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Reflections on Engineering Education: Past, Present, Future

Abstract
Spending almost a half century in engineering education as an undergraduate student, graduate student, lecturer, professor, department chair and dean, has given me an opportunity to witness many changes. From the slide rule to the tablet computer, the changes have been rapid and presented a number of challenges to engineering faculty. We have been faced many questions. What are the fundamentals of engineering? How many credits does it take to educate an engineer? What are the expectations for faculty? The foundations we have established over the past years and are currently building on must serve us in the future. This paper explores how the classroom lecture has changed with technology and student expectations. Current discussions and conflicts on what engineering education should look like in the future will be discussed as well as the dilemma facing new faculty with increased expectations to achieve tenure. Cutting funds for higher education by many states has been a high priority of legislators and research funding is being cut by the federal government. So why should one go into a career in higher education? The important rewards are still the same as they were a half century ago!

Foundations for the Future

For the past several years there was an article published on the incoming class of freshman students with the emphasis being on the many things they had not experienced that the faculty have lived through. I remember one such fact which was that the new class of students had never rolled up the window on a car by hand. This stunned me for a few minutes when I read it, but then I remember my parents buying a car in 1953 which had power windows! Many young people don't realize how things have changed over the past half-century. It is also true that many of our current faculty members have not experienced the past half-century of engineering education. They have little appreciation of the foundations of engineering education on which they must build the future. We usually only publish our successes and few of our students and faculty members understand the importance of learning from our mistakes and using these to build a strong foundation. While Henry Petroski was concerned about failures in engineering design, I believe the same applies to education. "I believe that the concept of failure – mechanical and structural failure in the context of this discussion – is central to understanding engineering, for engineering design has as its first and foremost objective the obviation of failure".[1] We also must learn from our past failures in engineering education. How can we justify such low graduation rates?

I will take a brief tour down memory lane before looking at where we are today and where we may be going in the future. Let's start with the tools we had as engineers. To be an engineering student, you had to have your own slide rule and drafting set. (Many of us still own them!) The slide rule was worn on the belt at all times when attending classes. Part of the drafting set was a razor blade for correcting India ink drawings. Mistakes were costly and time consuming so you learned to work very slowly and carefully. I would be remiss if I did not mention the pocket protector that we wore to enhance the image of engineers as nerds.

The curriculum required somewhere between 136 and 145 semester hours for graduation. In electrical engineering we were required to take a course called "Engineering Manufacturing Processes" which included using machine tools, casting in sand molds and using measurement instruments. We had to understand such things as tolerances, dimensions, volumes and most of all what went into manufacturing a mechanical product. Do we worry about manufacturability in most of our programs today? No! Especially not in electrical engineering. There are only 21 accredited manufacturing engineering programs in the U.S. today. Is it any wonder that most of our manufacturing is done elsewhere? As electrical engineers we had 10 credit hours in passive circuits so that we had a good understanding (foundation) in basic electrical circuits and components. That sound foundation in passive electrical circuits has been reduced to 3 credit hours or less and we wonder why the students don't understand many of the fundamentals. We practiced solving almost every passive circuits problem the instructor could think of. Have the students been shortchanged in the fundamentals?

Looking around the classrooms there were no women students or faculty in electrical engineering except for one graduate instructor working on her Ph.D. The fact that there was one woman TA was really unusual because there were no women students or faculty in any of my engineering classes. Today, ASEE reports that 13.2 percent of the engineering faculty numbers are women.[2] Those few back in 1960 were the leaders for our faculty today and were laying a foundation for women in engineering. Is this good enough?

