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The 21st Century Engineer

Abstract

Engineering education reform is not a new issue or a new debate. However, engineering education reform is now a global crisis that is being brought into sharper focus as the world begins to confront such transnational issues as climate change, decaying infrastructure, infrastructure security, natural disasters, etc. While engineers remain strong in terms of their technological skills, they are generally weak in terms of their management and communication capabilities. They do not fully understand the concept of globalization; have a firm grasp of the issues confronting the 21st-century engineer; lack the competencies that would enable them to rise to leadership positions within government and industry; and are not developing curricula that would train engineers to anticipate and focus on the rapid changes by which the 21st century will be at least partially defined.

The American Society of Civil Engineers (ASCE) with its Body of Knowledge has highlighted the need to quickly develop continuing education modules in order to best prepare the engineer for enhancing their skills to in turn enhance the profession. This concept is founded on the concept that *all* engineers need to broaden their skill sets if they are to become leaders in business and public policy. The paper is geared toward engineers interested in enhancing their skill sets, be they company executives who are trying to determine what continuing education is needed for their employees so their companies will succeed; students who want to enhance their studies and get a head start in their careers; officials with government entities as they face critical engineering issues and determine how best to solve them; and educators, who can truly make a difference in engineering education reform.

The need to educate the engineer of the 21st century more strategically is essential to the endurance of the profession. Developing a proposed education program through modifications of successful programs to meet the needs of the 21st-century engineer will enable engineers to acquire the skills necessary to succeed in the world economy and to grow within the domestic engineering and construction market in a more transparent manner. This paper is based on the author's book *The 21st Century: A Proposal for Engineering Education Reform* which will provide the reader with a better understanding of what a 21st-century engineer may be facing in his or her endeavors, of how we as a profession must elevate our public standing and increase the public's confidence in us, and of what skills may be necessary to add to one's individual tool box in order to succeed in the 21st-century global marketplace.[1] The paper also provides a model for engineering education suggesting curricula which could be used for a master's degree in professional engineering management.

Why the Need For Engineering Education Reform?

The world changed more during the past hundred years than during any preceding century. By the dawn of the new millennium, the developed world constituted the healthiest, safest, and most productive civilization in history—a civilization that has advanced and continues to advance with extraordinary rapidity, in large measure through the achievements of the engineering profession. But the speed with which this civilization continues to advance is fundamentally challenging the way in which engineering is practiced and the way in which engineering students are educated. Technological breakthroughs—the Internet most prominent among them—have effected an

increasingly global "workplace" in which the collaborative efforts of multinational teams are unhampered by geographical distance or time zones, and this global workplace in turn is introducing new imperatives not only to engineering practice but to engineering education as well.

For nearly 20 years, numerous journals, articles, reports and studies have been prepared by the American Society for Engineering Education, the Academic Press, the National Science Board, the National Science and the American Society Civil Engineers which discuss the critical need for change to engineering education. Yet despite the numerous literary library on the subject of engineering education reform, the engineering curriculum of today still does not provide the foundation necessary to ensure the engineer's success in the 21st century. A report by the American Electronics Association in 2007 notes that the 21st-century global economy portends to be very different from that of the 20th century and that national public policy must be viewed through the prism of education as a lifelong process.[2] In the past, the skills workers acquired would serve them well for decades. In the 21st century, however, an engineer's success or a firm's success will be measured against how well they can adapt to new conditions and technologies. Thus to remain competitive in this global and knowledge-based economy and to ensure that the quality of life improves for everyone around the world, engineers must be educated differently.

If engineers are to compete successfully in this global workplace and establish themselves as leaders in solving many of the world's most pressing problems, engineers must embrace the need for professional innovation and they must do so quickly. The debate over whether a four-year degree is sufficient to be a practicing professional engineer has been debated for at least two decades. However, despite the debate, credit hours continue to decrease. Companies and Governmental bodies alike are crying out for engineering education reform that will allow engineers to broaden their technical skill sets with those skills required for engineering management in the 21st Century. Engineering education will need to reform and expand beyond the current four-year degree akin to the proposals by the ASCE Body of Knowledge, the U.S. Council on Competitiveness, the National Academy of Engineering (NAE) and the requirements set forth in the proposed "Model Law" by the National Council of Examiners for Engineering and Surveying (NCEES). Engineering educators must understand that long-established methods of practicing engineering and educating engineers are in critical need of reform, and they must understand that they must act decisively within the next several years to ensure that these reforms are adequately formulated and implemented.

