AC 2012-4414: GENERAL EDUCATION: KEY FOR SUCCESS FOR AN ENTREPRENEURIAL ENGINEERING CAREER

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Engineering and General Education:
Partners for an Entrepreneurial Engineering Career

Abstract

If an engineering program has superb technical content, what, if anything, can be done to raise the level of educational excellence in its graduates? Especially, if a key intent is to increase the degree entrepreneurial-mindedness of its graduates and promote innovation? We believe the answer is to truly integrate the core professional competencies cultivated by general education into the engineering curriculum and to have general education courses more specifically connect to issues that engineers need to be more aware of in a career climate of extensive globalization. General education is an essential educational component to be embraced as being on par in importance in an engineering curriculum with technical topics, science and math. The definition of general education is intended to include the humanities, social sciences, and business.

The purpose of an education is not just to provide job skills, but to provide the foundation for a lifetime series of careers. Engineering graduates should recognize that while technical skills are readily perishable, professional skills/competencies are more likely to endure. The latter skills will play a key role in career advancement and job survival since professional skills, when accompanied by technical skills, provide long-term career value. This includes but is not limited to the ability to recognize societal needs, assess perceived versus real needs, work with others to address these needs, communicate effectively, and provide innovations that contribute commercial value. For the development of entrepreneurial minded graduates, the educational contributions provided by general education are essential for career success.

Introducing an entrepreneurial mindset in an engineering curriculum will not be accomplished by adding courses. This challenge must be addressed by making the liberal arts, social science, and business topics relevant to engineering students in a practical sense that allows engineering graduates to commit to engaging in a world driven by more than technical facts. Professional competencies and engineering skills/knowledge must be integrated, together in the same course, because that is how the graduates will engage their careers and innovate.

Introduction

Bob Taylor (Taylor Guitars) states "…. This is how every business starts, with creativity and vision. As a business grows and matures, this is the most important thing to hold onto to. I think there is a tendency for a business to get stale as it gets bigger, but it can't be allowed to. That creative spark has to be nurtured, and a business, no matter how large, has to stay willing to completely change, sacrifice and remake itself in order to stay fresh and relevant." [1]

For all businesses and organizations, for profit or non-profit, regardless of size, innovation and an entrepreneurial mindset form core assets for long-term survival. How does a curriculum, a program, and faculty instill and nurture the spirit of innovation in the first place?

What is often lost in the educational process is that businesses and organizations, at a minimum, must have some essential components. Among such essentials are:

- A revenue stream
- A business plan for profitability
- Leadership

One can argue about adding one or two more to the list. And, one can argue how best to phrase the items on the list. But the essence of the list remains. Engineers, because of their critical position within companies, are integral to addressing those essentials at some level. How is that being done in the typical engineering curriculum?

The important questions presented in life generally have no single correct answer, and few answers that are dependent on mathematical precision. Problems faced are murky with many possible ill-defined boundary conditions. The careers pursued by engineering graduates are defined by technical issues, pressures involving cost of idea/product development, time to market, market share, and project profitability. If the latter items aren't part of one's career thinking, that career is in great jeopardy because one is pursuing one's career as if it is a hobby. Would you as the owner or manager of a company pay someone to pursue their hobby? Probably not. Others won't fund your hobby either. Engineers need to contribute to the revenue stream, business plan, and leadership. How is that being taught in the typical engineering curriculum?

The rapidly changing scenario playing itself out on an international stage is redefining the competitive nature for both companies and individuals as they attempt to navigate the waters of greater uncertainty to be dealt with in a shorter time frame. Disruptive technologies seem to abound all around and the need to adapt to this speed of change tests the economic vitality and survival of many a company, witness the fortunes of Motorola (from dominance to being bought mainly for its intellectual property).[2] Similarly, the fate of engineers is such that in the long run they are apt to fall victim to the succeeding wave of new technology unleashed by the next generation of graduates from their alma maters.

Old News – New News

For the engineering community the situation described is both old news and new news. It is both praised and feared. But, above all, it is inescapable and needs to be dealt with. It is old because technology has been changing for a long time, especially since WWII. But the speed of change and the hugely increased pool of real and fierce competition by the entry of developing nations into the mix have made the topic very urgent.

