word "moral" is used to connote excellence in practice or conduct [9].

The Hammond Report lists the following more specific competences which the engineering student is expected to acquire in humanities-social science programs.

1. The understanding of the evolution of the social organization within which we live and of the influence of science and engineering on its development.
2. The ability to recognize and make a critical analysis of a problem involving social and economic elements, to arrive at an intelligent opinion about it, and to read with discrimination and purpose towards those ends.
3. The ability to organize thoughts logically and to express them lucidly and convincingly in oral and written English.
4. An acquaintance with some of the great masterpieces of literature and an understanding of their setting in and influence on civilization.
5. The development of moral, ethical, and social concepts (and values) essential to a satisfying personal philosophy, to a career consistent with the public welfare, and to a sound professional attitude.
6. The attainment of an interest and pleasure in these pursuits and thus of an inspiration to continued study [10].

Some other more or less related objectives are frequently stated:

1. Free the student from slavery to the contemporary and the narrow, and broaden his perspective so that he can interpret life and humanity in terms of the broad expanse of history and the entire spectrum and depth of human knowledge.

2. Give the student a deep understanding of and capacity to live within the freedom-responsibility relationship.

3. Develop in the student an understanding of and commitment to the concept that living for the maximum personal well-being is coincident with living for maximum contribution to society and human progress, that truly "getting the most out of life" is, in fact, giving the utmost to humanity. The success of democracy is dependent on this concept.

4. Develop a sense of mission or commitment to a great cause.

5. Broaden capacity for critical creative thinking, discovery, analysis and synthesis, by giving the student experience in these activities in areas other than the physical sciences and engineering; reduce barriers to transfer of power in analysis and synthesis; aquaint the student with new concepts in analysis and synthesis.

Characteristics of Humanities-Social Science Programs [11]

Humanities-social science programs vary suprisingly. In general, they consist largely of formal courses and seminars in the humanities, including the arts -- music, painting and other fine arts, literature, language and logic, philosophy and history--and of courses and seminars in the social sciences including economics, political science, history, and the behavioral sciences -- psychology, anthropology and sociology. Under ECPD's 1961 statement of criteria for accreditation, accepted curricula should include at least the equivalent of one-half year's course work "selected from such fields as history, economics, government, literature, sociology, philosophy, psychology, or fine arts" excluding "such courses as accounting, industrial management, finance, personnel administration or ROTC" [12]. Freshman English courses in which mechanics such as grammar are emphasized, are also not ordinarily included for obvious reasons.

At present, the humanities-social science course work content in engineering curricula in U. S. universities averages 13-17 per cent [13] and varies from about 1/8 (a frequent figure) to about 1/3 of the total engineering program. Part of the variation is due to variations in definition. ECPD recommends that 20 per cent of the engineering program be devoted to humanities-social science course work. Concentration of these courses in the first two years is most typical [14]. However, there are many five-year programs, including the 3-2 programs (three years at a liberal arts college followed by two years in a professional school) which provide for distribution of humanities-social science course work over three years and an increasing number of engineering programs which require distribution over the entire four (or five) years.

In approximately half of those universities responding to a recent survey [15] the student is given great latitude in selecting humanities-social science courses. At these institutions the student selects from a tabulation of courses in humanities-social science areas, many of which are especially organized for the program and which may be broad integrative courses crossing departmental boundaries. In some institutions, the student must include some well-conceived sequences in his program and in others some penetrating upper division (junior and senior level) integrating courses [16].

It is my opinion (and this is shared by others [17] that in many present university and engineering college environs, the student commonly makes his choice based on scheduling convenience or other trivial grounds with interest in the hours rather than in the educational content and, in some cases, simply because a course is considered a "breeze." This is not to say that these programs are necessarily unsuccessful--but if the student has complete freedom to select his course work, a university, and especially an engineering college atmosphere, strongly supportive of the humanities-social science program, is a requirement for success as is indicated later.

On the other extreme, at some institutions, courses are prescribed with little or not choice left to the student. In many programs, part of the course work is prescribed and part is selected by the student [18]. Courses, whether prescribed or elected, vary from conventional introductory courses to highly integrated, inter-disciplinary courses. The latter are a development of the humanities-social science movement and are designed especially to give those who do not specialize in the humanities-social science areas the most meaningful experience within the rather limited time and to provide a basis and motivation for continued study.