Practicing engineers must also embrace the need to enhance their image on the world stage—to elevate their professional standing to the highest level. Engineers by and large have come to be viewed as technicians—as commodities of sorts, not as practitioners of a profession engaged in a high calling comparable to the practice of law or medicine, for example. It is essential that engineers alter this perception. Of course, in order to elevate their professional standing on the global stage, engineers must understand why and how they must do so.

Central to the question of *why* they must do so is the engineering profession's very survival. If engineers are relegated to the role of technician, they will no longer command the levels of responsibility that will enable them to successfully compete in the global economy or assume the

leadership roles that will enable them to elevate standards of living worldwide and provide enhanced protection of the environment. Central to the question of *how* they must do so is engineering education reform. Engineers must understand that the four-year engineering degree is no longer adequate. The engineering student will not—indeed cannot—learn within a four-year time frame everything that he or she will need to know in order to perform adequately, let alone successfully, as an engineering professional in this rapidly advancing global marketplace.

Once they become practicing professionals, engineers must understand that the world in which they are working is an ever-changing milieu: not even the fundamentals are fixed as new technologies continue to emerge. Engineers must accept full responsibility for their own continued education, and engineering schools must prepare them to do so by teaching them how to learn on a lifelong basis.

Skill Sets Needed for the 21st Century Engineer

Today's engineers simply do not possess many of the proficiencies needed to compete internationally or to advance the engineering profession. While engineers remain strong in terms of their technological skills, they are generally weak in terms of their management and communication capabilities. Moreover, they do not fully understand the concept of globalization; they do not have a firm grasp of the issues confronting the 21st-century engineer; they lack the competencies that would enable them to rise to leadership positions within government and industry; and they are not developing curricula that would train engineers to anticipate and focus on the rapid changes by which the 21st century will be at least partially defined.

In its 2004 book *The Engineer of 2020: Visions of Engineering in the New Century,* the National Academy of Engineering defined the engineer of the 21st century as follows:

"Engineering is problem recognition, formulation, and solution. In the next twenty years, engineers and engineering students will be required to use new tools and apply ever-increasing knowledge in expanding engineering disciplines, all while considering societal repercussions and constraints within a complex landscape of old and new ideas. They will be working with diverse teams of engineers and non-engineers to formulate solutions to yet unknown problems…. The engineers of 2020 will be actively involved in political and community arenas. They will understand workforce constraints, and they will recognize education and training requirements necessary for dealing with customers and the broader public. Engineering will need to expand its reach and thought patterns and political influence if it is to fulfill its potential to help create a better world for our children and grandchildren."[3]

The global picture of the 21st Century is one of megaprojects, sustainability, infrastructure security, and multi-cultural teams-all that will pose engineering management challenges and for which engineers of today are largely unprepared. The practice of engineering continues to grow increasingly more complex. As a result of the rapid rise of information technology, the explosion of knowledge in engineering and construction, the enhanced public awareness of and involvement in engineered projects, and the growing complexity of civil infrastructure systems around the world, the job performed by the engineer continues to become more demanding. This

trend is almost certain to accelerate, and as a consequence engineers will be expected to possess both a breadth of capability and a specialized technical and managerial competence that are greater than was required of previous generations. These requirements will demand that the engineering profession acquire a *new* skill set in order to perform successfully and be respected by the public. In addition to the technical skills, engineers must become more aware of the need to work in teams, consider social issues, understand political and economic relations between nations and their peoples, and understand intellectual property, leadership, risk management, project management, dispute resolution, multilingual influences, and cultural diversity, as these factors will drive the engineering practice of the 21st century. It will become essential that engineers know how and when to incorporate social elements into a comprehensive systems analysis of their work.