The engineering community has responded to this situation with various efforts that focus on the attributes of the engineering graduate of the future, be it the year *Engineer of 2020* or some other time frame.[3], [4] There is general agreement by a number of groups on most of the attributes and overlapping lists are formed. These lists include ABET's well known (a-k) Student Outcomes[5]:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice."

Specifically to be noted are the strong inclusion of educational aspects that do not focus on technical matters. Even technical knowledge is presented in the context of being able to apply that knowledge in a demonstrable, meaningful, understandable manner.

Another related effort is the directional setting outlined by the National Academy of Engineering in "The Engineer of 2020" [3]:

- "We aspire to engineers in 2020 who will remain well grounded in the basics of mathematics and science, and who will expand their vision of design through a solid grounding in the humanities, social sciences, and economics. Emphasis on the creative process will allow more effective leadership in the development and application of next-generation technologies to problems of the future."
- "Just as important will be the imperative to expand the engineering design space such that the impacts of social systems and their associated constraints are afforded as much attention as economic, legal, and political constraints (e.g., resource management, standards, accountability requirements)."
- "…. issues related to climate change, the environment, and the intersections between technology and social/public policies are becoming increasingly important."

The related suggested attributes of engineering graduates that would allow those graduates to more properly address such aspirations are projected to be:

- Strong analytical skills
- Practical ingenuity
- Creativity
- Communication
- Business and management
- Leadership
- High Ethical Standards
- Professionalism
- Dynamism, agility, resilience, flexibility
- Lifelong learners

More recently the Kern Entrepreneurship Education Network (KEEN) entered the scene, determined to change the state of engineering education by focusing on an educational process that would instill into every engineering student the need for and the tools for being entrepreneurial in their career pursuits upon graduation.[6],[7] To accomplish that the following "KEEN Student Outcomes" are defined:

1. Effectively collaborate in a team setting
2. Apply critical & creative thinking to ambiguous problems
3. Construct & effectively communicate a customer-appropriate value proposition
4. Persist through failure to learn what is needed to succeed
5. Effectively manage projects and apply the commercialization process (within respective disciplines)
6. Demonstrate voluntary social responsibility
7. Relate personal liberties and free enterprise to entrepreneurship

The KEEN outcomes both overlap and complement the ABET outcomes, but also go much further. The attributes of "The Engineer in 2020" are more closely aligned with the KEEN outcomes but lack the support of active engagement that KEEN provides to fund curriculum and faculty development that would result in a graduate who is entrepreneurial minded. KEEN in its purpose is much more explicit.

Defining the Problem

As educators we have the responsibility to address the issue of how to prepare students to seek wisdom and relevance within the turbulent sea of information which surrounds us all. That responsibility is exercised when we design and create the various aspects of our curriculum. The question to be answer in doing that task is not "What do we as faculty wish the curriculum to be?" but rather "What must the various aspect of the curriculum be in order to assure the competitive success of our graduates?"

Education is more than the building of core knowledge of facts, principles, tools, and technical relationships. It is more even than the development of professional skills. Education in the current era should result in a sense of identity that provides direction and drive for seeing and addressing opportunities surrounding us and providing meaningful solutions in people's lives.

Survival Necessity

How does an engineer survive in an environment that promises to maintain, and most likely increase, its growth rate of technological improvements and inventions?[8],[9] Simply telling students and graduates to keep their nose to the grindstone and work hard is not a coherent and realistic response. That message lacks direction and does not significantly improve their career opportunities. The challenge faced by engineers as they age is the typical challenge of middle management, either move up or, as a minimum, increase the value they contribute as their cost to the company increases with their age. And, keep abreast of new developments so that when technology shifts occur they can move with those shifts and not be left behind. This issue is

particularly acute in the field of Information Technology (IT),[10] and affiliated fields such as software engineering.

How do we propose to prepare our students to do this?

Speed of Change

Same genes, faster pace. That is the dilemma graduates face. Just how fast can we change? And, somehow the process is not just address how to survive but how to thrive in an environment of change. Our graduates cannot have the attitude of waiting, because surely change will pass them by, but be proactive; lead, not blindly follow,

How do we propose to prepare our students to do this?

Flat World?