In a typical integrated humanities course, three to five great periods in Western civilization, in which most significant contributions to cultural development were achieved, are selected for study in considerable depth. The responses of great individuals and people to problems and forces as represented in their literature, fine arts, and philosophy are critically examined, in social and economic context, for inter-relationships, validity, meaning, etc., and also for contemporary relevance. Periods such as the Golden Age of Greece, and Rome, the Renaissance, etc., and literary works, for example, such as those of Sophocles, Plato, St. John, Machiavelli, Calvin, and Shakespeare, might be considered. Integrated courses in the humanities-social science area assist the student to gain a broader integrated vision of inter-relationships between the various arts and the social sciences and the factors that make people and nations great and those that cause disintegration and provide an excellent basis for more meaningful additional study.

Integrated courses may be aesthetically, culturally, or philosophically oriented but usually combine these approaches. Philosophically oriented courses may be restricted to one great issue such as human freedom. The same great periods and many of the same books, etc., used in a general integrated humanities or social science course might be used, but one great issue, human freedom, would be the central theme and concern.

In recognition of the present reality of world citizenship, Oriental cultures or civilizations are subject matter in many humanities-social science programs, and very appropriately so.

There is evidence that the most effective programs consist of an uninterrupted sequence of courses, each building on its predecessor, extending throughout the four (or five) years. These permit systematic development of concepts and adjustment of content and procedures to the increasing maturity of the student. Also, there appears to be virtue in an initial two-year prescribed sequence of integrated humanities-social science courses followed by two (or three) years of approved courses elected by the student to meet special interests he may have developed. A general integrated course is very appropriate for the mature senior.

Procedures which involve the student extensively in personal experiences and discussion are most effective. There is a trend to fewer lectures and more small-group discussions or conferences. In an interesting innovation, the University of Kansas chemical engineering staff members conduct discussions involving about a half-dozen students or so as part of a carefully outlined humanities-social science program.

Required attendance at the drama, symphony, great issues forums and debates is effective.

Starting about five years ago, a humanities-social science program was adopted for an undergraduate chemical engineering seminar at the University of Utah. In this program, sophomore, junior, and senior chemical engineering students attend the one-hour seminar each week and a minimum of 15 high-quality, cultural events during the school year. Many of the events are made more meaningful by having artists, for example, discuss and explain dramatic and musical productions, etc., prior to attendance. For instance, one of America's outstanding choreographers and teachers of ballet discussed the meaning of a forthcoming ballet and had one of his students, a member of the ballet troupe, demonstrate ballet routines. (I might add that his student was a pert young lady in the customary attire and, needless to say, very few students slept during this seminar.) On another occasion, an outstanding pianist in Salt Lake City to present a concert, discussed and illustrated characteristics of the great composer whose music he was going to use in the concert, before a joint chemical engineering-music department seminar. In addition to these "preevent" programs, the most outstanding scholars and creative individuals of the University of Utah faculty, representing all fields of scholarly endeavor, are invited to lead discussions and present lectures on topics including in most cases, research in which they are enthusiastically and deeply involved. Some most stimulating discussions are generated by these scholars. The great sense of mission, commitment to excellence and enthusiasm for their work and profession displayed by these artists and scientists from many areas make a deep impression on the students. These seminar presentations have, in many cases, been the subject of discussion among students sometimes for months after the performance.

Experiences with greatness through literature, music, history, or course work independent of the area of learning -- arts, sciences or engineering-- is a most important aspect of any humanities-social science program and especially if with the individual in person. Such experiences give the student an image of greatness, concepts of the ingredients of greatness (excellence, dedication, etc.), and the rewards of greatness which should stimulate the student to more purposeful living. Greatness breeds greatness!

Results:

There is little doubt that in certain areas of learning, carefully planned and skillfully and scholarly conducted humanities-social science programs are successful. Many present humanities-social science programs are effective in stimulating the student to the acquirement of knowledge in the humanities and social sciences and in the development of capacity for critical creative thinking (analysis and synthesis) and discriminating insight in the social sciences and the humanities. It seems clear that in many existing programs, students acquire intellectual capacity to arrive at intelligent decisions in the areas of the humanities and social sciences.

It is not nearly so clear that any of the existing programs are more than partially effective in stimulating students to make intelligent decisions and follow through with the indicated action. In other words, their values are not, in general, greatly affected and this seems especially true in the area of ethics, honesty, integrity, morality, character, and commitment to causes affecting the general well-being of mankind wherein immediate personal gain is to them not obvious.