Inadequacy of the Four-Year Bachelor's Degree

A comparison of the historical educational requirements for the legal and medical professions serves as an ideal starting point for formulating a platform for engineering education reform. In 1900, the U.S. medical profession required of its graduates three years of college academics followed by a one-year internship. At that same time, the legal profession required two years of collegiate study. The engineering profession—in stark contrast—required *four* years of college study and was considered the most demanding profession in which to gain entry. But not only did the engineering profession fail to maintain a competitive pace with the legal and medical professions during the ensuing century, it actually reduced the number of credit hours required to earn an engineering degree. A few decades ago, the average number of credit hours required for an engineering degree was 140; today—in more than half of American colleges and universities—the number of credit hours required is only 124. The engineering profession is no longer comparable to the legal or medical professions in terms of educational demands and is one reason its image on the professional stage has been diminished. The public shares this view: engineering is not perceived as being as "tough" as law or medicine in terms of educational rigor.

The engineering profession is being asked to do what the medical profession did by requiring medical students to understand human behavior and to develop a sensitive bedside manner so that they could more effectively treat their patients and establish a sense of trust. Additionally, the medical profession determined that general practice would require four years of pre-professional collegiate study followed by four years of professional study and one year of internship. Physicians aspiring to practice as specialists would be obligated to undertake an additional two to three years of study followed by residency in a hospital. The legal profession also increased its educational requirements; aspiring attorneys must complete four years of collegiate study followed by two-three years of study in law school. If engineers are to remain a respected profession as the legal and medical professions are, they are going to need to follow similar education requirements.

The objectives of engineering education simply cannot be achieved within a four-year period of study. As Dan Henry Pletta observed in *The Engineering Profession*, the objectives to which the engineering profession should aspire should be;

- To educate novices for the responsible practice of a specified professional art;
- To transmit applicable existing knowledge after first "distilling" it for concise presentation;
- To search for new knowledge that enhances the art involved;
- To convey a sense of ethics and professionalism;
- To motivate novices for public advocacy roles to protect the public health, safety, and welfare as well as the earth's resources and its environment; and
- To groom societal leaders for a technological civilization that will protect freedom.[4]

The diminishment of engineering education requirements is perhaps rooted in the splintering of the profession into areas of specialization that include, for example, civil, mechanical, chemical, nuclear, mining, electrical, and metallurgical engineering. In 1980, ABET, Inc., listed 21 programs in engineering and 48 in technology. Unlike the legal and medical professions, which speak via one primary professional organization respectively, engineering speaks via dozens of specialty organizations. The engineering profession must compensate for this splintering by making a concerted effort to reestablish unity and focus on shaping educational curricula that educate engineers who can succeed in the 21st-century global marketplace and knowledge-based society.

The fact is that today's engineers are faced with challenges that are vastly different from the challenges faced by previous generations. These challenges include global commercial competition, intelligent technology, and a constantly changing work environment. These demands require knowledge that cannot be acquired by means of a four-year curriculum; they require knowledge acquired via graduate study. It is critical for the engineering profession to understand that the four-year curriculum is no longer adequate—that given the rate of change within the field of technology and the need to cope with the increased breadth and complexity of modern engineering practice, additional subjects of study must be incorporated into engineering curricula at both the undergraduate and graduate levels. These subjects include globalization, leadership, communication, social management, ethics and professionalism, public policy, diversity, project management, risk management, and dispute resolution.

In an article in the *The Bridge,* Theodore C. Kennedy writes;

"We have to change what we expect from engineers, and we have to turn out graduates with broader skills, interests, and abilities. With the commoditizing of basic design engineering and the migration of that function overseas, the traditional training ground for recent graduates is no longer available in the United States.…

I look for different skills than I did 10 years ago. Today, it is not unusual for good candidates to have global references and experience on projects and assignments around the world. I think we must prepare our graduates for that type of career….

I need graduates who can speak before an audience to make a point, either to me or a client. Comfortable or not, engineers today are constantly selling—selling an idea, a concept, a study, an alternative, or just the need for a new document control system….
Engineers must be able to write reports, studies, or routine business letters … I am tired of "cite," "sight," and "site" being used interchangeably."[5]

Heretofore, engineering education has emphasized technical content and has all but ignored professional obligations to the public. Engineering education has largely been developed by educators rather than practitioners, but collaboration between the two segments is essential if engineering curricula are going to impart a thorough understanding of what is required for an engineer to best serve society today. The consistent lack of emphasis on professionalism, ethics, and leadership—even within doctoral programs—has hampered engineers in their service to society.