One extremely important development for engineering education was accreditation which was directed toward insuring quality in our graduates. In 1932 the Engineering Council for Professional Development (ECPD) was formed and started accrediting programs in 1936. This was "an engineering professional body dedicated to the education, accreditation, regulation and professional development of the engineering professionals and students in the U.S." There were seven professional societies involved, including what is now ASEE (Society for the Promotion of Engineering Education). This was the foundation for our current accreditation agency ABET and established many of the curricular developments in engineering based on professional society input which included a strong industrial component. The criteria were largely prescriptive with the important check sheet which counted the number of credits in mathematics, engineering science, and yes, "design." If you had the proper number of credits for each of the required ABET areas, it was felt that the students were well prepared to be engineers. There was always the question of whether faculty really knew what "design" was because many had no experience in engineering design. By the 1960's most engineering schools had the four major programs, civil, electrical, mechanical, chemical and some universities had programs in mining and metallurgical engineering, petroleum, aeronautical and nuclear engineering. There were likely more accredited programs in nuclear engineering then, than the 21 we have today. The demand for nuclear engineers waned and reactors were expensive burdens on institutions so programs were shut down.

We see today that there are 29 professional societies comprising ABET and 27 different criteria for program accreditation. Programs such as computer engineering, biomedical engineering and biological engineering were unheard of at that time. Engineering education accreditation has changed significantly over time. Today, we have to measure outcomes with industrial survey and student interviews and we are evaluated on how well we meet our "objectives." Does this new criteria insure the quality of our graduates?

In the early years of teaching, I would come from a lecture covered in chalk dust. A few colleagues were allergic to chalk and had to use white boards. Then we adopted the technology that had been used by bowling alleys and industry for a number of years-- the overhead projector. The students then had to listen to us and write down what was on the transparency. But, we could do really neat pictures, graphs and illustrations! We adopted the technology to make our work easier with very little attention given to student learning. Students often complained that it was impossible to listen to the faculty member and write down everything on the transparency. To address this complaint, some faculty members made copies of the overheads available to the students before class so that they could listen and make notes on the handouts. This was an early attempt to become student centered in our teaching techniques. There were actually faculty discussions about whether this was good pedagogy since the students would not need to listen to the lecture as closely. And what happened to the slide rule? It gave way to the calculator and caused a great deal of debate by faculties about whether calculators should be allowed in examinations. Some students might not be able to afford a calculator or what happens if the battery goes dead in the middle of the examination. Then there were the memory calculators which could store equations. Was this fair to use on an examination? We all know how these questions were eventually answered, but were they the right answers.

Where are we today?

We have built on these foundations and engineering education in the U. S. has been a model that may other countries have tried to duplicate. ABET is now international as well as most of our engineering societies. We have been a leader over the past half century and have established the foundations for engineering programs in many countries. The changes to the accreditation criteria in 2000 focus on continuous improvement but were reluctantly accepted by some faculty. Often the comment was heard, “Don’t fix it, if it is not broke.” We were able to move past the discussion stage and early detractor’s arguments into the stage where the accreditation criteria is being evaluated and improved. The goal of improving the quality of our graduates builds strong programs for the future. We still have issues to deal with concerning public perception of quality and legislators often question the value of higher education. A quote from a recent Washingto Post article illustrates this. “The failure of colleges and universities to teach basic skills, while coddling them with the plush dorms and self-directed ‘study’ is a dot-connecting exercise for Uncle Shoulda, who someday will say – in Chinese – ‘How could we have let this happen?’ One of the most damning indictments of higher education came this year with a book Academically Adrift: Limited Learning on College Campuses, by Richard Arum of New York University and Josipa Roksa of the University of Virginia. …but the authors’ finding are compelling. Just two examples:

- Gains in critical thinking, complex reasoning and writing skills are either ‘exceedingly small or nonexistent for a larger proportion of students’.
- Thirty-six percent of students experience no significant improvement in learning (as measured by the Collegiate Learning Assessment) over four years of higher education.” [3]

This type publicity may not apply to engineering programs but is a good resource for a legislature wanting to cut budgets!