1. Intellectual development, the acquiring of knowledge, and capacity in analysis, synthesis, and discrimination in the humanities and social sciences is significant as evidenced by written and oral examination. Students do acquire a more thorough knowledge of social science, the principles of economics, psychology, political science, the arts, music, etc., the history of their development and the interplay and influence of these in shaping history. They acquire knowledge of the attributes of man and insights into the nature of man's aspirations and potential. They become familiar with the great achievements of man in the arts and social sciences, the qualities, principles, ideals, or forces which played a vital role in the development of our culture; and understanding of the pertinent forces, principles and ideals or values and how they have operated in the rise and fall of nations and cultures.

2. They acquire increased skill in discerning the operation of principles of economics, psychology and morality, human values, etc., in the shap-

ing of history and can apply these to an increased extent in creating or prescribing solutions to personal and public social problems.

3. They do acquire capacity for fuller living. They can and do more knowingly, intelligently, and interestingly engage in discussions in the arts and social science areas. They have greater capacity for aesthetic experience, for critically and competently examining art, social developments, and other achievements of man on a greatness scale. In consequence of humanities-social science programs, many become actively interested in and participate in art events and public affairs, in some cases for the first time in their lives.

   Many students who take the music appreciation course at the University of Utah develop interest in fine music and become more or less regular participants in the symphony and other fine music presentations. Some University of Utah chemical engineering students become interested in the legitimate drama through the humanities programs. Since the adoption of a five-year engineering program with increased emphasis of the humanities and social sciences at Rice University,

   > ...there has been an increasing participation by engineering students in student affairs, notably in student government and in such activities as dramatics, service clubs, etc... An increasing number of students discover before completion of their undergraduate program that they have live interests in such things as literature, art, music, history, politics, etc. [19].

4. Good humanities-social science programs can have a desirable influence on performance of students in engineering course work. It has been frequently observed that through good humanities-social science programs, many students "come alive intellectually and professionally," become more discriminating, more intellectually curious, more committed to excellence and in some cases dedicated to a mission in life, and become "alive and creative intellectually in their approach to engineering"[20].

Although the foregoing indicates development of values in the arts (taste) for good drama, music, etc.) and, to some extent, in public responsibility on the part of engineering students, some studies of the influence of the university on student values or ideals are not so encouraging. For example:

> A study of what happens to the values of American students of today shows that their college experience barely touches their standards of behavior, quality of judgment, sense of social responsibility, perspicacity of understanding, and guiding beliefs [21].

Such reports should not discourage, for all of us are aware of many cases where students "find themselves" through a great teacher, class, a special project, etc. Many professors can be cited who seem to be very effective in developing a sense of mission in their students as judged by the record of post university performance. The unusual performance of graduates from certain colleges is further evidence that values can be and are changed by university experiences. We need to learn much more about how it is accomplished so that means to more general success can be developed and employed. On the other hand, we may not be employing means already available to full advantage [22].

Means for Strengthening Humanities-Social Science Programs:

The most important element in the humanities and social science programs is the development of values supporting character and service to the progress of man and, as suggested above, this appears to be the weakest link in these programs since our understanding of how, in terms of effective teaching and evaluating procedures, is not adequately developed. Many recent studies and conferences have been devoted to this task and progress is being made [23].

It is interesting to consider the potential outcome of an investment in research into the nature of man and human behavior comparable to our present and contemplated investment in space exploration!

A few means of strengthening the teaching of values and humanities-social sciences programs in general follow:

1. Strengthen the general university support of humanities-social science programs. The humanities-social science program and its objectives must be conceived not as a group of courses or as the responsibility of a college division but as a university undertaking superimposed upon the already existing structure and a specific responsibility of all colleges and departments. It must be considered an integral part of of professional education. The general university atmosphere has a most significant influence on value development. Witness the identifying characteristics of Harvard, M. I. T., and especially Reed College graduates, to name a few. A general university atmosphere and tradition which embodies or emphasizes broad insightful learning and the highest standards in moral, ethical, and responsible social behavior and human aspirations, and has a built-in expectancy of student performance and behavior in accord with these ideals, stimulates and encourages the development of corresponding values in the students. This strong influence of college atmosphere, including expectance, was observed and emphasized in an extensive research study by Eddy and others [24].