In *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*, the National Academy of Engineering recommends that the four-year engineering bachelor's program be considered merely a pre-engineering or engineer-in-training degree and that a master's degree be considered the professional degree.[6]

At a press conference held at the National Academy of Engineering in Washington, D.C., on February 25, 2004, ASCE presented its report, *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future*[7] and, in essence, took a stand that the four-year bachelor's degree is not adequate and that additional requirements would be needed that the 21st-century engineer would need to posses in order to become a licensed professional:

> *The first proposal by any engineering discipline to take the educational prerequisites for engineers beyond the four years of formal education, the report also calls for the acquisition of experience before a civil engineer can sit for the licensure exam. It may also be possible for distance learning programs and corporate and government agency educational programs to substitute for traditional academic paths beyond the baccalaureate…. The Society hopes that the report will lead to a revision of current undergraduate and graduate programs to reflect the basic skills, knowledge, and attitudes that will be expected of professional civil engineers and that eventually new programs will be developed.*

ASCE continues its work on the Body of Knowledge and released a draft of the second edition in 2007.[8] The key differences between the first and second editions focus on the aspirational vision for civil engineering, an increase in the number of outcomes and a more highly structured approach to the level of achievement expected for each of the outcomes, at various stages of a civil engineer's education.

Is Engineering Accreditation the Answer?

Over a decade ago, in 1995, *Accreditation Board for Engineering Education and Technology* (ABET) set out the draft of "Engineering Criteria 2000"[9] as a mandate to educators to design curriculums that could produce engineers with the right skill sets to enter the job market. On November 2, 1996, the ABET Board of Directors approved what was initially known as the Engineering Criteria 2000 but is now known simply as the ABET engineering criteria. In the new criteria, there are a set of eleven outcomes that all engineering baccalaureate graduates should possess.

The goals for the criteria were universally and simplicity. The criteria writers concentrated on what it was that all engineers should be able to do which resulted in eleven desirable outcomes, no matter what the discipline. The criteria can be divided into two categories: "hard skills" and "soft skills" or what is becoming increasingly better known as "professional skills". Six of the eleven outcomes address the professional skills including:[10]

- an ability to function on multi-disciplinary teams
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context
- a recognition of the need for, and an ability to engage in lifelong learning
- a knowledge of contemporary issues

The ABET EC2000 accommodates the ASCE *"Body of Knowledge"* discussed earlier.[11] However, while curriculums at many colleges and universities and corporations have been tweaked and even overhauled in some cases in response to ABET's criteria, the quandary is how fast are the new approaches being woven into the coursework? In general, there appears to be a frustration on both sides that it is not happening fast enough.[12]

ABET continues to work though these issues in order to better the curriculum, however, many universities are still struggling of how best to meet industry's needs. According to ASEE, employers want an engineer to be able to do the following in his/her career:[13]

- An ability to apply their knowledge of mathematics, science and engineering to design, conduct experiments, and analyze data
- An ability to perform on multidisciplinary teams and communicate effective solutions in a global and societal context. That means a smattering of everything from history to sociology to psychology
- A yen for lifelong learning
- A bona fide knowledge of contemporary issues

The ABET EC2000 criteria is a first step, however, it is not possible to educate engineers in an undergraduate degree relative to what is required for engineering management skills. While several recommendations and universities have made steps in integrating these soft skills within current engineering curriculum as described in a paper by L. Shuman, M. Besterfield-Sacre, J. McGourty, entitled *"The ABET Professional Skills - Can They be Taught? Can They Be Assessed?"*[14], in order to fully educate engineers to be proficient in the professional skills required to lead and to become policy makers, it will be necessary as recommended by the U.S. National Academy of Engineering to have a Master's Degree which will then provide in-depth studies on these issues. It will then be necessary for ABET and other accrediting bodies of the world to recognize these degrees and universities that provide them as an accredited program. Only in this way will graduate engineers be willing to go back to school for a Master's Degree in this area of engineering education. It will be necessary for ABET (or other government body accreditation institutions) together with industry and engineering professional societies to work together on this critical issue and in concert with one another, promote the benefits of such a

degree and encourage all engineers to go forward with higher education. Only in this way will the engineering profession protect its members, the engineers, from becoming a commodity on the world market and to gain the public trust and recognition that is required to move engineers to a higher plateau.

