NEW ROLES FOR ENGINEERING FACULTY

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Abstract – This paper addresses needed key changes in engineering education that many faculty are reluctant to make. Problems are explained. Part I provides background data and documents U.S. engineering enrollment trends. The private sector for-profit business of education is discussed. Part II speaks to the need to re-engineer the engineering degree and highlights issues in need of resolution. The issue of whether “degrees” or “knowledge” will be the coin of the realm in the future is discussed. Will degrees or knowledge, however it may be obtained, be more important in the future? Finally, Part III, the heart of this paper, covers how engineering education must change if we are to attract the brightest men and women to engineering. It discusses the education/learning process and the fact that solid engineering principles generally have not been applied to engineering education. Engineering education can be more efficient, effective, and exciting. Suggestions to accomplish this are made.


PART I, BACKGROUND AND SOME FACTS

What I share with you today is solely my view as shaped by many factors. Those include ten years as a Dean of Engineering, Chair of the Engineering Deans Council of the American Society for Engineering Education (ASEE), President of ASEE, and Senior Education Associate in the Engineering Education and Centers Division of the National Science Foundation (NSF). My views were formed by the experiences in these assignments, but they are my own and not necessarily the views of these groups.

To judge the view of ASEE and the Engineering Deans, read a report prepared as a joint project of the Engineering Deans Council and the Corporate Roundtable of ASEE entitled, “Engineering Education for a Changing World [1].” Several needed major changes in engineering education were stressed in this seminal report. The bottom line is that the report says that engineering education programs in the future must not only teach the fundamentals of engineering theory, experimentation and practice, but be relevant, attractive and connected – three key words.

Regarding NSF’s view on engineering education, the Engineering Directorate of NSF has for more than a decade been committed to engineering education reform. The 1989 report of a NSF panel of experts concludes with the following summary [2]:

“The task force advocates, as a national imperative, a much strengthened undergraduate engineering initiative by the NSF in supporting the development of consortia of educational institutions as a complement to current engineering undergraduate curriculum activities and in this way to enhance the quality of the undergraduate educational experience in engineering. The balance in many leading U.S. engineering schools between the teaching and research activities of faculty members can thus be restored, and the U.S. technological workforce’s capability can be greatly enhanced. In this increasingly technological era more investment in the capability of the Nation’s human resources in engineering is overdue.”

This report led to the establishment of the well known NSF engineering education coalitions. There are numerous other NSF reports on needed improvement in engineering education, as well as science, mathematics and technology education. In the last decade NSF has spend over $150 million on engineering education reform, a large part on the engineering education coalitions program. So NSF’s commitment to improving engineering education is well established. For a comprehensive review of engineering education studies in the U.S., see a report by Ed Ernst [3].

Now I will identify the broad engineering education issues that in my judgement will predominate in the years ahead. These are: a) engineering enrollments, b) the changing nature of engineering employment, and c) the for-profit business of education.

Changes in Engineering Enrollment

According to the most recent data from the NSF Science and Engineering Indicators publication, undergraduate engineering enrollment declined from a high of 441,200 in 1983 to a low of 356,000 in 1996 [4]. This represented a 19 percent decline. The undergraduate enrollment hit bottom in 1996 and had increased 3% by 1998. Interestingly, part time undergraduate student enrollment didn’t decline during the 86-96 decade and remained stable at about 10 percent of total enrollment.

The decline shown graphically in Figure 1 was rapid until 1989, and then stabilized until 1992, before resuming its decline. The fact that the enrollment decline stabilized in 1992, after six years of decline, may indicate that the historical supply/demand cyclical forces were attempting to come into play. However, the historical (approximately

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every six years) cycles were overpowered by the events of cold war cessation and industry restructuring/mergers, and the resulting consolidation of the workforces. These trends are vividly shown in Figure 1, provided to me by Richard W. Heckel. He is Commissioner at Large, Engineering Workforce Commission of the American Association of Engineering Societies. The NSF numbers given above vary slightly from those in Figure 1 because of different sources. The data in Figure 1 prior to 1966 were from the U.S. Department of Education and, thereafter, from the Engineering Workforce Commission.

