BACK TO BASICS

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Introduction

In the 1967 movie *The Graduate,* Benjamin Braddock is advised to take up a career in plastics: *"That's the future, son."* Plastics, after all, defines us and defines the modern world. But, Chemical Engineering as we know it will in all probability cease to exist in the near future, though this does not mean the end of the discipline. Chemical Engineering has morphed and mutated but basically it has remained the same. This might seem like a contradiction but it is true nonetheless. It is the endeavor of the author of this paper to present his views as one who has been involved in almost all aspects of the practice of chemical engineering. Perhaps the credentials of the author are pertinent at this stage.

I have been heading the process design department of an engineering company that serves the Chemical. Petrochemical, Fertilizer and Refinery sectors in India. I have been involved in recruiting Chemical Engineers, both fresh from university and also experienced engineers. I also train new hires. In addition, for almost ten years I have also been an Adjunct Professor at the Indian institute of Technology, Bombay, where I have been teaching core chemical engineering courses, both independently and in association with other faculty. I do this during my normal work hours, which is a form of commitment by my organization to the development of the profession. To top it all, I present this paper in my capacity of President of the Indian Institute of Chemical Engineers. Thus, I have had a hand in making, customizing and utilizing the product called the Chemical Engineer, and presumptuous though it may seem, I feel I have an interesting tale to tell. .

Historical background

Chemical engineering education in India has almost entirely been modeled on the American pattern. For historical reasons, most branches of engineering in India have been based on the British pattern. The exception has been Chemical Engineering education, which in its current form is relatively new in India, being about 60 to 70 years old. Perhaps in the flush of political independence following the end of British colonial rule in India, we tried to look at the other option available to English speaking engineers: the American model. Thus, all Indian Chemical Engineers have cut their professional teeth on American textbooks, starting with Unit Operations by McCabe and Smith, Mass Transfer by Treybal, Transport Phenomena by Bird et. al, and of course, Perry's Handbook, etc. These worthy books and other American texts still form the bedrock of Chemical Engineering education in India. A point to note is that this trend continues though very good books — notably the Chemical Engineering Series of the British authors Coulson and Richardson — are freely available. Still, we prefer the American pedagogy. This is true on a pan-India basis. Thus, the Indian

Chemical Engineering curriculum and the issues facing it mirror the problems of American academia.

The nature of the curriculum of Indian Chemical Engineering

Currently, the undergraduate engineering program consists of eight semesters of 16 weeks each, and is spread over four years. Entry to the program is after 12 years of school. The entrants have a grounding in Mathematics, Physics and Chemistry, and an introduction to calculus. The first-year engineering student is not less than 17 years of age. On an average, each semester is comprised of five courses excluding laboratory work. The first two years are predominantly devoted to Mathematics, Physics, Chemistry, language, social sciences, etc. This leaves only about 20 courses in Engineering, a significant part of which will necessarily have to be general engineering (Electrical, Mechanical, etc). There is no alternative to this: if we still cherish the label of 'Engineers' then there is no escaping the basic engineering tools viz., Mathematics, Physics, Applied Mechanics, Strength of Materials and Electrical Engineering. I would like to insert a caveat: this is a broad description and there is a significant difference in how various institutions conduct their courses. The university system differs markedly from that of the autonomous Institutes of technology. There is a wide variation in the course content and pedagogical methods across institutions.

Chemical Engineering by its very nature needs a strong grounding in general subjects: more than other disciplines of engineering it is a truly interdisciplinary engineering course. So, willy-nilly, the chemical engineer has to spend a lot of time on 'non-core' subjects. The net result is that this leaves very little time for any specialization and today, specialization is essential.

The Environment

Speaking from the Indian perspective, Indian Chemical Engineering is only now coming of age. Even today, almost if not all industrial technologies are either European or American in origin, with American technologies being predominant. Indian engineering effort is still at the tertiary level with basic engineering and know-how coming from abroad. This is true of all large capacity capital-intensive production facilities. Despite India having a very large Chemicals sector, there has been very little world class technology developed in India. In India, what we are doing is more in the nature of residual and detailed engineering, which requires more tertiary and volume-intensive skills. But we perceive a change: witness the pharmaceutical sector, where from copycat technology one is beginning to see more of research and development at the molecular level. A new business stream is contract research with many big names setting up elaborate establishments in India. India is now a favored destination for such activity. The reasons are pretty clear. Low costs are only part of the story. The availability of technical personnel in fairly large numbers was a plus point but protection of Intellectual Property Rights (IPR) was a major issue. Once India became a signatory to the WTO patent regime which protects IPR on both product and process know-how, it opened the floodgates for contract research and also gave the necessary reassurance to technology leaders enabling them to be more open with their know-how. That India is a democracy where the due process of law prevails, is an important factor. All this bodes well

for the fresh engineer provided he* has the wherewithal to exploit the situation. The rub is how to provide him with the tools for the trade.