What the Profession is Doing to Address the Lack of Skills

On April 24, 2007, the ASCE Board of Direction approved an updated Policy Statement 465 which incorporates refinements reflecting progress and change within the profession.[15] As ASCE began to set the foundation for "raising the bar," other professional societies including the National Society of Professional Engineers and the National Academy of Engineering began to take note and offer support. The National Council of Examiners for Engineering and Surveying (NCEES) voted in August 2005 to change the Model Law for professional engineer licensure to include additional education beyond the bachelor's degree beginning no earlier than 2010.[16]

At the 2006 Annual Business Meeting of NCEES, the following language was added to the NCEES Model Law:

> *"Licensure by Examination (effective January 1, 2015)*
>
> *The following individuals shall be admitted to an 8-hour examination in the principals and practice of engineering:*
>
> *An engineer intern with a bachelor's degree with an additional 30 credits of acceptable upper-level undergraduate or graduate-level coursework from approved course providers, and with a specific record of an additional 4 years or more of progressive experience on engineering projects of a grade and a character which indicates to the board that the applicant may be competent to practice engineering.*
>
> *An engineer intern with a master's degree in engineering from an institution that offers EAC/ABET-accredited programs, or the equivalent, and with a specific record of an additional 3 years or more of progressive experience on engineering projects of a grade and a character which indicate to the board that the applicant may be competent to practice engineering.*
>
> *An engineer intern with a doctorate in engineering acceptable to the board and with a specific record of an additional 2 years or more of progressive experience on engineering projects of a grade and a character which indicate to the board that the applicant may be competent to practice engineering.*
>
> *An individual with a doctorate in engineering acceptable to the board and with a specific record of an additional 4 years or more of progressive experience on engineering projects of a grade and a character which indicate to the board that the applicant may be competent to practice engineering."* [17]

While endeavors are under way in the United States, the United Kingdom, and Asia to revamp systems for the certification of engineers and while progress is being made in the accreditation of universities to ensure consistent engineering programs in Asia—particularly in Japan—there is currently no adequate educational system for the engineer of the 21st century in any developed nation. No engineering educational program at either the undergraduate or graduate level teaches the fundamental capacities now required. Developing a proposed education program through modifications of successful programs to meet the needs of the 21st-century engineer will enable engineers to acquire the skills necessary to succeed in the world economy and to grow within the domestic construction market in a more transparent manner.

As the trend toward a more global and more knowledge-based society continues, the practice of engineering must be changed, and this change must be accomplished through engineering education reform. The engineering curriculum can no longer remain as it has for essentially the past 40 years. The subjects of globalization, diversity, world cultures and languages, communication, leadership, and ethics must constitute a core component of the overall engineering education just as physics and mathematics do.

The content of engineering education was diminished across the globe over the course of the past century in an effort to reduce the cost burden to students and to produce more engineers and to process more revenue through the educational business faster. While this devolution resulted in an emphasis on the technical aspects of engineering, it eliminated other critical aspects of engineering education and studies that are fundamental to the very essence of engineering, which is to improve the quality of life and to protect the public safety, health, and welfare. If an engineer is not trained in public policy, ethics, leadership, communication, and management, an engineer cannot adequately serve the public.

In *Educating the Engineer of 2020*, the National Academy of Engineering notes that the practice of engineering needs to change further because of the demands for technologies and products that exceed existing knowledge bases and because of the changed professional environment in which engineers need to operate. That change must be encouraged and facilitated by change in engineering education.[18]

Steps forward[19]

Most of the senior members of our profession likely graduated from baccalaureate programs which required 145 to 160 credits for graduation. The norm today typically ranges from 120 to 135, and these requirements continue to be reduced steadily, not by engineering programs but by universities and legislatures. The effects of such reductions are significant on engineering programs and their coverage of technical and managerial subjects. This trend is also likely to continue into the future; there is no indication of its reversal. How can engineers continue to do more, with less education? The answer is they cannot and if engineers, academe and industry do not work with government to effectuate change, engineering will cease to be a profession and will be a trade on the world commodity market. The time is now and time is of the essence in which change must be made on a global front. Key nations, however, including the U.S, the UK

and Japan must be the leaders in this change and must take action in collaboration with each other if we are to truly make a difference in the near future.