The December 1999 issue of *Engineers* very succinctly summarizes the U.S. engineering enrollment decline of the last decade or so [5]. This report states: “In 1999, the number of bachelor’s degrees awarded in engineering declined – again – to 62,500, despite significant increases in first-year enrollment over the previous 2 years, according to the Engineering Workforce Commission’s survey report Engineering & Technology Degrees, 1999. The 1999 undergraduate degree total is the lowest since 1980, when the total was 58,742 but was rapidly increasing to an all-time peak of 78,178 in 1986. Careful analysis of the enrollment data indicates this should be the last year of decline for some time.”

In reference to graduate degrees, the report further states: “The total of engineering master’s degrees actually increased by a meager 17 degrees, though the steep decline in bachelor’s awards since 1986 suggests that the pool of potential graduate students has dwindled and that the totals for master’s degrees will decline in following years. Similarly, engineering doctoral degree awards dropped off significantly, falling from 6,567 in 1998 to 5,833 in 1999, an 11.2 percent drop. This decline comes on the heels of a 6.0 percent decline in doctoral degrees between 1997 and 1998.”

**The Changing Nature of Engineering Employment**

It is very difficult to predict the future in the current environment where new technologies and new types of jobs surface each day. Today, in a matter of days, a new technology can make an old technology obsolete and virtually worthless. Left brain dominant engineers tend to think conservatively and most observers believe are not visionary. I disagree. Note that others have the same problem as shown by some past predictions made by informed leaders who were knowledgeable in technology [6]. Examples are:

- “I think there is a world market for maybe five computers.” Thomas Watson, Chairman of IBM, 1943
- “I have traveled the length and breadth of this country and talked with the best people, and I can assure you that data processing is a fad that won’t last out the year.” Editor in charge of business books for Prentice Hall, 1957.
- “There is no reason why anyone would want a computer in their home.” Ken Olson, President, Chairman and Founder, Digital Equipment Corporation, 1977.

While predictions are risky, nonetheless we must look at employment shifts in industry and judge if these shifts are likely to continue. Luker and Lyons in analyzing U.S. data report that for the period 1988 to 1996, the computer and office equipment category (SIC code 357) had a net employment decline from 455,000 to 357,300 – a loss of 21 percent [8]. Note that “SIC” is Standard Industrial Classification and SIC 357 relates to manufacturing. For the same eight-year period the computer and data processing services category (SIC 737) had an increase in employment from 656,700 to 1,139,100 – an increase of 73.5 percent. There is a strong shift from manufacturing to services. The services share of all R&D-intensive high tech employment rose by almost 11 percent from 28.0 to 38.9, between 1988 and 1996; manufacturing’s share fell during that period from 70 to 60 percent.

Luker and Lyons also present data on two past significant employment shifts in the U.S. high-tech industries: 1) very slow growth in overall employment, and 2) a shift in the industrial composition of high tech industries toward services and away from manufacturing. The shift is more toward the production of services than the production of goods.

Finally, Luker and Lyons show that in recent years more of the engineers are employed in small companies, a trend that is expected to continue. Of those engineers under age thirty, 27 percent are employed in companies with less than
100 employees, while 40 percent are employed in companies with over 5000 employees. Today, even the large companies generally will no longer give engineers a couple of years off to pursue a master’s degree. The small companies virtually never do—they never have been able to afford to do so. Thus, advanced education generally must come through some distance learning mechanism available while the engineer works full-time—creating a boon to e-education business growth. Moreover, this education must be flexible and help provide the fluidity that is essential as job assignments change more frequently.

The Business of Education

In the December 27, 1999, issue of the U.S. magazine Business Week, Gary S. Becker, a 1992 Nobel Laureate from the University of Chicago, speaking of web learning states, “Modern economies require that people invest in the acquisition of knowledge, skills, and information throughout most of their lives [8].” Becker, who has become involved in a for-profit company that specializes in online courses, predicts that soon there will be a global movement in online courses, particularly for highly skilled professionals. Business Week two weeks later analyzed the for-profit, private enterprise education movement [9]. Mike Smith, then Acting Deputy Secretary, U.S. Department of Education, predicted that in 2000 “dot.com will come to higher education in a way no one could have imagined even three years ago.” Smith further predicts that soon there will be tens of thousands of college courses on the Internet instead of today’s mere thousands. International Data Corp. projects corporate elearning, with a market of U.S. $550 million in 1998, will explode to U.S. $7.1 billion in 2002.

