WHAT INDUSTRY EXPECTS OF THE CHEMICAL ENGINEER

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You have spent a week of concentrated effort on the content of courses in chemical engineering education. As a finale to this strenuous week of looking at the trees, perhaps it is well to take a few minutes to look at the forest.

Much has been said about the diverse occupations of chemical engineers and the wide scope of chemical engineering activities in industry. On the surface, the multiplicity of duties seem to elude classification. They seem to deny any simple statement of what industry expects of the chemical engineer and what should be his education.

The chemical engineer is one who realizes that local temperatures differ from bulk temperatures; that laboratory experiments are neither adiabatic nor isothermal; that a slender pressure vessel is cheaper than a fat one; that the heart of a control system is the primary signal; that mixing is not instantaneous. He knows that the container walls are part of a reaction system; that dq is not a perfect differential; that a major part of the cost of heat is the cost of transfer surface; that all practical materials contain minor and perhaps unknown impurities that can build up in a process or alter the reactivity of a catalyst or surface. He knows that problems of mechanical fabrication require a compromise with requirements of physical chemistry; that designs technically feasible are often unacceptable economically; that actual process plants are subject to leaks, mechanical failures and mis-operation.

The chemical engineer knows these things and many more. He has learned them partly from fundamental courses, but mainly from solving design problems in school and in practice. If he hasn't learned them, he's in trouble no matter how thorough his theoretical science.

Through all of these diverse bits of knowledge there is a thread of continuity, a unifying theme. That theme is process development and design. The career of the chemical engineer is process centered. He may be measuring transport properties, correlating reaction data, doing research on fluid mechanics, operating a pilot plant but always the goal of his team is new or improved processes.

Process design is much more than heat and mass transfer and reaction chemistry, more than a series of black boxes interconnected by heat and material balances the insides of which are the responsibility of some equipment supplier. Processes have become increasingly complex, involving more specialized hardware, more sophisticated control and advanced techniques of optimization. More and more players are on the team and the chemical engineer is the focal point of communication among them. He is required to understand and interpret the data and ideas of the chemist, mechanical engineer, instrument engineer, applied mathematician.

Now, let us look at the forest instead of the trees.

There appear to be two aspects to what industry expects of the chemical engineer. First there are the functions he is expected to perform, and second there are the attitudes he is expected to have.

As to functions, industry expects the chemical engineer to be able to participate in various parts and stages of process development and design. In some situations he is expected to be a specialist in those fields of knowledge that are traditionally identified with chemical engineering. He is also expected to be the generalist who brings to a focus the work of many specialists. The focus is a commercial process that will operate efficiently, safely and economically.

The chemical engineer doesn't have to be an expert in everything. We don't expect him to compete with chemists, mathematicians or electrical engineers. We hire organic chemists to synthesize new compounds, physical chemists to develop new catalysts, electrical engineers to design amplifiers and pulse generators, mechanical engineers to design tube sheets. But we do expect the chemical engineer to be able to talk to all these people, to understand their functions and above all to know how to use their help.

What does this signify for education? It means first of all, that the young man learning to be a chemical engineer must spend a large part of his academic career solving problems related to design, simple ones and specific ones, complex ones, and varied ones. The problems begin in engineering science courses for mechanics, thermodynamics, and transfer fundamentals and continue into courses specifically for design. But first he has to learn the fundamentals of physics, chemistry and mathematics, an array of difficult and demanding courses.

These requirements don't leave much room in the curriculum for courses with such labels as Biochemical Engineering, High-Polymer Technology, Ceramic Processes, and Cryogenic Engineering. What is needed is not a proliferation of novel courses, but rather that his science courses be up-to-date and that his concepts of the nature of the physical world be modern. We in industry can teach him biochemical engineering as applied to the biochemical process we are designing or high-polymer technology as applied to the polymer we are developing, and we can probably do it better than a college course since we are likely to know much more about our process or product than any author of a general text on the subject. But if to make use of a specialized cryogenic engineer we in industry have to teach him the fundamentals of thermodynamics, mass transfer, and fluid mechanics, the situation is hopeless.