The student

As mentioned earlier, Chemical Engineering is a long haul and requires an extended amount of study to lay the foundation for building a proper superstructure. In this respect, chemical engineering differs from other branches like mechanical, civil or electrical engineering where the undergraduates are good enough for direct employment, at least in not very technically intensive fields. The uniqueness of Chemical Engineering is that unlike the other branches of engineering that are all derived exclusively from Physics, it is the only discipline that also leverages the unique powers of chemistry to solve 'Engineering Problems'. Chemical Engineering is the only discipline that manipulates material at the molecular and atomic levels. Hence, a student of chemical engineering needs to spend a lot more time building the basics, which will include large dollops of chemistry. Of all engineering streams, chemical engineering has the largest areas of commonality with "new" sciences like Biotechnology and Nanotechnology. Chemical engineers are best positioned to exploit these sciences, for the betterment of life as we know it.

Chemistry

Historically, chemical engineering grew out of chemistry. The original chemical engineers were necessarily chemists with good business acumen. After all, engineering is making a product at the least possible cost. It worked fine so long as the scale of operations was small and processing, batch-wise. Continuous processing and the understanding that increase in scale brought its own economies meant that chemistry retreated into the background in chemical engineering operations. The commercial scale of even the immediate post-WW II era was little more than a pilot plant of today in orders of magnitude. The 'engineering' problems of the older generation plants could be resolved by a reasonably smart industrial chemist. But let us not forget that this practitioner had a strong grounding in chemistry. With the scale of operations increasing, the chemistry of the operations became less important and chemical engineering as defined by unit operations gained prominence. Hence the well worn adage that a chemical engineer need not know chemistry. A lot many chemical engineers were perversely proud of not being good at chemistry. The wheel has now turned full circle. Reaction mechanisms, bio-reactors, enzyme catalysis and process intensification are the new buzz words, and once again chemistry has come to occupy the high ground in the chemical engineers' world. So, to come back, the chemical engineer of today and tomorrow needs to study a lot more chemistry than the practicing engineer of yesteryears. Even the nature of the chemistry required has changed and we need more of biochemistry, molecular biology and thermodynamics. The problem is where to squeeze this requirement in the already crowded curriculum.

The users' perspective

The perspective of the layman, and also that of any prospective employer of a chemical engineer, is that he is an engineer first and so is expected to have a decent grasp of mechanical, electrical and civil engineering principles. Not surprisingly, no one expects a

civil/mechanical/electrical engineer to have even a modicum of understanding of chemical engineering. Thus a chemical engineer needs to spend a lot more time learning the basic things: Mathematics, Physics, Computer science and of course, a lot of Chemistry. He also needs Applied Mechanics, Strength of Materials, Electrical Engineering and an understanding of Theory of Machines. Like all engineers he needs an understanding of Economics, Management and Operations Research. Furthermore, no engineering education can be complete without an exposure to the liberal arts, sociology, etc., because, ultimately we need to prepare good citizens as much as we need to prepare good chemical engineers. These are the basic building blocks of chemical engineering and no matter what else we teach them, the basic core has to be forged. It is only after all this is done can we even think of chemical engineering or as I want to put it, basic chemical engineering.

Basic chemical engineering

Basic chemical engineering must cover transfer processes (fluid mechanics, heat and mass transfer), thermodynamics, reaction engineering, process control, unit operations and equipment design. Without these units one fails to see how a graduate can be considered a chemical engineer. Let us not forget that this is the minimum requirement. But the contention is that in today's milieu, such an engineer will be fit for only the simplest of jobs at the very bottom of the value chain, as the requirements of the industry have become extremely complex. In the era of flexible work environments, every engineer needs to be a multi-skilled multi-tasker. At the same time the Chemical Engineer must also specialize if he is not to stagnate at the bottom of the pyramid. It is only after this rather heavy meal of basic chemical engineering can we even think of specialization

Product mismatch

The fresh chemical engineers that I have interviewed are all too often familiar with stochastic differential equations and fuzzy logic theory but do not understand pump NPSH; they can manipulate a process simulation package but have no understanding of the Gibbs phase rule. They can work around HTRI but do not understand LMTD. In short, what we see is a lot of information but not much scientific knowledge or the ability to adopt and adapt knowledge at hand. Time and again, we get engineers who cannot 'think on their feet'. I repeat, we have a good looking superstructure built on very shaky foundations.