The classroom has moved from chalk and overhead transparencies to “smart classrooms” with computer capabilities and access to the internet. While we may occasionally cause student “death by PowerPoint”, we have moved to a student centered learning environment and young faculty have been very adept at using today’s technology. In some cases we have probably gone too far. I have sat in classes where students are surfing the internet, texting friends and watching videos. Faculty must set the standards and maintain control of the learning environment. Students must understand that the faculty member is not an entertainer but someone to help them learn. They must put some effort into the learning process!

What about the faculty? Have we adopted unrealistic expectations for them? We have gone from a time where faculty evaluations were based on teaching, research, publications and professional service but the only quantitative measure discussed during annual reviews was the number of publications and the expectations were relatively modest. Today, we are in an era where we are counting the quantity and quality of publications as well as research funding quality and quantity. Some faculty members argue that industrial research funding should not count as much as peer reviewed government funding. Over the years the bar has been raised considerably for young tenure track faculty. There are a number of older faculty members nearing retirement who have been excellent teachers but would not have been tenured under the current criteria. Faculty are expected to be excellent teachers (as judged by the students), have a specific number of publications each year in refereed journal publications, have research funding of several hundred thousand dollars per year, serve on several university committees as well as be involved in professional organizations and participate in K-12 outreach activities. All of this at a time when funding for faculty salaries are being cut or programs are being eliminated. Every time a new faculty member has gone through the tenure and promotion process and has raised the bar in one area, say publications, that becomes the new standard to judge all tenure track faculty on. Are we expecting our young faculty members to be super human?

Consider also what is happening with state funding. Over the past ten years, most states have cut funding to universities to the point where they feel they are state assisted rather than state supported. On the national front, if current budget cuts are approved, NSF will suffer funding cuts which will have a direct impact on research funds for our young faculty. The combination of state funding and federal funding cuts will curtail the development of new engineering programs which have been a valuable resource for engineering education changing with the changing needs of industry and society. We should not forget our students in all of this. Unfortunately, this puts engineering educators in the same position that our industrial counter parts have been in for most of their careers. We have to go where the money is and if the majority of your resources are coming from external funding and not student tuition, where are you going to put the majority of your effort? This shortchanges the students in the quality of education they receive.

Faculty members are currently concerned about salaries, research funding and the future of their jobs. This has caused many to question their decision to go into engineering education as a profession. Would you go into higher education again if you had to start now? Most of us answer, yes, without hesitation because the real rewards for us are not monetary but are the joy of seeing a student gain a new understanding of a concept, learning to solve a problem on their own, or designing something that really works. The rewards from working with graduate students on their projects and the relationships that are developed with them are still there. The freedom to work in whatever research area we choose is still a big draw for most faculty members.

The Future

The future is always uncertain but will certainly involve change. Much of the change will be based on the foundations we are building today. I certainly do not claim to have that crystal ball that lets me look into the future and a number of people have tried to predict the future. One attempt using engineering principles of feedback control systems was The Limits to Growth which predicted in 1972 our current energy resource crisis among other problems we face today.[4] It has amazed me how we as engineering educators have focused our attention only on our own disciplines without applying our knowledge to study the broader impact of technology on society and the future of the world. Have we isolated ourselves from the rest of the world?

We need to look at the future by looking at the students. They have accepted today’s communications and computing technology with open arms. They are often more comfortable communicating electronically rather than in person. I have watched many freshman students leaving a 300 seat classroom and immediately start talking on their cell phone to someone somewhere else on campus. Are they talking about the class they just left? Not likely. Think back to the days before the cell phone and we would have probably been talking about the course material, the teacher or something related to our homework. At any point we would have come to know our classmates better. Do the students know their classmates today? Is this important? I often found that when advising students having trouble with a class that they never talked with anyone in the class about the material or the homework problems. As we move to smaller and faster communication devices it obviously changes the way we interact with the students and how they interact with each other.