We need both scientists and engineers, but we don't expect a scientist when we hire an engineer. The engineer differs from the scientist in interests, motivation, goals and accomplishments. The scientist strives to know, the engineer to produce. Understanding is the goal of the scientist, utilization the goal of the engineer. The accomplishments of the scientist are based on analysis, those of the engineer on synthesis. If the education of the chemical engineer shifts to science, even engineering science, at the sacrifice of the arts of design, industry will use the future "chemical engineer" as a scientist, but will have to look elsewhere for process engineers. Does anyone really expect industry to be happy with two curricula in chemical engineering, one in engineering science for the good students and one in process design for the poor students? Industry must have good process engineers. Some industrialists go so far as to say that quality in process engineers is even more important than quality in applied scientists. In any case to give up design in chemical engineering education is to give up engineering. But an industrial society cannot give up engineering.

It was stated earlier that industry expects the chemical engineer to have developed some well-defined and essential attitudes. In addition to the general attitudes of the professional man industry expects the chemical engineer to have the attitudes characteristic of the engineer. Most important among these engineering attitudes are:

1. Willingness to proceed in the face of incomplete and often contradictory data and inadequate knowledge of the problem.

2. Recognition of the need to develop and use intuitive judgment.

3. Questioning of every bit of data, every method, every result.

4. Recognition of experiment as the ultimate arbiter.

5. Willingness to accept responsibility for the ultimate result.

There is no need, I think, to enlarge on the significance of these attitudes. They are generally acknowledge and have been often discussed.

It is generally agreed that the goal of the engineer is to use knowledge of the physical world for the benefit of mankind. He reaches his goal by designing apparatus, processes, and systems with sufficient precision to permit actual construction. The design problem forecasts action and ultimate physical hardware; operation "in principle" is not enough.

It is characteristic of the design problem that there is no one perfect solution, Usually there are incompatibilities, compromises and alternatives. And the solution finally chosen is profoundly influenced by social values, economics, safety, effect on neighbors (air pollution, etc.). Design usually involves several different disciplines, mechanics, electricity, as well as reaction chemistry, thermodynamics and transport processes, and skill in design is proportional to the designer's ability to focus various disciplines on the immediate problem. This focus is binocular, knowledge of science in one orb and art of application in the other.

"The obvious content of an engineering education is a body of knowledge (from science and experiment) and a set of skills (techniques and experience) useful in solving design problems. But education is much more than this. Students acquire attitudes and habits as well as information and techniques.

"College courses in chemistry, mathematics and physics, in mechanics, thermodynamics and transport processes have a common characteristic; they present to the student a series of single-answer problems. Such problems are those which can be answered with numbers or functional relationships, those which have answers generally agreed upon.

"Examination of the effect on engineering attitudes of single-answer problems reveals:

1. Incomplete or contradictory data have little place in single-answer problems;

2. Engineering judgment is not required of either the student or the instructor;

3. The existence of a standard answer puts the instructor in an impregnable position where skepticism and the challenging attitude are not encouraged. Neither the data, the method, nor the result are open to question.

4. The single-answer problem usually suggests the infallibility of logic rather than the ultimate rule of experiment. The early history of science bears witness to the paralyzing effect of this attitude."*

Would this difficulty be lessened by crowding the curriculum with more specialized courses? Or is it more likely to be resolved by making room for comprehensive problems in design? These are loaded questions, I know. Also I well realize that it is much easier to call attention to problems in education than it is to solve them, especially when there is no pat answer. And I know, too, that you are well aware of this problem and have long been struggling with it. I merely recommend it to you as currently the dominant problem in chemical engineering education, as it has been in the past and probably will be in the future.

* Quoted from "Report on Engineering Design", J. Eng. Education, V. 51, p. 645 (April 1961).