Tom Friedman was extremely insightful in his book "The World is Flat - A Brief History of the Twenty-First Century".[11] There are additional observations that need to be made. The "flatness" as it applies to mobility of ideas, technology, and competition we readily observe. And, we all have anecdotal data points of graduates who operate comfortably in that environment of mobility and technology coming from all parts of the world, in particular China and India. But, that flatness is actually very "lumpy and bumpy" and not at all bidirectional for most American engineers, who have a more limited international background in comparison to our foreign competitors, and encounter "borders" of language skills, culture differences, geography, living standards, and political systems.[12] Their world is smaller and flat within the geographical boundaries of the US.

How do we address those issues within an engineering curriculum?

By the Numbers

The engineering educational process must embrace broader competency parameters, including technical/global/professional/personal. That challenge can be defined in mathematical terms. We compare the essentials of a normal engineering education, its emphases on technical courses, math and science, to that of the professional competencies. Expressed in a ratio of percentages the reality and the desired outcomes for graduates can be stated as:

An 80/20 curriculum must result in a 50/50 graduate[12]

How do we propose to design our engineering curricula to do this?

No Additional Courses

The movement in engineering education is to cut, not add, courses to the curriculum.[13] This is sometimes mandated by legislative bodies. The expense to students is also a competitive factor. In any case, would the addition of courses really be a solution for achieving an education that

allows greater competitiveness on the part of the graduate? To some degree, probably yes. But it is not a fundamental solution.

How do we propose to design our curriculum? What should the goal(s) be for revamping a curriculum? The answer(s) must address the industrial competition that companies and individuals face.

What to do?

How should (not could) we prepare our graduates for today's career environment? The year 2020 is too little, too late – the action will be substantially over – it is too far into the future. We should address the year 2012.

Answer: ***Engineering education by itself as practiced today is not capable of meeting the current educational needs of its students.*** *We must have an intertwining partnership of engineering and liberal arts and business education. Together the educational goals, in the form of the desired attributes can be achieved. All the partners have a vested interest in the education of our institution's engineering students.*

Which stem is the source for a given leaf?

Figure 1. Intertwining of Engineering and General Education[14]

Our statement is bold because the issues are too important to dance around by saying engineering programs presently require numerous general education courses and, hence, are doing a good job. The former is true but the latter is not readily claimed. While the general education courses may serve the students in that major quite well, the question we are concerned with is "how does a limited set of such courses serve the professional preparation of engineering students?"

Employers commonly raise the topic that engineering programs need to improve the professional skills of its graduates in order to match the job demands (becoming true worldwide).[15],[16],[17] The Academy of Engineering stated the issue well in *Engineer of 2020*, as already noted.

Engineering education very properly places strong value on teaching engineering knowledge, along with the normal complement of math and science. That is what traditionally has been viewed as having met the requirement for entry into industry. While that is substantially still true today, it does not meet the requirements of preparing for a career. And after all, education has as its purpose the preparation for a career, not just the entry level job. Much more is needed than just a technical knowledge. We must have an educational process where the curricula of engineering, liberal arts, and business are intertwined and ingrained into each other. It must be a process affecting every student.

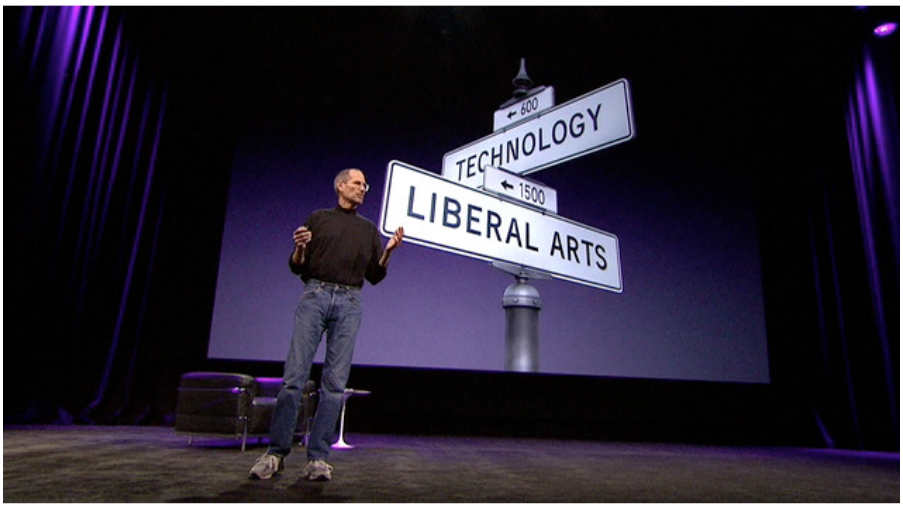

Figure 2. iPad Launch [18]