The combination of added educational demands and declining credit hour requirements has had a significant impact on undergraduate engineering education. There has been a decline in the required core engineering coursework which crosses discipline lines. Civil engineers are increasingly less likely to be required to take courses such as thermodynamics and electrical circuits, affecting the breadth of their technical education. Some engineers now take a one semester course entitled statics / dynamics. Basic engineering coursework requirements within disciplines are also decreasing in many universities, as evidenced by transportation engineers who haven't had surveying and thus lack the basics of geometrics, or electrical engineers who understand power distribution but not controls, or vice versa. Further, the practice of civil engineering has become increasingly more complex technically in the past 30 years, yet the technical content of the undergraduate curriculum has not changed substantially during that period. *How can more complex technical issues, resulting from decades of engineering research and technology-driven changes in professional practice, be added to an otherwise over-full undergraduate curriculum in the face of declining credit hour requirements?* In ASCE's view, it's not possible in the future. As engineering is the agent of progress and so the agent of transformation of human life, it is time not only to meditate but to change and to do effectively something to make it better.[20]

If engineers are truly going to be prepared to work in a knowledge-based 21st Century Society, across all borders of the world, then there must be an immediate reform to engineering education. What is needed is a master's degree program that will provide the skill sets that are required to work in a global economy, but are lacking from today's engineering curriculum, either at a bachelor's or a master's level.

Innovative and creative ideas must be considered in order to motivate both the employer as well as the current working consulting engineer to reenter the academic environment in order to gain the required skill sets that will result in a win-win situation for both industry and academia and the individual. Thus, consideration must also be given to reaching beyond traditional forms of engineering education in order to accommodate the working consulting engineer. New forms of education include distance learning, cooperative education between industry and academia as well as special lecture series which can be accomplished in an intensive week of full day education requirements from practitioners in the industry. Effective master's programs require flexible structural characteristics, strong institutional and faculty support, and educational components that give students a sense of identify with engineering practice.[21]

While several schools have begun taking action to offer courses which will meet the new ABET criteria and/or assist in the philosophy of the Body of Knowledge proposed by ASCE, no schools that were surveyed in the writing of *The 21st Century Engineer* offer what the public and businesses are seeking – a program that gives an engineer the necessary skills to work in the 21st Century. However, recognizing that professional skills are requisite for 21st-century engineering practice, several universities in the United States have begun to shape their informational literature to underscore their emphasis on professional skills. For example, the College of Engineering at Purdue University is rethinking engineering education and enacting change-

through original research, through curricula reform, through the innovative design of new facilities and by emphasizing engineering experience, both within the classroom and outside it in order to graduate a "Renaissance Engineer of 2020 who can respond to the global technology, economic, and societal challenges of the 21st Century.[22]

The University of Wisconsin at Madison offers a master of engineering in professional practice (MEPP), which is closely aligned with both my proposed master's degree and the attendant proposed method of education. The MEPP is an online degree that is designed to enable the practitioner to advance his or her career as an engineering leader by participating in the advanced educational program while remaining in active practice:

> *The Master of Engineering in Professional Practice (MEPP) degree provides a blend of technical and management expertise that you can apply to your current position while preparing for engineering leadership roles. A better investment than an MBA for most engineers, this two-year program will improve your ability to: lead engineering projects and teams, communicate effectively as a leader, make effective engineering and business decisions.*[23]

This online program enables an engineer to complete the master's degree within two years without interrupting his or her career. The degree consists of 26 graduate credits obtained by completing 10 courses as well as two week-long summer residencies at the university. The courses that most closely align with those of my proposed master's program include engineering economic analysis and management, technical project management, communicating technical information, international engineering strategies and operations, and quality engineering and quality management.

