While fundamentals are essential in the undergrad Engineering Education Curriculum
They are by no means sufficient

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ABSTRACT

As a chemical engineer with over thirty years international experience with the Shell group and a subsequent more than twenty year adventure as an adjunct associate professor at Queen's University I have observed some profound changes in the Engineering Profession as well as in the education of proto engineers.

The core body of knowledge expected of a graduate in Chemical engineering has been expanding at a considerable rate. The impact of the computer has been profound as has the impact of new technologies. In my experience faculty (who to a significant degree have no industrial experience to speak of) seem to be more interested in the esoteric rather than the basic fundamentals of sound reliable process engineering. A comment was made at a conference at the University of Michigan that in many respects academe has drifted so far from the "Engineering Professional Skills" that a realistic communication is often not possible

It has often been stated that Sputnik had a profound impact on Engineering Education. As a result of the large degree of concern in the West and in particular United States, Science essentially crowded out Engineering in many Universities

At a recent FIE conference a senior officer of NSF pointed out to me that when we graduated in some cases 50 years ago life was so much simpler and most new grads could make some modest contribution to their employer's workplace with the limited amount of material they had been exposed to while at University. Today this is simply not the case. In my case I was extremely fortunate to be in an organization where I must admit I got most of my engineering education from excellent mentors and coaches.

In Canada the rapid growth of the community college system which at the present time attracts more students than the Universities, has in some quarters become known as the best grad school for engineering graduates. The issue here is that the job market for new graduates is no longer as good as it has been and many new grads have found that further education in the practice of engineering can be invaluable when looking for employment.

Some of the important issues in professional practice are the regulation environment which continues to become more restrictive and compliance issues much more common. Other vital issues in a chemical engineer's education are the issues of Loss and Process Safety Management as well as process troubleshooting.

To cover the obligatory fundamentals of Mathematics and the Sciences such as Chemistry as well as design and "soft Issues" such as communication in a four year program and to meaningfully introduce the issues of Professional Skills mentioned above would appear to be virtually impossible.

While the co-op model at some Canadian Universities tends to address this problem, at Queen's we have our TEAM program where a truly multi-disciplinary

team of senior students carry out a "consulting" project for a fee paying Industrial client. In our view learning in the context of application, while not appropriate for all learning styles has shown to be effective for most students.

This paper will discuss the Technology Engineering and Management program, what we hope to accomplish and present some feedback from TEAM participants over the years.

Introduction

What I hope to achieve in this paper is a considered reflection on my personal experience in the field of Engineering Education, what I have observed over some twenty some years as an adjunct Associate Professor of Chemical Engineering. It is of interest to me the history of the evolution of Engineering Education to the point where research is the driving force of most Universities. Having been a practising professional for over thirty years, I am aware that our graduates need a balanced approach to education, not a purely science approach. I have had a profound interest in the process of learning and I sincerely believe as many others do that change is essential in the sphere of education of proto engineers. Lastly I intend to describe the TEAM program with which we try to address some of the needs of our students. .

At an FIE conference a few years ago I was discussing how the requisite core body of knowledge expected of a Chemical Engineering graduate has expanded dramatically since he and I graduated in the middle 1950's. At that time what little we took with us from University had some modest value to our employer, but today that simply is rarely the case.

I was fortunate in joining a company, Shell Canada that at the time had a policy of a two year internship where a new grad spent time in various refinery units. My first design experience was a challenge since most of the methods and principles were something I had never heard of before. Although at that time most of the principles of the MESH equations that had to be solved in order to calculate the anticipated behaviour of a fractionation column, a separation device which was and still is the mainstay of the petrochemical and refining industries, were well known. The problem was that it simply wasn't possible to solve these iterative equations with a slide rule. Mostly "Short-cut" procedures were used and a most generous over design was applied. Many columns of that era were "de-bottlenecked" several times. Capital and Operating costs were not as critical in that era.