University atmosphere is a summation of the effect of the surrounding university environment (physical, intellectual, and spiritual) and the values of the founders, present and past administrators, and especially of the staff.

> If, as our evidence seems to indicate, the faculty member plays such an important role in the development of the student, we need to know more about him. Where does he come from? Where is he heading? What are his motives, his attitudes, his values? If the student is silent, is it because the generation before him is even more quiet? Here is a project deserving serious study [25].

Care in the selection of new staff and education of existing staff can make a difference. University atmospheres change slowly and not without superb effort on the part of those concerned. But university atmospheres have been and are being upgraded. Many of the important factors have been identified and thus many means for upgrading are available [26].

2. Generate a more strongly supporting atmosphere in the engineering college. The college of engineering staff, especially, must value and be actively committed to the objectives of the humanities and social science

program. For the program to be successful, the student must come to regard the humanities and social science course work and program in general to be a main-line constituent of the engineering program and the development of this concept is importantly dependent on the engineering college staff attitude. According to the report on the ASEE humanities-social science research project, it must be recognized that "Literature and philosophy and social organization are, like science itself, basic concepts of human activity in which depth of understanding provides the only sound foundation for the student's further growth." [27] The engineering staff must, in fact, regard the humanities and social science stem to be a vital constituent of engineering education.

> The sober truth is that the attitudes of the engineering faculty communicate themselves to the engineering students. ... At institutions where the engineering faculty displayed a sympathetic understanding of the humanities and social science, student resistance to the program was at a minimum.
>
> This whole matter of atmosphere, difficult though it may be to pin down, is of central importance in education. ... Perhaps it is not too far-fetched to say that the college environment conditions the future intellectual development of the young man in the same way that the home environment conditioned his emotional development as a child. In both instances, the basic attitudes of those around him are communicated indirectly, by subtle signs and clues dropped in the course of conducting quite ordinary affairs. If the engineering faculty are to hope for a maximum return from the time invested into a humanistic-social program, they must help provide a climate of opinion congenial to all serious intellectual inquiry [28].

The student in class, and especially through personal contact, senses the values and attitudes of the staff and tends to adopt them. The real message or meaning of a superficially innocent statement such as "See if you can find a three-hour humanities course to fill that spot," is sensed by the student. Staff regard for the humanities and social science program can be improved by careful staff selection and education through joint humanities-social science staff-engineering staff seminars, committees, etc.

3. In further support of the humanities-social science program, institute humanities-social science teaching as an explicit function of the engineering staff to be achieved as a concomitant and in integrated part of engineering course work. As suggested in the foregoing, concomitant learning or acquirement of values through staff "aside" comments, behavior, attitudes, classroom procedures, standards, and other revelations of staff values, is occurring in the engineering course classroom and in other student-engineering staff contacts. In the development of values such as integrity, ethics, and morality--character--the staff play a very important role.

> Indeed, one of the largest forces for developing a sense of dignity and integrity will build up from within the speciality. Moral and ethical attitudes, for example, are rather more likely to develop from the codes of fellow scholars in the speciality than from sermons delivered in general courses [29].

By insisting on, demonstrating, and encouraging the highest standard of morality, ethics, honesty, integrity, and responsibility in all student contacts (we cannot "let our hair down" in some areas) these values are developed in the student. Also, in the area of motivation, for example, staff interest and enthusiasm for research and passion for learning in engineering (and in the humanities and social science areas) is contagious, as I am sure most of us have had personal occasion to observe. The history of engineering, historical background, and technical and social significance of science and engineering discoveries, for example, can often be very effectively introduced into engineering course work and with gain in technical achievement. The engineering staff should be explicitly selected for their potential extensive and healthy influence on students. Through staff conferences, discussions, committees, etc., the staff should be encouraged to be meticulously careful to reflect through their behavior only the highest moral values and interest in the humanities and social sciences. Also, explicit and calculated means should be introduced into engineering courses, procedures, and subject matter, to show relevance of the humanities and social sciences in engineering and great living and especially to develop character and commitment to causes vital to human well-being and progress.

It is important to note that the major conclusion of an investigation conducted by Eddy and others was

> ...that the college's unique and best contribution to character is a direct product of a properly balanced emphasis on learning. We found that the conditions conducive to the development of character are, in many ways, the same ones which are conducive to good teaching and sound learning. In similar fashion we would hold that the elements in the campus community which encourage character are those which also encourage learning [30].