This first became a concern in the 1980’s when we started offering video courses to graduate students in industry. Questions about how the distance students would interact with the students in the classroom were often raised. Also there was a concern that the distance students would not learn as much as the in-class students. It turned out that the course I was teaching through one-way video and two-way audio in 1987 was enriched by the industrial students. While not in the classroom, they often contributed important current and practical information to the class that I would never have had access to as an instructor. The industrial students thought the course was great, but the in-class students had reservations about the unseen industrial students. Technology has certainly changed since then and we have the ability for two-way audio and video with these students which would enhance such a course. The students are no longer concerned about the face-to-face interactions and accept internet interactions as a preferable alternative to classroom instruction. It is obviously the preferred method of social interaction.

It seems as though we have no reservations about a new technology and assume it will be good for us. When I was teaching a large class of engineering students in Australia in the early 1970's, I was telling students about the exciting possibilities that wide band (fiber optics) communication systems would bring to their lives. One thing that was discussed was electronic mail, electronic newspapers and books. I did an informal survey and asked the students whether they would use electronic mail. Well over 90 percent of them said they would not. (I must admit that I had some reservations about it as well.) Now students can hardly wait to adopt a new technology for the simple reason of having the newest, fastest, smallest or coolest device. We must consider this as we develop new course content and new methods of instruction. It seems that we have to keep up with the students to remain relevant in their fast moving world.

Using the dynamic modeling techniques developed in reference 4, we tried to predict the future of telecommunications systems and how society would accept them. While the model was an interesting attempt at engineering prediction, we completely missed the advent of the cell phone and the rapid acceptance of this pervasive and invasive technology.[5] As faculty we must be attuned to new technology and how we can use it to improve our teaching. I cannot attempt to predict the future of communications technology, but I know it will come and will be adopted rapidly by the younger generations of students. This is a new challenge for our faculty.

Another thing that we must consider in the future is the financial resources available to higher education. Can we afford the physical classrooms on our campuses or will we have to become more efficient through communications technology? How much research funding will be available to support our expensive research programs? From everything I read about the financial future, it is uncertain at best and if Congress continues to be "dysfunctional," we may have a period of five to seven years of budget cutting.[6] There is a wonderful little book by David Boren, president of the University of Oklahoma that I recommend reading.[7] "America is in trouble because its people are losing faith in the country's future. We have grown cynical of our political system and dubious of its ability to effect meaningful change." The attitude of society toward our government's inability to solve the debit problem may affect the number of students entering our programs and resources for teaching and research. While this may seem very negative, our past has shown that we have a strong foundation to build on and we will change to meet the challenges. The most important rewards for faculty will still be there.

It is quite appropriate that we are meeting in Philadelphia, the birthplace of our democratic form of government, and discussing the future of engineering education. We need to develop a strong alliance among engineering educators such that we educate the public on the importance of engineering education to the future of our country and society. Companies are built on an educated workforce and new innovations come from our students when they enter the workforce. Most leaders in the area of economic development realize that companies locate where there are adequate technical, business and engineering employees. It is up to us to provide the fuel for economic development.

How will the curriculum change to meet the needs of our future society? The current discussions about a five year first professional degree, while having merit, may well be overshadowed by state legislators pushing for shorter degree programs (120 hours) and greater retention of entering students. If such occurs, we must work to maintain the quality of our programs in the face of budget constraints. While 120 credit hours may be sufficient for a degree in general studies or liberal arts, it becomes problematic for engineering programs to squeeze everything into that number of credits. What can we cut from the curriculum and still provide our students with the quality foundation upon which to build their engineering careers?