PART II, RE-ENGINEERING THE ENGINEERING DEGREE

Does all the information given above apply to all engineering? The facts presented are for engineering in general. Some might argue that it doesn’t apply to all engineering because their profession is different. To do so is a serious mistake. Are engineering faculty so naïve as to think that engineering education will be immune to the market forces as entrepreneurs take advantage of the ballooning business of e-education? Regrettfully, many that I know are.

Issue: The Current Professional needs more Information

Proposals that suggest needed changes in engineering education programs are controversial, but I am yet to hear a good argument that more information/knowledge is not needed. The ever-marching advance of technology will demand more and more knowledge. We engineering professors argue against change generally saying, “If it isn’t broke don’t fix it.” Engineering education may not be totally broke, but it is in serious need of preventative maintenance or a major overhaul. I say there are many micro-cracks in the structure even if they are hard to see. To address this matter, I see several options.

Option 1. Increase the number of credit hours required for the 4-year B.S. degree in engineering. There are many examples in the U.S. showing that there is no single approach likely to be acceptable, politically or socially. Given the advancing cost of education, increasing credits for the B.S. degree is not likely to be politically acceptable.

Option 2. Recognize the B.S. degree is not a professional degree and go to the masters as the first professional degree. The farsighted Board of Direction of the American Society of Civil Engineers has adopted this as a desirable approach and, controversial as it is, recommended that serious consideration be given to it. While most will not accept it, it is a realistic approach in my view. Although I support this notion, there are many hurdles to be overcome before this approach will be widely accepted.

Option 3. Subsequently, in this paper I suggest that the efficiency of teaching/learning can be increased. This of course could provide a third option.

Option 4. High schools in the U.S. are not as effective as they could be, and this is widely recognized. There is no reason why more science and math and some engineering could not be taught there. This has successfully been done in other countries and needs to be explored in the U.S.

Issue: Insufficient Number of Engineering Students.

Students vote on their college major with their feet, i.e., they select their college major. We can’t force them into engineering. And the generation of students we now have is impatient for exciting things to do. They believe that each person can and should enjoy life and have fun now. Older professors like me may think that students should see the light of exciting professional engineering practice at the end of the long, dark tunnel of engineering education. That is not realistic today. We must make engineering education more exciting, particularly in the freshman and sophomore years.

Faculty members usually think the best answer to enrollment decline is improving recruitment. The thought of retention comes second. Truthfully, we should first focus on retention and then recruitment. Each freshman who enrolls in engineering has already been sold on the idea of being an engineer. We should nurture that potential future engineer and reinforce from the very beginning that engineering is an exciting and caring profession. Our job, as faculty members, is to help hard working students succeed. Faculty members should devote at least as much time, probably more, to freshmen as compared to students in other classes. And, yet, too many of the faculty attempt to avoid the duties of counseling and mentoring freshmen and are loath to teach freshman courses. Is it any wonder that so many of our
freshmen students opt out of engineering during or immediately after the freshman year?

Many faculty are more interested in research than teaching. This must change. Better integration of teaching with research at all levels should be the most exciting endeavor in which a faculty member can be engaged.

Don’t be left with the notion that recruitment is not important. Recruitment is where we sell the excitement of engineering. But if we initially convince students to study engineering, and don’t see them through to the engineering degree, we have wasted energy and resources. While we lose some students that are not well suited for engineering because of lack of interest or ability in math and technical subjects, most that we lose are capable of being good engineers but become disinterested.

Issue: The For-profit Business of Education.