It is suggested that each engineering college or engineering department organize a committee consisting of engineering college staff, humanities and social science area staff, and education college staff to develop more effective classroom and counseling procedures supportive of the humanities-social science program objectives including strong character and dedicated, creative living.

4. Increase the extent of course work in humanities-social science area by adoption of a five-year engineering program. In many cases, effective humanities-social science programs have been developed by adopting a five-year program. However, some five-year and 3-2 programs are believed to be no more effective (some less) with respect to the objectives of humanities-social science programs than are many four-year programs. The ECPD research project committee reported the evidence to be inconclusive [31].

5. It is suggested that engineering curricula be re-examined to determine if the objective might be better achieved by changing and/or dropping some course work to provide additional time for humanities-social science course work.

In developing a university curriculum, the objectives in terms of the information, intellectual qualities, and values or ideals to be acquired by the student must be first clearly defined and explicitytly stated. Next, the procedure, namely,"the how, wheres, and whens" can be outlined as far as possible. Course content and teaching methods are selected explicitly and clearly to achieve most effectively the objectives. Information and activities which do not contribute to the objectives are excluded. It is my experience that such procedures have not been generally followed and that, worse, few departments have provided means for continual discussion and re-evaluation to insure that all staff members are aware of the general objectives or the specific role assigned a particular class in the achievement of of the objectives, and to insure that objectives and means for achievement are continually revised to conform to increased knowledge and wisdom. Some of the courses of action which have been taken or which might be taken in accordance with the findings in a re-examination of an engineering curriculum follow:

(a) Some engineering schools are dropping or making elective such courses as business law, accounting, engineering economics, business administration, speech and report writing [32]. The functions of some of these courses such as, for instance, speech and report writing and economics, may be integrated into humanities-social science and engineering course work.

(b) Many freshman composition courses are not humanities courses since the major concern is with the mechanics of writing. It is suggested that competence in the mechanics of writing--grammar, spelling, punctuation, etc.,--be made an entrance requirement. (Those not competent in the mechanics of writing may be required to take remedial non-credit course work.) Restructure the freshman course as a university-level course in the language art of effective communication, as many have suggested [33]. Or, devote the freshman composition course credit hours to the humanities and social sciences and make the development of power in communication an integral part of humanities, social science, and engineering course work. M. I. T. makes writing an integral part of the first and second years, good mechanics thus being assured. In any case, increase the extent of writing and speaking in engineering course work and insist on the highest standards in mechanics and in communication effectiveness in all written and oral work, including examination. Base the grade in all engineering course work, to an important extent, on the quality of communication. To insure continued emphasis on the mechanics of writing, the Chemical Engineering Department at the University of Utah has for several years employed English Department instructors and, more recently, a retired English teacher to grade student reports for mechanics. Up to 50 per cent of the report grade may be determined by the quality in communication. This approach is effective.

(c) At some schools a specialized approach in technical course work has been replaced with a more general and fundamental approach and with a significant saving in time.

(d) The elimination of unnecessary duplication, for instance, in physics and engineering mechanics has been a means of saving time.

(e) Experimentation with integration in engineering course work as a means of saving time has been suggested [34].

Summary[*]

Effective humanities-social science programs are supportive of excellence and greater achievement in engineering course work.

They are successful in achieving intellectual objectives such as increasing knowledge of humanity and capacity for critical, creative thinking, and arriving at sound conclusions in humanities-social science areas. However, more effective means for the development of compelling values - stronger character - supportive of ethical, moral, responsible behavior including service to humanity and commitment to great causes must be found or developed and reduced to practice. Humanities-social science programs are also successful in achieving aesthetic objectives.

The most effective humanities-social science programs are likely total university undertakings which consist not only of course work in the area but include general campus activities and especially activities and policies in the department of specialization explicitly conceived for strong support of the humanities-social science program objectives.

The values of staff members, especially in the department of specialization, have a very important influence on student values. Staff selection and education to support the objectives of the humanities-social science program are suggested.

Our nation's presidents have called for increased spirituality. To me, spirituality includes a sense and concept of purpose in the universe, a sense of mission in life; <u>ultimate concern</u> for the well-being of mankind, that is, compelling values in service to great <u>causes</u> basic to the well-being of humanity and to human growth. Freedom, the discovery of facts and principles in science and engineering, engineering achievement (new materials, structures, devices) enabling more significant human living, broader human experience, greater efficiency in human endeavor, relief from disease, malnutrition and sub-human activity are such causes. Every humanities-social science program should have at its core effective elements for the development of greater spirituality, a requirement for realization of great human progress and preservation of freedom.