> *"The reason that Apple is able to create products like iPad is because we always try to be at the intersection of technology and liberal arts, to be able to get the best of both." (Steve Jobs, Jan 27, 2010 iPad launch)*
> *"It's in Apple's DNA that technology alone is not enough. It's technology married with liberal arts, married with the humanities that yields the results that makes our hearts sing." (Steve Jobs, March 2, 2011 iPad 2 launch)*

Engineering, liberal arts, and business have educational differences in terms of specific facts learned, knowledge base developed, tools used, etc. But they are *highly complementary in their desired student outcomes*, such as being able to solve problems, create value and jobs, communicating needs, and work on teams. In other words, we have always been on the same side, even if we all too often fail to recognize that simple fact.[19]

Engineering as a discipline has some particular characteristics:

- It is engaged in continued technical development
- Devotion to precision and accuracy
- Conviction that there is THE correct answer

General Education, on the other hand, has some characteristics that are often viewed as weaknesses by engineers:

- Less concern about precision
- Provides range of answers

The characteristics for General Education are in fact strengths. There is no a priori correct answer for opportunities and situations that are not clearly defined. The wider, more open view of the world that is encouraged by General Education can provide a deeper understanding of the problem being addressed and greater possibilities of a solution that addresses more than just technical factors.

A recent study of NSSE data suggests "that different educational outcomes between majors are the result of programmatic differences. The packed engineering curriculum requires students to make trade-offs between gaining practical/marketable skills and participating in educationally enriching activities." And, "the greater workload engineering demands and the packed curriculum require students to choose between earning the engineering degree and participating in enriching educational experiences."[20] Such a choice is bad for students and their careers, bad for companies who expect capabilities not being developed, and bad for the competitiveness of the nation. There must be deliberateness in the design of the curriculum.

What are some aspects of such a revised curriculum? We propose:

- Not being able to add additional courses requires the existing courses to be co-designed. The courses include those offered by the humanities, social sciences, and business. That also eliminates the need for a "champion" since the material will be truly rooted and isn't an add-on. This allows for a lasting impact.
- We must invert the "funnel" that characterizes much of our educational process. The engineering educational process often is like sausage making. The curriculum casing generates an "admirable uniformity" that tends to channel thinking along approved directions. This is not very entrepreneurial. We must expand the universe that students perceive as they go through the curriculum.
- The curriculum must open the window of the mind. And, we should worry less about the uniformity of the end "product." Student should see problems as opportunities that can provide value.

What are some specific attributes that should be encouraged, developed, enhanced, and promoted in a curriculum in order to have a graduate who is open-minded to the world's need, is personally driven by an understanding that he/she needs to innovate, and that career success is driven by adding value in some contexts. A reasonable list of attributes would probably include:

- Communication skills
- Teamwork
- Problem solving
- Inquisitiveness
- Self-starter
- Recognizing needs as opportunities
- Thinking in terms of technology and business
- Thinking of the end use

Other attributes can be added. **The key is that these attributes must be part of the design of the curriculum and extracurricular activities. And, this is what should be emphasized in the educational process**.[21],[22]

How is it that student can learn "to see the un-seeable" and, finally, do the "undoable?" They must learn a simple truth that as a graduate they ".. start with the customer and work backwards."[23],[24] Such is the power of a mind that is open to the needs of the world that some see it even as a vehicle for addressing major social differences.[25]

Examples of Curriculum Planning

Milwaukee School of Engineering (MSOE)

Milwaukee School of Engineering (MSOE) is a private, non-sectarian university serving approximately 2,400 undergraduate students and has a primary focus on engineering education. The various engineering programs are divided among three departments, each of which contains multiple programs; example, EECS has a total of five undergraduate programs and three graduate programs. Having such a strong focus on engineering can serve as an advantage since changes to the core liberal arts curriculum would affect all engineering programs.