I do not realistically think that we can do anything to stop the for-profit business of education. Our nation promotes free enterprise systems and entrepreneurs who see opportunity in for-profit education activities will be hard to stop. Nor should we try. Still, there are some concerns that I will mention. First, there is the issue of quality of the education and whether there is false advertisement associated with it. That is a matter of concern to organizations such as the professional engineering societies and accreditation bodies like the U.S. Accreditation Board for Engineering and Technology (ABET). There is also concern that one of the strengths of education in many of our universities, is the integration of education with research. There may be a deficiency here when education is devoid of research involvement, and we should increase our efforts to maximize the synergistic benefits of education at a university actively engaged in research. Quality is an issue to those of us from traditional universities, and we can always identify cases of concern. Nonetheless, the quality of the for-profit education is probably not that bad. We would be well advised to focus on improving what we do as a first order of business. We should also better integrate engineering education with engineering practice, something the several for-profit education institutions do well.

PART III. RE-ENGINEERING ENGINEERING EDUCATION: EFFICIENCY, EFFECTIVENESS AND EXCITEMENT

The term re-engineer is sometimes misused and, unfortunately, it tends to be a catch all term. I will try to use it in a true engineering sense. In the ensuing discussion I use the three engineering terms of efficiency, effectiveness and style (excitement). I could add maintainability to these.

Engineers look at problems in an organized, rational way and try to understand all of the processes involved. They know they must. The engineering method is an orderly, common sense approach recognizing that you can’t improve a system unless you well understand all the processes involved. Let me illustrate with an example from the automotive engineering arena. Postulate that the task is to improve the fuel efficiency of an automobile by 30%. Engineers in a rational, orderly fashion look at the vehicle weight and search for lighter materials that will work better. Energy losses are studied to see if they can be reduced (aerodynamic drag, friction losses in tires and moving parts, wasted energy lost as heat in braking, etc.). Losses resulting from varied driving conditions and when the car is not moving are analyzed. The power system including the internal combustion engine is studied to determine if there are systems that will reduce losses (such as mechanical-electric systems), alternate power systems (fuel cells), and electrical braking generating power to be stored and later used. More items could be listed, but these present the notion of the engineering method.

You see engineers using engineering logic (the engineering method) reduce the problem to the fundamentals knowing that substantive changes will not result until those fundamental processes are understood and each element in the process optimized. I submit that engineering educators have never looked at the engineering education process with an engineering approach – and analyzed each element in the learning and teaching process. We have left that to the cognitive scientists, pedagogy specialists and educational psychologists. They do their job well, but may not approach the problem in the orderly, logical fashion of the engineer. The latter is what I suggest that engineering educators do.

I firmly believe that both the efficiency and effectiveness of student learning can be markedly increased. Let me define the terms I use in an engineering sense. I also think that the excitement of engineering can be improved and I will try to reduce that to engineering terms. Finally, I will mention the increasingly important lifelong learning and try to put that in a traditional engineering context. Please recognize that I do not suggest that we ignore the cognitive scientists and learning specialists in this process. I suggest that we team with the learning experts and add the “engineering approach” to education for the benefit of all.

Efficiency of the Education Process

Efficiency is a well-understood engineering term. One of Webster’s definitions of efficiency is, “the ratio of the useful energy delivered by a dynamic system to the energy supplied to it.” So it is output over input. In education let’s consider the efficiency of education as useful knowledge gained per unit of time spent learning, i.e., knowledge acquisition over time spent learning. I will not argue that this ratio is dimensionless as engineers prefer, or even how useful knowledge is measured. But it does fit another Webster definition, “effective operation as measured by a comparison of production with cost (as in energy, time, and money).” I have earlier discussed an example regarding how engineers
Effectiveness of the Education Process

Effectiveness is not a common quantitative engineering term. It means, “producing a decided, decisive or desired effect.” Effective learning occurs when learning is in the context of currently understood problems and world issues. The acquired knowledge is not forgotten. It is available to the user when needed. How often do you hear the statement – we covered that in college, but I have forgotten it? We might think of effectiveness using the engineering term, reliability. Is your education reliable and the knowledge still there in your brain memory cells when you need it, or has it long since been forgotten? I contend that we can improve the education process so that it is more effective and the knowledge reliably retained to be available when needed. The knowledge must be relevant in some context that the students understand. If students see the relevancy of the topic being taught, they won’t be so likely to forget. So, again we must have active learning, with everything made relevant through real world examples. If a professor cannot develop real world example cases where the material being taught applies, then we should question if the material is germane to engineering. Hands on learning is effective learning. One of the advantages of the coop students have is that is of such value to industry is that working while they learn makes their education more effective; its all relevant.