The progress of humanity, with freedom as a basic condition, must become an individual and national purpose. In this, university humanities-social science programs can play a vital role.

[*] For extensive presentations of the philosophies, objectives, nature, specific examples with details, and evaluations of the wide variety of humanities-social science programs see especially references 7, 11, and 35.

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Ethics for Chemical Engineering Teachers

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The title of this essay is not intended to imply that chemical engineering teachers should subscribe to some unique code of ethics; or even that chemical engineering teachers differ in their ethical practices from other chemical engineers or other teachers. Instead it is a recognition that this group, like any other group, has its particular interests and activities, and so differs from other groups in its relationship to a broad and general code that covers all engineers, all teachers, or even all civilized people.

The very broadest code of ethics, for all Christian people, has been laid down in the Golden Rule and the Ten Commandments. Other religious faiths have corresponding statements, generally similar but not identical. Recognition of some such code, and an honest attempt at adherence to it, is one mark of a civilized person. Another mark is respect for the codes of other groups, although such respect need not include approval and emulation in all details.

But, in the complexities of modern civilization, these very broad ethical principles are not enough. Any professional man who takes his responsibilities seriously, be he in medicine, theology, law, engineering, or something else, welcomes a specific code to cover his own area. The Canons of Ethics for Engineers, prepared by Engineers' Council for Professional Development, present such a philosophy and principles. More specifically, the American Institute of Chemical Engineers publishes a code of ethics as a fundamental part (Article VIII) of its Constitution.

An A.I.Ch.E. subcommittee, under the chairmanship of R. P. Dinsmore, is preparing a commentary on ethics for the chemical engineering profession. The first paper, for the teaching group, is published at this time to provoke discussion.

All chemical engineers, including teachers, are expected to guide their professional activities by these rules. In order to keep this code under continuing review, to interpret and clarify it, and to prevent any tendency toward stagnation, A.I.Ch.E.'s Professional Development Committee has established a special subcommittee on the Background of Professional Ethics, under the chairmanship of R. P. Dinsmore. The author has the specific assignment of "University Professors," and will devote the remainder of this paper to that topic. The manuscript has been reviewed by the subcommittee, but has not been formally approved. It is published here in hopes of provoking further discussion and criticism.

Special Features of Teaching

Many professional codes, after general statements on integrity, justice, and courtesy, are subdivided into such sections as relationship to the public, to the employer or clients, to employees, and to fellow engineers. Perhaps a similar classification or interpretation of the general codes is in order for teachers, particularly in this exploratory paper. Let us investigate the chemical engineering teacher's ethical relationships: to his students; to his department head, dean, and other officers; to his teaching associates; to other engineers; to the public; and his ethical obligations as an individual. Some of these topics pertain to a broader base than chemical engineering teachers alone; such will be covered but briefly in hopes of inspiring further study and writing by those most interested.

Relationships to Students

The primary duty of teachers is to teach; hence the principal obligation of the teacher is to his students. This is quite apparent for the teacher who does nothing else; it is just as true for those who engage in research, writing, administration, consulting, or any of the other duties usually expected of good teachers. All of these are subordinate to the teacher's responsibility to his students.

The first responsibility to the students is to provide good teaching. Obviously the teacher should know his subject matter thoroughly, and he should use the most effective teaching techniques. He should keep up to date on chemical engineering technology, and on pedagogy, by all possible means including reading, attendance at meetings, responsible consulting, and research. Each time the teacher meets his class, he should be as thoroughly prepared as possible—even prepared to handle the unexpected question or situation which he did not specifically anticipate. Inadequate preparation cannot long be concealed from the student, and is a disservice to him.

A second obligation of the chemical engineering teacher to his students is the courtesy of sympathy. It is frequently the teacher's duty to chastise his students for poor work by low test grades, failing term marks, or even expulsion from the university. Most students, even after severe discipline, are willing and eager to accept advice, even though this may be directed toward the student's future outside of engineering or away from further academic training. It is the teacher's duty to advise, to the best of his ability, students who need minor discipline, or repetition of a course, or transfer to another field of study or to a job without further study. This form of sympathy and recognition of the student as a fellow human being, though possibly not as a future chemical engineer, may be particularly difficult for the younger teachers who lack experience with other people and who are overly engrossed in the technical aspects of their profession instead of the humanitarian.