This all began to change with the advent of the computer, and the other quite important change was that computers allowed the designer to better represent the phase behaviour of the mixtures and provide better estimates of physical and thermodynamic properties of the compounds or mixtures involved.

In my case by the time I "early retired" I had become quite expert in my field of Chemical Process Development, Process Design, and Process Troubleshooting. All this knowledge was acquired from some of the best mentors and coaches in the field that one could ask for.

In today's economy unfortunately there is not often the same opportunity for young engineers to have this level of support from their employer.

Did I gain the knowledge to carry out these responsibilities in University, certainly not?

This does illustrate the obvious fact that an undergrad degree simply provides the student hopefully with the tools to survive in the profession. As in my case it is the "learning" that occurs as a result of the demands of their employment that is critical for their success. In my view if we can foster the ability to learn as these graduates deal with the need to solve problems that should be the fundamental role of a University education.

Considering the enormous variety of fields that chemical engineering graduates find themselves in, the requirements for a chemical engineer in the patent field for example or the medical field the science and technical requirements are obviously quite different and just as essential. It is obvious that no University degree can provide an individual with the skills and knowledge required to deal with one's unique experience. This being the case what is the role of Engineering Education?

Engineering Education

I had always had an interest in education since I found that I quite often was expected to "educate" new employees about various aspects of the petrochemical or refining industries. I have over the years developed a profound interest in how people "learn", and what is the most effective way to educate our young men and women who wish to become professional engineers.

On the basis of my professional experience and my years as an adjunct associate professor at Queen's it is interesting to look at how engineering education has changed, and the impact these changes have had on undergraduate education. The Engineering Literature over the years that I have been involved has had many articles calling for change. I personally found the definition of required change by John Prados (1991-92) ABET (1) president most significant.

A new engineering education paradigm is required built around active, project-based learning, horizontal and vertical integration of subject matter , the introduction of mathematical and scientific concepts in the context of application, close interaction with industry, broad use of information technology, and faculty devoted to developing emerging professionals as mentors and coaches rather than all-knowing dispensers of information (1)

I often refer to Goldberg's paper of April 1996 (2) which delineated the necessity for change in Engineering Education, his reasons for the necessity for change and his suggestions to achieve change. Fifteen years later I hear the same issues being discussed. The first issue is the conflict between research and "teaching". I personal dislike the term "teaching', a system that dates at least as far back as Aristotle, where the knowledge expert (the teacher) tells the novice (the student) about his discipline. Accepting the fact that there are different learning styles this model is generally accepted as not being universally effective.

Having spent several years in my career in research establishments, I certainly recognize the value of research. My concern is an issue of balance.

The other issue is a Myth as suggested by Goldberg where basic research is the overarching mission of an engineering college/University. This myth originated from the misguided view that the success of the Allies in the Second World War was mainly due to the efforts of scientists, in particular physicists rather than engineers. When the Russians launched Sputnik this certainly had a further effect of promoting science to the relative exclusion of engineering practice in the engineering curricula. In an extreme form basic research is a "virtue" as compared to the applied.

There is an excellent paper by Bruce Seeley (3) that gives an overall history of Engineering Education from 1900-1965. It is quite clear from this history that although the Second World War had a great impact on the evolution of Engineering Education to a science based curriculum this move had begun years before by the entry of several notable European trained engineers to the U.S. system.

The capstone design course is another issue of importance. DESIGN is the quintessential aspect of the professional engineer. Although few of our graduates will have the opportunity to be involved in a major design, the design process is fundamental to many aspects of engineering. Chemical process design depends to a great extent on project planning, economics, regulatory compliance and fundamentally Process Safety and Loss issues. A capstone design course is usually quite labour intensive for faculty and is best conducted by someone with extensive experience in the design field.

This assessment of how change over the years has resulted in curricula that in my view is unbalanced, where fundamental science seems to have crowded out the issues of Professional Skills.

