Symposium

ChE UNDERGRADUATE EDUCATION: PATTERNS TODAY- EXTRAPOLATION TO TOMORROW

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IN ORDER TO develop the most effective and efficient undergraduate educational programs it is necessary to pause occasionally and consider our present posture, evaluate what we see as the future needs and determine if we are proceeding in the proper direction. This type of analysis is particularly crucial in a rapidly expanding discipline such as chemical engineering which is increasing in scope and at the same time besieged with pressure both to reduce the required number of credit hours for graduation and expand the number of non-technical electives. Should our programs remain as general as possible or should each university develop its own special areas of emphasis? How should our instructional techniques be modified to take full advantages of new teaching aids such as "talk-back" T.V. systems and realtime computers? What modifications should be made in the traditional chemical engineering laboratories? Are we producing graduates which are in phase with the needs of industry?

THE FOLLOWING PAPERS were presented in a symposium on Chemical Engineering undergraduate education at the 68th Annual Meeting of the AIChE in Houston. Although there was insufficient time to review all of the aspects of our undergraduate educational structure, many of the important trends and projects were considered both from the standpoint of industry and its needs and the university and its goals.

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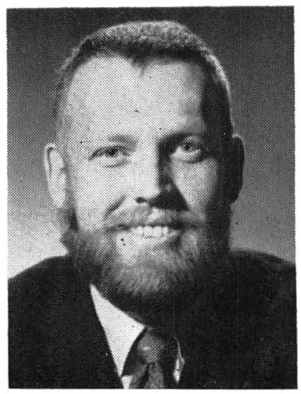

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PREPARING THE ENGINEER FOR HIS UNIQUE ROLE

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I am not here today to speak as an expert in undergraduate engineering curriculum, but as a chemical engineer in industry who has a strong interest in his profession. I have observed many newly graduated engineers begin their careers in industry and have developed some ideas pertinent to the role and education of engineers that I wish to share with you.

I will discuss two basic areas: first, a concept of the unique role of the engineer, and second, using this concept, important areas in the engineer's education required to best prepare him for this unique role. I plan to deal with this subjective and complex subject in a very simple form in order to concentrate on a few basic concepts.

AN ENGINEER'S ACTIVITIES require him to work in three basic areas (Figure 1). These are economics, mathematics and the physical

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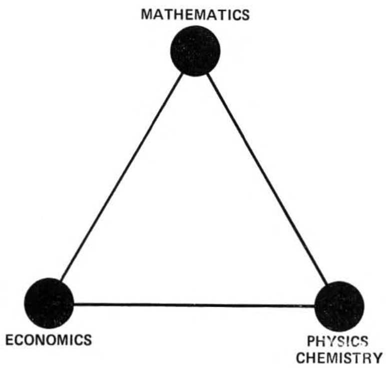

Figure 1

sciences. By physical sciences, I mean physics, chemistry, biology, etc. Of course, there are other activities in which an engineer must get involved. An example is the engineer's increasing involvement in the ecological and social concerns related to technology. Yet we can still consider that the engineer's *basic* role consists of the aforementioned three areas.

The engineer is not a specialist in economics, mathematics, physics or chemistry, for then he would be an economist, mathematician, physicist, or chemist. However, he is very knowledgeable and comfortable with these areas (Figure 2). He acts as a *translator* between these sciences and *relates* them to the physical world. This is the engineer's *unique role.* He is able to translate physical sciences into mathematics and into economics and vice-versa.

For example, a chemical engineer is able to

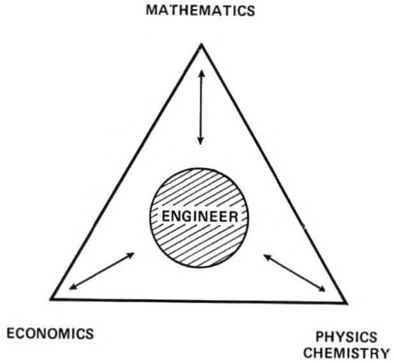

Figure 2

translate chemical reactions from the test tube into economical processing units. Here chemistry is related to physics as well as mathematics and economics. Neither a physicist, chemist, mathematician, nor economist is properly trained to do this job effectively, only a chemical engineer is uniquely trained for this assignment. He, however, uses the tools and expertise of these other professions.