A necessary qualification of the chemical engineering teacher is the ability to make decisions, and to stand by them unless they are proved to be in error. In the American manner of education, the teacher must "grade" his students at regular intervals, based on individual papers, recitations, assignments, and a cumulation of all these. Although the good teacher has some degree of personal relationship with each student, his grades must be as objective as he can honestly make them. The grades should not thereafter be changed because of special pleading by the students, or for unrelated circumstances.

This is not to deny that a grade may be changed if the instructor has made an honest technical error. A mistake in grading, particularly if it applies to a large segment of the class, may call for an apology, and usually some correction of the grade. Both younger and older teachers may find this difficult: the younger because they are building their reputation and resent any admission of an error as a slur on their ability; the older because they have made most of the possible mistakes that can be made, and now hold themselves beyond the possibility of error. Fortunately, most teachers fall into neither of these categories.

To the best of his ability, the chemical engineering teacher should strive to impart not only technical knowledge but also some concept of professionalism. The dignity and value of engineering, the competence and integrity necessary in those who practice it, and the obligations and duties associated with it: all these can be brought to the students' attention.

Perhaps better than a formal lecture on the subject is the frequent and casual comment and, of course, the example. The implication here is that each instructor should be thoroughly imbued with a truly professional attitude.

In addition to the broad obligations listed above, the chemical engineering teacher owes special duties to particular groups. Graduate students, even though they are learning to be self-reliant, need advice on choice of courses, conduct of research, acquisition of equipment, preparation of seminars, and almost countless other topics. Seniors need guidance on the decision between graduate study or employment, and on individual opportunities within each category. The poorer students seek encouragement, or help in choosing an easier schedule, or even a different field of study. Personal advice cannot be forced on the students but it is often sought; it should be given honestly and respectfully.

Such subjects as politics, religion, and race do not customarily belong in the engineering classroom. They may be discussed with an individual student if they represent problems on which he is honestly seeking advice. The teacher, as a thinking individual, has the obligation to respect all sides of any many-sided question.

Responsibilities to the University

It is quite apparent that the chemical engineering teacher, like any other teacher, has a very considerable responsibility to the university, which provides his employment, furnishes his working facilities, and pays his salary. Some of the more tangible obligations are really responsibilities to the students, and have already been discussed. Also in the tangible class is the fairly general obligation to do more than teach: most teachers should also be active in research, writing, professional committee work, or perhaps all of these. Research should, when possible, be a balance of both fundamental and applied. The teacher should also expect to attend seminars, to serve on university committees, and to study and discuss all of the usual academic problems: courses, curriculum, student discipline, laboratories, and the hundred and one similar matters. A less tangible obligation is the requirement of loyalty to his university and to his department and college, and a reasonable amount of school spirit that is sincere though perhaps less uninhibited than that of his students.

Life on the academic campus is generally less rigorous than in an industrial organization. The department head, dean, and other administrative officers are not so much "bosses" as associates with lesser or greater degrees of authority. Nevertheless this authority must be respected, and the teacher's superior must be consulted and obeyed on all matters of administrative concern: office hours, contacts with individuals or organizations outside the department, sharing of facilities with other faculty members, absences from the campus, consulting work, political activities, and the like. Perhaps some of these activities do not require approval by the administrative officer, but the courtesy of keeping him informed is certainly obligatory.

Responsibilities to His Associates

The chemical engineering teacher's responsibilities to his associates are more in the nature of courtesies than obligations. Thus he is not obliged to prepare a "guest lecture" for another's class, but it would be a strange and unsocial instructor who would not gladly do so. Many academic problems can be solved, or at least alleviated, by discussions among the faculty of a department or school. These problems include new or untried teaching techniques, research bottlenecks, criticism of papers, student discipline, student guidance, and many other facets of academic life. The mature professor can be helpful to the younger in problems involving teaching and personalities; the younger can often be an inspiration to the older because of his enthusiasm, more recent technical training, and spirit of venture. It is foolish (not to mention unprofessional) for either to deride or overlook these different attributes of the other.

Research and writing are best conducted in an atmosphere of encouragement. Only part of this can come from the university administration; each faculty member has an obligation of this nature toward his professional associates.