This then brings up the question of increasing competition in the field of Engineering Education.

There is a question that I often ask myself. "What are we doing that can't be done in a "trade school". In Ontario the Community Colleges are thriving and now enrol more students than the Universities. The Community College system has moved significantly away from its original focus of the traditional "trade school". Some of our grads upon getting their bachelor's degree and finding it a difficult job market take one or more practical courses at a Community College, since they find it does enhance their resume. Where do we draw the line between material that is taught at a University and that taught at a Community college? Engineering is a profession often described as applied science, but that still doesn't answer the question. I recently reviewed a research display at a large community college and I couldn't tell the difference between the thesis work of the students and the thesis work of our students.

Engineering has been defined as a profession that works at the margins of a number of pure disciplines, *a gloriously marginal profession.* What is it that we in the colleges and Universities offer that is unique? The college system is based primarily of the potential areas for employment of their graduates. It is a quite nimble system where courses can be instituted or dropped depending on the potential for graduates to find employment.

I would like to think that "Professional Skills" is the area where a University degree should offer a significant difference. There is no question that a practising professional engineer today is likely to be confronted with ethical considerations on more than one occasion. One area which has changed dramatically in the time since I graduated and today that being Health Safety, the Environment, and the need to comply with a rapidly increasing number of regulations many of which overlap between municipal, provincial and federal. There is a rediscovery of "Green Engineering" which in many respects seems to infer that plants designed in the 50's and 60's are inherently unsafe. This is certainly not the case.

As an example of a profound change that has affected the practice of Chemical Engineering is the issue of "chemicals" in the environment. It isn't all that long ago where DuPont had a slogan "Better Living through Chemicals" As a result of prominent disasters, such as Flixborough in the UK, Sevesto in Italy and Bhopal in India the general public began to take a considerably negative notice of "chemicals:" in the Environment. Rachael Carson's well known book "The Silent Spring" precipitated a host of misguided developments which had major serious effects such as the vast number of unnecessary deaths in Africa as a result of the banning of DDT. . The petroleum and petrochemical Industries have been fundamentally affected as a result of these issues which have resulted in a generally negative view by the public at large and a considerable increase in regulations.

This then brings me around to a discussion of how we at Queen's University attempt to approach the issue of "Professional Skills", our Technology Engineering and Management TEAM program (4). Queen's certainly is not unique as there are many other approaches at other schools particularly in the U.S.

TEAM is a fourth year project course open to the various branches of Engineering, Business Students, Law Students and other faculties who wish to participate. Multi-disciplinary teams select an industrial project of their choice and spend their final year working on this project for a fee-paying client. While most projects are in North America we have had projects in Europe and Asia. We have found that as long as the client has financial commitment they tend to be more involved with the student teams. This program began in 1994 as a joint effort between the School of Business and Chemical Engineering.

The projects are very diverse in nature from pharmaceuticals to essentially business management exercises. All teams have a professional advisor usually from outside the university, and there are regular meetings with the TEAM coordinator to make sure that the projects are on track. Of course Project Management is a major part of the program but there can be significant environmental aspects as well. One project one year carried out on behalf of the Canadian Chemical Producers Association comparing Canadian and International regulations resulted in a final report that was given an ISBN number as a reference document for members of the CCPA. This project was a joint effort of law students and engineering students.

Process Safety Management is an issue that often comes up when dealing with chemical or refining processes. This is a subject that we consider almost obligatory for those who intend to enter the hydrocarbon processing field. Of course we must recognize that many of our students will never practice engineering, either using the degree as a starting point for a study of medicine or law for example, or as a background for a career in finance. In this respect Chemical Engineering tends to focus much more on process rather than product which lends itself to many fields other than engineering. To some degree the projects we have in TEAM demonstrate this, most of them requiring an in-depth analysis of the financial aspects of the project.