In most chemical engineering curricula in India, we have a 'Home paper' where a student is expected to design a plant for a specified chemical. This calls for an extensive survey of the literature, flow sheeting and design of major equipment, topped off with a financial analysis of the proposed project. Now, one finds almost all the information in the dissertation to be sourced from the internet without any assessment of the reliability of the information provided.

Take the case of trawling for information. Those of my vintage know the pain and pleasure of combing through the 'Chemical Abstracts' for information. Though a mouse click on the net is much faster, is it a better alternative? I do not decry these new tools, but there is no substitute to understanding the fundamentals.

Is there a better way? My contention is that what we need to do is spend more time on the basics. Chemical Engineering is surely changing but some things remain the same. Today the stress is more on the new engineering which is not a bad thing in itself, but unfortunately it is coming at the cost of basic knowledge and this is the pitfall that we need to avoid. We need to stress on basic engineering and of course on Chemistry. Ultimately, it is Chemistry that defines us. But the chemistry we need to impart to NextGen is different. This Chemistry should be biased towards Thermodynamics, Surface and colloidal Chemistry, Electrochemistry, Biochemistry, Catalysis and Materials Science. Specialization at the undergraduate level is counter-productive as the Chemical Engineer needs to have a reasonable depth in other disciplines of engineering also. Unfortunately, what one sees is a reduction in emphasis on the core courses mentioned above, in favor of the newer and non-core subjects. Received wisdom suggests that such courses would attract more students. Whether the premise is true or not, the fact is that the end product is virtually unemployable in the conventional industry which still needs conventional nuts and bolts ChEs. Not surprisingly, the student chemical engineer is a very confused person. He is nearly half way through the four year program before he develops even the vaguest of ideas of what chemical engineering is all about. Simultaneously, the student is presented with a wide variety of unrelated electives and so behaves just like a child in a sweet shop: he wants everything. He is fed so much of other 'soft' information that he has all but lost the appetite for rigorous technical analysis. By now the initial enthusiasm is lost and the student is ripe for poachers (the IT sector being the biggest attraction). What we need to do is: motivate the engineer through the basics; explain how Chemical Engineering is 'different' from other branches of engineering; get them used to the inevitability of a specialization after the basic degree. Most universities in India got it right when they considered Chemical Engineering distinct from other branches. Now the tendency is towards amalgamation and to label chemical engineering as just another branch of engineering. This is wrong. To repeat, Chemical Engineering is different.

Specialization

As mentioned earlier, the future of chemical engineering is in specialization but this specialization can happen only after the undergraduate program is complete. This is similar to the model adopted in medical schools where virtually no doctor voluntarily terminates his academic pursuit after the basic degree. The medical student knows very early that specialization is necessary and is also made aware that this can happen only after the basics are mastered. Medical specialization is not done at the undergraduate level as there is simply too much to do in general medicine and this leaves no time for specialization.

Some initiatives

Earlier, plant visits used to be a high point in the engineering curriculum. Today, for various reasons entry to most plants is restricted. Hence it is necessary for organizations not subject to such concerns to take up the slack and encourage strong interactions with the academic world. Industry-academia exchanges in the form of lectures need to be stepped up to enthuse and encourage the aspiring chemical engineer. IIChE is also doing its bit by reaching out to the students in various ways. A recent initiative is having a separate annual

convention only for students, which is highly popular. We need more student specific activities, if only to make them feel that they belong to a highly sought-after fraternity..

Conclusion

To sum up, Chemistry defines us. It is our claim to exclusivity. It is why we are different. It is why we are. We must ensure a firm foundation in the basics at the undergraduate level and leave specialization to the graduate degree. We must say to the young chemical engineer, *"Go back to the basics, son."*

*Note: The use of the word 'he' is not intended to be gender specific