A good engineer uses math as an invaluable tool for predicting results rather than relying on inefficient trial and error methods. Yet he does not work in the abstract alone. It is imperative that he also be able to *relate* his results to the physical world. He must be able to usefully apply his results.

A good engineer is also always conscious of economics and cost-benefit relationships. Feasible results can be meaningless unless they contribute to the goals of an organization, especially when these goals are economic. Even non-profit organizations want the best cost-benefit relationship.

If we could plot the course of the engineering profession on the previously mentioned triangular coordinates, I think we would find that it has shifted during the last 30 years, on Figure 3, a movement from "A" and "B". Whereas we

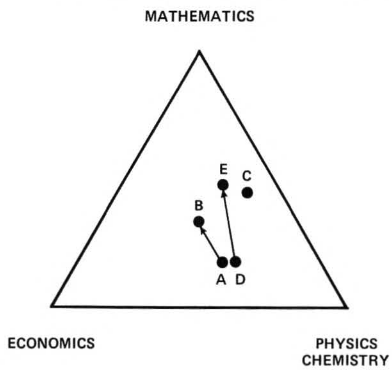

Figure 3

were once more closely tied to physics and chemistry and made use of correlation techniques, we now have become more mathematically and theoretically inclined and more conscious of fundamental understanding of the sciences. During this period, economics has retained its emphasis. Of course, we have become more sophisticated in all three sciences.

Continuing on our plot, I think we would find a typical researcher located somewhere near the line between math and physics/chemistry point C. A typical process design engineer would be near the center of the plot, point B.

Our engineering education institutions vary considerably on the plot. Some schools achieve a balance of these sciences, others are more mathematically inclined, while still others emphasize chemistry and physics. Few schools are strongly economics oriented. Industry needs engineering graduates from each of these schools with their various emphases. On the average, I think engineering schools have moved from "D" to "E" during the last 30 years, a direct movement toward a more mathematical and theoretical orientation. Economics has retained its minor emphasis.

WITH MY CONCEPT OF the engineer and his unique role, how can we best prepare students for the engineering profession? Of course a good foundation in physics, chemistry, mathematics and economics is essential. There is yet this other skill of extreme importance. That is, the ability to *relate* these sciences and to be able to *translate* between them. Today's engineering graduate is overall better prepared than any of his predecessors in the technical knowledge of the day. While his technical, analytical, and manipulative skills are being keenly developed. I believe his ability to translate and relate is not as sharp as that of some of his predecessors. How, then, does one develop this skill?

In dealing with this question, let me discuss some changes I have observed in undergraduate engineering curricula during the last decade or so which I believe have improved the engineer's education, but which I also believe may be weakening somewhat his ability to serve as the translator between the essential sciences discussed in this paper. These changes are primarily due to the very rapid growth of technology, the greater emphasis on theory and fundamentals, and the development of new scientific tools such as the computer. I will address myself to some changes in the chemical engineering curriculum with which I am familiar.

A good engineer is always conscious of economics and cost-benefit relationships . . .—uses math as an invaluable tool for predicting results . . . —is able to translate chemical reactions from the test tube into economical processing units.

Among these changes, courses in mechanical drawing and descriptive geometry at some schools for certain engineering disciplines have been dropped, quantitative and qualitative chemistry courses have been reduced, and laboratory courses in general have been decreased. The time spent in these courses was not as meaningful and valuable as it became when spent in new courses evolving from technology growth. Yet these courses had helped the student, in an inefficient way, relate his studies to the physical world. Descriptive geometry had helped him visualize concepts on paper, but a full year of mechanical drawing was not necessary. "Quan and qual" analysis had helped him physically perceive what he was doing with chemical equations and his slide rule, but two years of these courses and long labs were not efficiently using educational time. Still, such courses had helped him to *relate* and develop the skill of translating.