There is however one fundamental aspect of learning that we are trying to achieve here. Student teams are faced with a problem that in most instances is something for which they have no background. "Just-in-time learning is an essential requirement for all teams, something that they are likely to be faced with most frequently in their careers. They are in a diverse team, often with people from different faculties. One Commerce student who has become very successful said that TEAM was the most valuable experience at Queen's as it gave him a "Bean Counter" an understanding of how "Propeller-Heads" engineers thought. They have to develop a project plan and keep to it, not simply to satisfy an instructor but a fee paying client. While it is impossible to introduce specific learning expectations, all students will be exposed to communications problems, within their group as well as with the client. There often are ethical issues involved, for example is a client using a team of students to gain information about a competitor. Environmental issues seem to be part of many of the projects. There is usually a fair amount of travel involved and the students must budget and control their expenses. Having to coordinate TEAM meetings when there are a diverse group of students from different faculties in a team is always a challenge.

We insist that the students make a professional presentation of their results at the office of the client wherever possible. We recognize that traditional individual assessment approaches are not possible for this program however we do use peer assessments and on occasions individual students have been assessed a zero as a result of these (If you want a mark in TEAM, same time same place next year). What we try to do is to emphasize that we have a high expectation of performance from all teams. If they achieve this they essentially get a "pass" an 85 %. The basis of this is that there will be no marks in their career. The other faculties involved accept this mark for their students. On one occasion we had community college students' work on a team with mixed success. We strongly recommend that we reintroduce this concept in the future. Engineers seldom if ever work in isolation, they work in teams, which often include Community College Graduates.

CONCLUSIONS

There appears to be an on-going conflict between Research and “Teaching” in Canadian Universities. One’s career is predicated to a major extent on one’s research rather than their “teaching” performance. I am sure that this is generally the case in most Universities

There is no question that grounding in fundamentals is essential for our graduates. A complete Capstone Design exercise should be essential as well. Employers currently place a lot of emphasis on “soft skills” which are basically teamwork, and communication skills. Professional Practice Skills should be a large part of an undergrad education, for that matter they should also be introduced at a graduate level.

Our students are entering an industrial environment that is increasingly team-oriented, multidisciplinary teams, where they will be expected to solve problems.

A large body of research and experience shows that “active” learning is in general significantly more effective than the traditional “passive” learning in a lecture environment.

All of this presents a major conundrum. For the benefit of our students and the profession we should introduce more problem based learning, we should spend a great deal more time on “Professional Practice Skills’ and we should try to minimize lectures. Unfortunately with class sizes of well above 100 students this simply is not an option. In a four year undergraduate program there simply isn’t enough time to cover all this properly. A five year program would be an improvement but the question is who would pay for this?

Fundamentally what we must strive for is to develop an ability of our students to attack unfamiliar problems and “learn” what is necessary to solve these problems. In industrial practice this is of much greater validity than vector calculus. This not to say that there may be a problem that requires advanced mathematics. And unquestionably many of our graduates will have to rely on science and mathematics in their careers. It is recognized that in today’s very connected world, it is usually not much of a problem to find information concerning issues of fundamentals without having to retain this knowledge in ones head.

The TEAM program attempts to do this by placing a multi-disciplinary team in the position of working for a fee-paying industrial client on a real world problem. Hopefully we can introduce some of the issues mentioned previously.

Judging by the popularity of the program and feedback from students who have participated we seem to have achieved this. It is interesting that in many instances the law students are the most enthusiastic.

A recent talk on TED talks discussed the growing popularity of Studio schools in the UK where student teams work on problems supplied by industry and business. This has been reported to be very successful. The point of this is that TEAM while unique in Canadian Universities to the best of our knowledge is certainly not the only approach to providing effective active learning. Harvey Mudd College in California has a very similar program.

TEAM is labour intensive and expensive. There is a great deal of travel involved much of which is long distance (Kingston to Calgary for example). Although the client fee covers a significant amount of this, TEAM has been supported for several years by a major grant from Shell.

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