We also need to educate people that we are becoming a much more technical society and need to have some basic understanding of technology. "Though ours is an age of high technology, the essence of what engineering is and what engineers do is not common knowledge. Even the most elementary of principles upon which great bridges, jumbo jets, or super computers are built are alien concepts to many. This is so in part because engineering as a human endeavor is not yet integrated into our culture and intellectual tradition. And while educators are currently wrestling with the problem of introducing technology into conventional academic curricula, thus better preparing today's students for life in a world increasingly technological, there is as yet no consensus as to how technological literacy can best be achieved." [1]

What are the facts on nuclear energy? What is global warming and how much is generated by automobiles, power plants and our use of energy in our homes and industries? What about the third world countries which are struggling to gain some of the luxuries that this energy has provided to us? My last two years of teaching provided me with the unique opportunity of working with a colleague in political science to teach an introductory course in Renewable Energy which was open to students of all disciplines.[8] This course provided me with a new appreciation of the importance of building a foundation of understanding for the students based on three legs of a stool; the technical, the policy and the economic. How many of your courses do you try to tie all of these together for the students? It is easy to discuss the technical issues of renewable energy with our engineering students but much more difficult to get a political science student to understand even the first two laws of thermodynamics. And the engineering students have just as much difficulty understanding policy concepts such as "public good" or the energy policy act of 1992. Can we afford to isolate ourselves from our colleagues on campus and turn out graduates with a very narrow perspective? While technology may drive many of the changes in the future, public policy, regulations and subsidies may well determine which technologies are successful. Do the people making the policy decisions understand even a small amount of the technology? Is it important that they understand the technology issues or should energy policy be based on subsidies to certain states because they have an abundance of corn, natural gas or coal?

A major driver for engineering education for the future will likely be the number of students adequately prepared in science and mathematics when entering the university. Most of our state schools have a large number of freshman remedial courses. The majority of students enrolling in remedial math and science courses are not interested in engineering but those who are interested seldom make it to our courses because they do not develop the strong math skills or they realize they may take several years longer to get their degree and they cannot afford it. We have made great strides in working with the K-12 system to interest more students at an early age in science, technology, engineering and math courses, but we are still behind. Will funding be cut from such STEM programs as our resources are cut? We must realize that these students are our future.

It seems to me that the demands on faculty will increase in the future. They must be excellent teachers using the most modern communications technology. They need to attract significant amounts of research funding, they need to publish extensively and they need to help develop the K-12 pipeline into an engineering career. In addition, they need to insure that the curriculum is up-to-date and meets the needs of new and developing industries.

Will the rewards still be there for our young faculty members? Can we maintain the tenure and promotion bar at a level that is reasonable to attain or will we lose too many of our good teachers? We also must look at opportunities to use retired engineers from industry to teach some of our courses and laboratories. Their experience is valuable to our students, but we must treat these instructors with the respect they deserve. I have seen too often that such faculty members are viewed as second class citizens by our tenure track faculty. They are also often underpaid for the amount of work involved. With budget cutting we often lose our temporary faculty funds and have to load our faculty with additional courses.

So what does the future hold for us in engineering education? Engineering education programs have a number of strengths based on our past focus on quality. We still have a number of weaknesses that we need to address such as requirements placed on faculty for tenure and promotion. New opportunities to build on a sound foundation of quality are certainly in our future and we have to face the threats of budget cutting which could destroy the foundation we have built.

1. To Engineer is Human, Henry Petroski, Vintage Books, 1992
2. ASEE DataBytes, Faculty Demographics, September 29, 2011
3. The Washington Post, September 30, 2011, "Our unprepared graduates" by Kathleen Parker
4. The Limits to Growth, Donella H. Meadows, Dennis L. Meadows, Jorgen Randers and William W. Behrens III, Universe Books, 1972
5. T.E. Batchman and A. I. Wearing, "Application of Dynamic Modeling to the Social Consequences of Tele-communications," IEEE Transaction on Systems, Man and Cybernetics, Vol. SMC-6, 9,(Sept. 1976) pp. 612-622
6. AP story, October 1, 20011, "Analysis: Congress' dysfunction long in the making"
7. A Letter to America, David Boren, University of Oklahoma Press, 2001
8. Christopher A. Simon, Alternative Energy, Bowman and Littlefield, 2007