The unit operation courses and labs have been modernized, often reduced in scope, made more relevant, and in some cases displaced by theoretical courses. It is true that the student need not become an expert in "hardware." He has plenty of time to become expert if he chooses this area after he is in industry. But, an effective course in unit operations does help him *relate* his chemical engineering to the physical world and develop skill as a translator.

The general reduction of laboratory courses, along with other improvements, has allowed more efficient use of time and the introduction of valuable new courses. The new courses and laboratories that have emerged are more abstract. I refer to such courses as Applied Differential Equations, Transport Phenomena, and lab courses such as computer programming. Valuable as these may be, overall these changes have been a movement away from developing the skill of *relating* the sciences and *translating* between them.

In industry during recent years, I have seen new engineering graduates even with advanced degrees who have had a limited ability to visualize their problems, relate the various facets of the problem, recognize and define open-ended problems, and convert theory into practice. Many of these people had heavily oriented computing backgrounds. While technology is moving forward requiring new concepts and new tools like the computer, we must not overlook our objectives and become overly concerned with our new tools or new developments in pure science. We must be able to use these in *relating* and *translating*.

Years ago, a new engineering graduate might have received several years of apprenticeship before being assigned major responsibilities, so that the skill of translating and relating could even have been developed on the job. Today new graduates are given more responsibility earlier in their careers. It is not unusual to find a young engineering graduate in a large corporation designing a million dollar project after he has been on the job less than a year. So it becomes increasingly important that the translating and relating skills be developed during his education.

In developing the skill of translating and relating, I don't think you need long labs and "make work". The educator does need, however, to be sensitive to the importance of teaching his students to translate. Obviously a single course cannot teach this, but the coordinated efforts of all courses can accomplish it. Certainly some courses help the student acquire this skill more than others. Meaningful laboratory courses are very effective. The type of problems assigned in the courses have a significant impact on developing this ability. Relevant open-ended problems in which solutions can be related to physical results are very beneficial. Educators with industrial experience can be effective in developing meaningful problems. Plant tours, especially when associated with a problem-solving course, help students visualize their results. Well taught design courses are perhaps the most effective courses in developing the translating skills. Summer jobs in industry involving engineering applications are important to a student's development. The former co-op student who combined his education with industrial assignments invariably is superior to his colleagues in his ability to translate. MIT's well-known practice school has achieved good results. I am confident that creative faculties can develop many effective methods for developing the skill of translating and relating.

During the last decade as engineers have become more mathematically inclined a vacuum has been created in the area of economics. Accordingly, the MBA has moved in to fill this area, as

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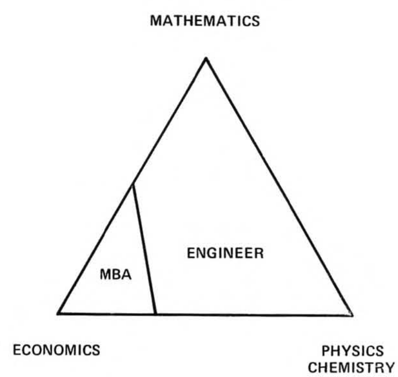

Figure 4

can be seen in Figure 4. Neither the engineer nor the MBA is as effective as the man who *truly* has the ability to relate both areas. A few courses such as Operations Research are sometimes included in engineering curricula, but the translation of math/physics/chemistry into economics has not had the emphasis or the growth as the translation between the other sciences. We normally think of the translation into economics as being unsophisticated and elementary. However, the work interfacing math and economics in recent years has proven to be quite the contrary. I refer to such subjects as optimization techniques, resource allocation, and economic evaluations. The engineer will not be as effective in the area of economics unless it is given more attention. The chemical engineer normally works in a capital intensive industry where capital, profits, and cost play a very important role, while such policy restraints as safety, pollution, and legal and social concerns are met.

If the engineer of today and tomorrow is going to fulfill the ever increasing requirements of his unique role, he must be better equipped to serve as the essential translator between economics, mathematics, physics and chemistry. To prepare him for this role, the student's curriculum must help him relate abstract problems to the physical world and translate results in different forms to other sciences. □