Responsibilities to Other Engineers

All engineering codes of ethics include some discussion of the responsibilities of engineers to each other. The chemical engineering teacher is not immune from these matters of mutual concern; perhaps it needs to be called to his attention that he has such an obligation. Most important is that he should join with nonteaching engineers in their societies and activities, in order that he may be conscious of himself as a member of the profession, and that his fellow engineers may recognize his kinship and his differences.

Certainly any American chemical engineering teacher who takes his profession seriously is a member of the American Institute of Chemical Engineers, and participates in its affairs as actively as time, finances, and his university will permit. Probably also he is similarly active in the American Chemical Society, and most likely in the American Society for Engineering Education. Beyond these three basic associations, there are many others of specific interest. The teacher need not be merely a "joiner," but he should participate with other engineers to a real degree.

The teacher is no different from other chemical engineers in these responsibilities, but perhaps needs special reminding of them lest he hold himself aloof from the nonacademic members of his profession. He has much to offer them, and has much to gain for himself by stepping outside the cloistered walls occasionally.

Responsibilities to the Public

All chemical engineers have certain obligations to the public, the teacher perhaps more so than the rest. The public holds the engineering teacher in high esteem and, rightly or wrongly, holds itself entitled to bring to him its questions on all sorts of personal and business problems. Perhaps the teacher at a government-supported school receives the larger number of these inquiries, but they come to all. Within reason, the teacher should try to be helpful, thus continuing his teaching duties beyond the classroom. He should be particularly assiduous in this activity when matters of public or private health and safety are involved, when representatives of government request his technical advice, and when the press needs his engineering judgment. He should graciously refuse to answer questions that are not in his domain, or that are in areas in which he is not competent. He may reasonably excuse himself from persistent inquirers who demand unusual efforts or time on his part, perhaps referring such inquirers to a regular consultant, perhaps even to himself on a consulting basis. But it is his duty to be as helpful as he can without detracting from the obligations to his students and university, and without encroaching on the domain of the professional consultant.

Obligations as an Individual

The chemical engineering teacher has all the individual obligations of any responsible citizen in the community. Perhaps he should feel this obligation more deeply than most men, because an educator is looked up to as an example by his students, by other engineers, and by the public. His responsibilities in general are not different, but may be more significant.

Responsibilities of Administrators

The chemical engineering dean or department head has a special set of responsibilities to the faculty members under his jurisdiction. He must act as an administrator, just as the foreman or department superintendent in industry; but he must keep in mind that he is dealing with a different type of person. It is often necessary to refuse a request, but it is usually desirable to explain the reasons for it if possible. The university professor is rarely satisfied with an unreasoned and arbitrary pointblank refusal.

The administrator must give advice

and counsel to his faculty members, especially to the younger individuals. He may suggest teaching techniques and advise on grading policies and discipline. He may appear to be arbitrary at times in assigning teaching and nonteaching duties, but it should be assumed that the overall good of the department and university is in his mind as well as the needs and desires of his faculty. Course content, too, must often be defined rather closely, in order that the entire curriculum can be adequately integrated. Often such matters are debated by a faculty committee or by the whole faculty, yet final decisions must be made by an individual administrator.

Despite the desirability of the administrator's advising his faculty, he must also leave them alone to the degree that they can develop responsibility and initiative. To the greatest possible extent, the individual teacher should be free to plan his courses, choose his textbooks, schedule and formulate his quizzes, and calculate his own course grades.

Conflicts

Only the very simplest code of ethics, such as the Golden Rule standing alone, can be fully free from conflicts of interpretation. When codes multiply and specialize, increasing difficulties are inevitable. In general, the more basic code takes precedence over the more specialized; but each individual must study each problem situation as it arises, as honestly and as objectively as he can. The guidance of older engineers, of more experienced teachers, or even of official committees on ethics may be sought in particularly troubled cases. Journal articles on the subject of professional ethics should be required reading for all developing engineering teachers, in order that they may better judge the relative importance of conflicting (or apparently conflicting) codes.

Conclusion

The chemical engineering teacher has the same ethical responsibilities as other chemical engineers, as other teachers, as other citizens. He has a few special added obligations peculiar to his profession, and he must bear in mind that he is constantly on display to the younger generation as an example of true professionalism. That most of our teachers meet these responsibilities with enthusiasm and pride is a tribute to them and to their profession.

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