What is chemical engineering?

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This 1990 Annual Meeting of the AIChE is the largest ever meeting of chemical engineers -- a field now so diverse that it divides into 21 parallel lines of interest, spread over five days.

There are 314 sessions, during which more than 2000 chemical engineers will present their latest contributions -- each convinced that they are adding to the core of chemical engineering knowledge -- or perhaps, since the Amundson Report, they would prefer to think of themselves as working at the frontiers, pioneers in expanding the horizons of chemical engineering.

But what is this "chemical engineering" that generates so much enthusiasm ? What is it that all these people feel they share as a common profession ?

I don't know if the AIChE has a formal definition, but the I Chem E in its early days gave great thought to the problem, and produced the following definition :

> "Chemical engineering is the branch of engineering concerned with processes in which materials undergo a required change in composition, energy content or physical state, with the means of processing, with the resulting products and with their application to useful ends.

This nails the flag of chemical engineering to the mast of engineering,defined in turn by the Engineering Council, London, as follows :

> "An engineer is one who acquires and uses scientific, technical and other pertinent knowledge and skills to create, operate and maintain efficient systems, structures, machines, plant, processes and devices of practical and economic value."

This definition of chemical engineering is satisfyingly general, covering purely physical as well as chemical processes, the plants, the products and their uses ! Yet somehow it makes it all sound like a pretty arid business, and it is not the sort of statement to enthuse bright young people in the schools to come to university and take up chemical engineering as a career. So the I Chem E tried again, this time with a poster for school's careers boards :

> "If you don't wash or use deodorant, shave or wear make-up, eat, feed your dog, work on a farm or wear wellies, drive a car, play records, go on holidays, or stay at home, sleep on a mattress or take pills, comb your hair or wear a hat, brush your teeth or wear false ones, go to the movies, watch television, listen to the radio, buy books or read newspapers, then CHEMICAL ENGINEERING does not affect your life."

What is interesting about these definitions is that they are framed in terms of objectives and achievements, rather than skills or techniques, and the same is true of the other engineering disciplines.

For example, electrical engineering is concerned with "the exploitation of electricity for practical purposes," mechanical engineering with "the design, manufacture and maintenance of machinery," while the Institution of Civil Engineers in London still sticks to its original mission statement of 1829 :

> "Civil engineering is the art of directing the great sources of power in Nature for the use and convenience of man, as the means of production and of traffic in states both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation and docks, for internal intercourse and exchange, and in the construction of ports, harbours, moles, breakwaters and lighthouses, and in the art of artificial navigation by artificial power for the purposes of commerce, and in the construction of machinery, and in the drainage of cities and towns."

-- though nowadays of course they have delegated some of these activities to more "junior" institutions.

Scientific disciplines on the other hand seem to define themselves in terms of the study of a range of phenomena. Biology is the study of living organisms, chemistry the study of the structure and behaviour of molecules (whatever they are). Physicists of course, like civil engineers, are a pretentious lot, and claim that physics is the study of all natural phenomena.

When you think about it, there is by definition no unnatural phenomenon, so they lay claim to the study of everything -- though if you suggest that an engineer or a chemist is therefore a physicist, they do look down their noses and tend to claim that only physicists really know what they are about.

When I was a newly appointed professor, my Head of Department -- Professor Ubbelohde, an Oxford chemist -- took me along to a private dining club of Fellows of the Royal Society to be shown off as his new protégé. During the dinner he got into an argument with the club president, a Cambridge physicist, about the dividing line between chemistry and physics, with lively participation of most of those present. After a while, noticing I had said nothing, Ubbelohde turned to me and said, "Sargent, as a chemical engineer you ought to be able to give an objective view on this." Thus put on the spot, I ventured, "Chemistry is chemistry until it is understood and then it is accepted as physics." I don't know which of them was the most offended, but it stopped the debate and I was never invited again!

On the differences between physicists and engineers, I am sure you all know the story about physicist, the engineer and the technical salesman, who were each given a barometer and challenged to use it to find the height of the Sears Tower here in Chicago:

The physicist carefully measured the pressure at ground level, then at the top of the tower, and thus calculated the height. The engineer took his barometer to the top of the tower, threw it out, and took the time before it hit the ground. The salesman took his barometer to the City Tourist Information Centre and said to the receptionist, "To become the proud owner of this beautiful brass barometer, all you have to do is tell me the exact height of the Sears Tower."

But to return to the matter in hand: To describe chemical engineering in terms of its objectives, or its range of applications, is to circumscribe it forever, to deny that its frontiers can ever be expanded, to condemn it to obsolescence in a developing world as surely as were the old craft guilds of London -- the Apothecaries, the Salters, the Fullers, the Mercers and the Chandlers. (Only the medical profession seems to have a satisfactorily open-ended definition in terms of objectives : "To keep people in good health, to treat injury and sickness, and to preserve human life.")