Excitement in the Education Process

Excitement relates to a deep personal interest in a process. In engineering its styling and color if you will. U.S. automotive industrial pioneer Henry Ford, referring to the Model T Ford, is reported to have said, we provide it in any color you want so long as it is black. This Model T early car was new to people accustomed to horses for transportation, so excitement was already there. But look at cars now. Marketers use styling, color and performance to convince you to buy a new car, even if you don’t need it. So I say that the engineering professoriate should concentrate on the excitement of and art in engineering and not just on its functionality. To illustrate, look at one of the books published by the American Society of Civil Engineers on new, modern bridges and note their architectural/artistic beauty. They are sleek with beautiful lines. This is an integral part of civil engineering and these new artistic forms are possible because of new materials and improved designs with old materials. They are beauties of art. We best not forget this art aspect of engineering if we want more students, and particularly if we want more female students who view engineering in a different and important way. Let’s learn from marketing specialists whose stock and trade is creating excitement in a product.

Lifelong Learning

I only want to touch on lifelong learning, but it is very important. The engineering term for this aspect is maintainability. Our education must provide the solid framework and broad structural base of fundamentals and liberal subjects so that any new knowledge needed in the career can be added as appropriate. We add knowledge to this strong base as needed. And this is not just knowledge in a technical sense. There are other elements just as important to the career long success of the engineer. Some have said fluency in more than one language is essential for the success of most engineers [10]. This is certainly true for the international audience at ICEE 2001. This view on language and communication is now accepted by many and will be true for most in the future, given our highly globalized, technology-based economy. So maybe improving the efficiency of the engineering education process will permit us to cover a second language in a meaningful way in the four-year degree – and still not shortchange the technical aspects. Let’s be sure that we have made engineering so exciting, learning so efficient and effective, that the engineer will want to maintain his/her knowledge in engineering – sort of like maintaining and nurturing a classic, vintage automobile. If we don’t maintain and build on what we have, its value will diminish. One thing is sure. If engineering is not exciting to the practitioner, he/she will not be interested in constantly engaging in learning more throughout life.

A comment on Information Technology

Before I summarize, I must mention that the primary enabler of the change in most engineering practice and education is the computer and information technology. And what we
have seen so far pales in comparison to the changes yet to occur. Change is scary and some faculty – even myself – may fear that education is a threat to them. Professors who do not accept and adopt the latest in information technology to make their courses better and improve student learning, should feel threatened. They will become obsolete and endangered of being replaced. Jack Wilson, a distinguished engineering educator at Rensselaer Polytechnic Institute stated the problem well when he said, “If a professor can be replaced by a CD-ROM, he/she should be.”

**SUMMARY**

The argument that I have made herein is that engineering educators have mostly approached education reform in a piecemeal fashion. The changes have usually been adding, dropping or modifying a course here and there. We have not used the traditional strengths of the engineering mind and the techniques of engineering analysis to break the engineering education improvement issue down to its fundamental elements – and see how we might improve the process in each. I have defined education efficiency, effectiveness, excitement and lifelong learning and used the engineering terms: efficiency, reliability, styling and maintainability, respectively, to illustrate how we might approach these. Information technology is the tool that will facilitate the improvements I have discussed. I do not provide answers, only suggestions. My goal is to stimulate thought and discussion on the engineering education improvement issue.

It is important that engineering educators benefit from working with cognitive scientists and education specialists. We have much to learn from them. At the same time, if we apply the principles of the *engineering method* to the education of our students, those education specialists can learn much from us.

**REFERENCES**

6. Taken from the Business Section of the *Kansas City Star*, January 17, 1995.