- When MSOE recently established a University Scholars program for engineering students, 12 credits of the freshman year, credits normally devoted to institutionally required courses such as English Composition, Speech, and other such topics, were taken and used to generate a totally new set of courses devoted to a theme that integrates a myriad of liberal arts topical areas and connects students to their engineering majors. Details of the course series is being presented as a separate paper at the 2012 ASEE Annual Conference.[26] A major strong point of this approach is that the courses are scalable allowing all liberal arts faculty of varied backgrounds and interest to teach in a manner that stays true to the required course syllabus.
- Incorporating entrepreneurial ideas into a required humanities course, allowing a business and engineering context for liberal arts issues.
- GS for a special topics seminar in Innovation Studies, allowing for a wide variety of non-technical issues to be joined to the innovation process.
- Team teaching by General Studies and Mechanical Engineering faculty members of a course on "Toy Design," allowing for mechanical engineering, material science, ethical, and other issues to be developed.

Western New England University

Western New England University (WNE) is a private institution severing 3,650 students, with 2470 students in full-time undergraduate degree programs including 300 students in the College of Engineering. Each program in the University promotes educational opportunities that are a unique in the 'integration of liberal arts and professional education, theory, and practice.' (WNE website) WNE follows a general education model that outlines fundamental competencies and sets requirements for every student seeking a degree from any of its three undergraduate Colleges (Arts and Sciences, Business and Engineering). The 'foundations' define the four areas

fundamental to every students success in college and beyond. Our engineering curriculum is strong in 1) mathematical analysis, 2) communications, 3) critical thinking and 4) computer competence and information literacy.

The First Year program at WNE establishes and assesses the students' first exposures, and then individual College's specify the requirements and assessment methods for their discipline specific curriculum. More specifically, our General Education model is rooted in the 'Perspectives of Understanding' and every WNE student must complete a minimum of seven perspective courses. It is within these courses that we can have the greatest impact on our engineers. To quote from our catalogue, "Ultimately these perspectives have the potential to deepen our judgments and inform our responses to the opportunities and challenges of life and work in the 21st century." This is very much in line the entrepreneurial mindset we are trying to bring to our engineering students.

Our courses, available to all students, will share our university's breath of expertise among both our faculty and students. Each perspective course contains three components; "1) method of analysis in the discipline, 2) factual foundation in the discipline, and 3) contribution of the discipline to a greater knowledge of contemporary issues to other phenomena relevant to the students' experience, or to personal career aspirations."(WNE catalogue) The Perspectives of Understanding include Natural Science, Behavior Science, History, Cultural Studies, Ethics, Aesthetics, and Integrated Liberal and Professional topics. Our ILP (*Integrated Liberal and Professional*) courses make a clear connection between liberal education and professional practice, and provide a unique educational experience for students. Examples of these courses are Cultures and Emerging Markets, Business and the Global Environment, Global Sustainability Management, Global Warming, Leadership and Group Skills, and Problem Solving Through Design. Most have been developed collaboratively by faculty from our different Colleges.

Another hallmark of our General Education Requirements is our *Learning Beyond the Classroom* (LBC) experience in which students formally connect their classroom learning to real world experiences gained in the workplace, in the community or in co- and extra-curricular activities. Each qualifying experience involves a minimum of 15 hours of outside activity and the completion of a 1000 word reflection paper on the values of the activity. Two experiences are required for graduation, preferably one sophomore year and the other senior year.

Conclusion

An intertwining partnership of engineering and liberal arts and business education is required to adequately prepare engineering graduates with the necessary attributes to be competitive in the current and foreseeable career environment. Engineering education by itself is not capable of meeting the educational needs of its students. Further, adding courses is not a realistic solution. It is the redesign of the curriculum using the existing credits that addressed the need to integrate topic areas vital to provide a more complete education.

A key element of the desired student attributes is to shape the mindset of the graduates to be entrepreneurial in recognizing problems as opportunities. Doing so adds value to their work and will enhance their career prospects. Doing this successfully requires a mindset that includes

factors such as societal needs and is customer focused. To achieve this liberal arts and business topics are an essential educational component to be embraced as being on par with technical topics.

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