Equally, it does not seem possible to follow the electrical engineers, and define chemical engineering as the application of a range of phenomena -- most of us feel insulted if we are called applied chemists, or even (in spite of the physicists) applied physicists.

Surely we all subconsciously believe that the real core of chemical engineering is a powerful methodology.

Chemical engineering did not really start in England with Henry Armstrong or George Davis in the eighteen - eighties. They were merely concerned with the scale-up of laboratory chemistry in glassware to bulk production in steel vessels, and the consequent need for industrial chemists to learn enough mechanical engineering to build the requisite plant. Chemical engineering was born in Massachusetts in the nineteen twenties with Warren Lewis's concept of unit operations, and the realization that the wide variety of chemical processes involved only a small number of basic unit operations combined in different ways. No less important was the realization that relatively simple models of these component operations -- involving such concepts as the theoretical plate, the perfectly stirred tank, and the two-film theory of heat and mass transfer--sufficed to provide reasonable predictions of process behaviour, even with the puny computational power of the slide-rule and the graphical constructions then available.

I think we can justly claim to be the first systems engineers, but since then the systems approach has been widely applied throughout all branches of engineering -- and each branch, as it has discovered it, has claimed it as its own. Indeed, the physicists would claim that it is merely another name for the scientific method, and that yet again we are usurping their territory.

In fact, chemical engineers turned their backs on unit operations as a basis for their discipline in the nineteen fifties, in favour of a more "scientific" approach. Walker, Lewis, McAdams and Gilliland's "Principles of Chemical Engineering" was displaced as the standard undergraduate text by Coulson and Richardson's "Chemical Engineering", and a new journal "Chemical Engineering Science" was launched.

Curiously enough, chemical reactors had been left out of the basic unit operations, but in the fifties people like Hougen, Denbigh, Danckwerts, Aris and Amundson established the study of "chemical reaction engineering" as an important new area which took the centre stage. At about the same time, Marshall and Pigford, and again Amundson and Aris, were making it respectable for chemical engineers to make use of mathematics, and "Coulson and Richardson" was in turn swept aside by Bird, Stewart and Lightfoot's "Transport Phenomena".

The fifties also saw the advent of digital computers, and over the years, as we have come to terms with the computer age, we have evolved a new kind of systems engineering, refining the technique of using our physical and chemical understanding to devise simple but adequate models for the purpose in hand, and making use of the increasing armoury of mathematical and computing techniques to make ever more accurate predictions of process behaviour, and to develop ever more powerful techniques for optimal design and operation of our processes.

Of course we still need experimental investigation -- in the plant as well as in the laboratory. But again this new systems approach can make the whole business of experimentation more systematic and more efficient . Using our general understanding of basic mechanisms, we can build up postulated models, then use simulation to explore behaviour and pin-point the critical areas for experimental verification; the experimental results in turn indicate the points of weakness in the model, leading to a new iteration of the process. Thus modelling and simulation are essential tools in developing our understanding of the physical world - and the knowledge and understanding gained is encapsulated in the models we develop.

This systems approach and the methodology surrounding it is of course the special concern of the CAST Division, and it is clear that this has a place of growing importance within the AIChE. Indeed there are some who have seen it as the nucleus of a new discipline, which in recent years has come to be called "process systems engineering".

Thus it will come as no surprise that, when we were bidding for funds for our new "Interdisciplinary Research Centre for Process Systems Engineering" at Imperial College, our mission statement was :

"To carry out research into computer-based tools for an integrated approach to all aspects of design, operation, control and management for the process industries".

Some might wonder what this leaves for the other chemical engineers to do, and indeed this statement was not merely intended to impress the selection panel. It is a highly political statement -- a claim to the high ground of chemical engineering, or even a take-over bid for chemical engineering itself!

But again we are not alone in developing this new systems approach to engineering, and we can hardly claim it as the unique contribution which defines our discipline, or even our profession.

Rather it is the sum total of the education we give our students which is the real strength of chemical engineering -- a thorough grounding in the basic sciences (physics, chemistry, and perhaps a little microbiology), mathematics and computing technology, the systems approach to analysing situations and solving problems, some introduction to the issues involved in managing men and money, and above all a motivation through showing how this collection of knowledge and techniques can be applied to solving worthwhile real-world problems.

The surprising thing is that there doesn't seem to be anything very specific about this programme (I didn't even mention the process industries) and this perhaps shows the futility of attempting a formal definition of anything as wide-ranging and diverse as chemical engineering.

Whatever it is, chemical engineering is the means of bringing together a wide range of people with common interests and common purpose, together involved in a fascinating world of exploration and in a thoroughly worthwhile endeavour for the betterment of mankind.