In reviewing the course offerings at various universities, several areas of emphasis emerge: communication, project management, leadership, the engineer's role in society, and the importance of ethics. Clearly, these areas are being emphasized at the postbaccalaureate level—and universities have devised flexible programs that do not disrupt engineers' careers. Numerous universities now offer programs online that enable engineers to complete much of their course work by means of distance learning rather than by attending on-campus classes. If universities are to be successful in attracting the working professional, and if the engineering profession is to continue to develop, it will be necessary for universities—working in collaboration with industry—to undertake significant reform with respect to the way advanced engineering education is delivered.

Engineering Education Providers of the Future

ASCE's "raise the bar" initiative is intended to apply to all engineering graduates seeking licensure, not just those who choose or are able to attend graduate school. It is anticipated in the future that those attaining bachelor's degrees in engineering will be able to attain the additional required education in a variety of ways, including the increasing use of distance education from quality engineering institutions, and the use of in-house education programs in firms, agencies and technical societies able to provide educational experiences which are documented to be equivalent in content, rigor, learning and assessment to current engineering education.

It is time for engineering educators and engineering institutions consider a master's degree of professional engineering management, or PEM—a 30-hour degree program that requires a written thesis, the subject of which is to be agreed upon by the student and the student's university adviser. This degree program could be completed within two years, but could also be extended over a three-year period, affording an engineer considerable flexibility in accommodating the demands of personal life and career. The degree title—master of professional engineering management—speaks to the acquisition of the professional skills necessary to manage and lead engineering teams and projects. The course work proposed for this master's program is designed to enhance an engineer's proficiency in management and communication capabilities—capabilities that are absolutely essential now.

The proposed master's program is designed for those students who are already at work in professional practice and do not wish to disrupt their practice to return to school, yet who fully understand the need to enhance their professional competence. This program integrates distance learning with on-campus seminars, but is designed so that the large majority of course work can be completed online. It is also founded on the assumption that specific firms will take a keen interest in such a program given the fact that it will enable their employees to advance professionally without disrupting their professional responsibilities to their firms. In fact, some of the courses proposed can be specifically tailored to meet the needs of a specific firm while simultaneously satisfying overall academic requirements. Such tailoring can serve to attract industry support to the program, encourage substantial numbers of engineers to enroll in the program, and enhance the quality of the program by means of an industry/academe interface. Many of the courses in the PEM degree lend themselves to such tailoring—and that can actually be taught on a firm's own premises. The future of engineering education and engineering management is through engineering education reform-reformed by industry and academe working in concert with one another to meet each other's needs relative to educating the 21st Century Engineer.

Conclusion

The move forward will require collaboration between academe, industry and professional engineering organizations. The issue of engineering education reform is being addressed the world over. The subject is of keen interest to the World Federation of Engineering Organizations (WFEO) and UNESCO. Concern by engineers the world over is that if engineers are not educated to deal with these professional issues soon, then the world itself is in peril since the increasing world population, especially in under-developed countries, will continue to challenge the world's resources. Sustainability and the understanding of globalization are critical to the survival of the world population as we know it today and to the premise of the idea that everyone is entitled to "a better quality of life". Engineers will have to develop solutions to deal with these new world problems. However, in order to do that, they must understand world politics and public policy, diverse team concepts, project management, as well as have the ability to communicate this information to others and become effective leaders. This can only be done through education and education beyond the undergraduate degree. It is now time to devise a Master's Degree that addresses these critical issues and to have accrediting organizations; industry and engineering organizations embrace such a degree in order to promote current and future engineers to embark on this critical engineering education.

The new master's degree must still be structured within the required 30 credit-hour required program, but it is how those 30 credit hours of education is provided which is critical if the engineering profession is to truly revolutionize the way engineering education is taught. This will be best accomplished by the reform of the engineering education system and the introduction of a Master's Degree level program in Professional Engineering Management which will cover the project management and professional skills that are now required of a 21st Century consulting engineer, including:

1) An understanding of globalization;
2) The importance of ethics and professionalism;
3) An understanding of diversity throughout engineering and the multi-disciplinary team;
4) Effective oral and written communications;
5) An understanding of leadership principles and attitudes;
6) An understanding of public policy;
7) Project management skills;
8) Risk management skills; and
9) An understanding of dispute resolution skills.

It will be these fundamental capacities that will allow Engineers to develop into independent professional engineers capable of working both domestically and globally, respected by the public and regarded by the government as professionals whose services are to be based on qualifications and not price.

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