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Current and Future Trends in Engineering and Technology Programs

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The practice of engineering – and its counterpart engineering technology – is predicted to be exceedingly different in the future than it is now. The desired end product of an undergraduate engineering technology program is quality raw material for industry. Therefore we have to address the needs of the industrial sector and provide an academic environment that prepares for expected global technological changes. The National Academies Press[1] published a paper in 2004 that stated that "Its principal focus is on the future of the undergraduate engineering education in this country, although it is appreciated that to understand the full perspective, engineering practice and engineering education must be considered in a global context." Educational institutions have started to prepare for those changes which will require a considerable re-development of the educational process: new labs, equipment, faculty, courses, teaching methods, etc. We need to decide, for example, whether to consider new engineering technology programs in view of all the current concern and activity, or initially fashion a program that has current possibilities and, possibly, future limitations. This paper will discuss the need to consider the incorporation of new program areas. This may include cultural/language requirements, bio-engineering, alternative energy and, particularly, interdisciplinary, project-centered programs.

Future Trends

The National Academies Press seeks to develop a vision for engineering by 2020. Some of the factors they have listed as engendering change include nanotechnology, biotechnology, materials science, information and communications technology, environment and the aging population. They noted that "The steady integration of technology in our infrastructure and lives calls for more involvement by engineers in the setting of public policy and participation in the civic arena." In their conclusion they stated that the engineer of 2020 will be faced with myriad challenges and that they "…will be expected to anticipate and prepare for potential catastrophes such as biological terrorism; water and food contamination; infrastructure damage to roads, bridges, buildings and the electricity grid; and communications breakdown in the Internet, telephony, radio and television."

Academic institutions are currently reviewing trends towards new educational approaches and there are corresponding technical articles describing the trends. Dean Paul Peercy of the College of Engineering at the University of Wisconsin-Madison, presented a paper in June, 2004 entitled 'The Changing Face of Engineering'[2] in which he noted that it is time to re-evaluate the traditional approach to engineering education and that the engineers of tomorrow must be conversant in technical fields outside of their major discipline. Further, "… engineers in industry increasingly work in multidisciplinary product design teams that may include members with backgrounds in business, marketing, sales and other areas, in addition to science and engineering." Dean Eleanor Baum of the School of Engineering at The Cooper Union informed the writer that, as Dean Peercy of UW Madison noted, engineering programs should be fundamental at its core. (We note, as a graduate of that college, that The Cooper Union required all of its engineering majors to take many of the same fundamental courses so that all students will have a broad and/or general exposure to engineering disciplines). Dr. Baum recommended that we start with a mechanical engineering-based program that has a principal (project-based) design function and to provide room for a specified variety of technical electives. The Dean also recommends that design opportunities and communication skills be introduced at the freshman level. Dr. Clive Dym of Harvey Mudd College was invited to The Cooper Union to discuss 'The Evolution of Engineering Curricula'[3] in which he noted that his college has a common core in their curriculum that emphasizes engineering design and practice and said that "…design should be the backbone of engineering education and should be highly present in the curricula." A Boston Globe headline stated that 'MIT is reviewing its curriculum for a possible overhaul.' The article noted that 'The Massachusetts Institute of Technology, widely considered the nation's top science and engineering school, is launching a two-year review of its undergraduate education, examining its required courses and other student experiences in light of new developments in science as well as the changing interests of students.' Dean of Science Robert Silby, who will chair the review committee, noted that 'There's much more biology in much of the research that we do' and 'There's much more interest in economics and social science among our students than there was 20 years ago.' A National Science Foundation Workshop in 2002 produced a report entitled 'New Directions in Mechanical Engineering.'[4] The Workshop included presentations in four core areas: Micro/Nano Technology, Biotechnology, Information Technology and Ecology/Energy. Its recommendations stated "…that mechanical engineering needs to anticipate the development in these and other enabling technologies in order to rapidly exploit them in research and educational experiences that we offer to our future engineers.'

Corresponding Technical Articles

A *Prism* article entitled '2020 It's Sooner Than You Think',[5] notes that "…the future engineer must be prepared to work in a time in which what we now consider to be engineering is more likely to be done outside the United States…and perhaps, a time in which the United States is not the world's leading economic power." Another *Prism* article, 'Engineering for Everyone',[6] states that 'In a Technology-Driven Society, everyone needs to know about engineering, and more and more schools are teaching engineering courses to non-engineers.' An article in the *Chronicles of Higher Education* entitled 'Building a Pathway for Occupational Students'[7] noted that "…employers increasingly demand workers who have not only technical expertise, but also skills in language, communication, problem solving and applied math." Further, 'The National Science Foundation's Advanced Technological Education program encourages stronger science and mathematics instruction in community-college technology programs and promotes partnerships between high schools and community colleges and between two-and four-year colleges to improve articulation among them all.' An October 2004 *Prism* article entitled 'Sweating the Small Stuff'[8] notes that 'Nanotechnology offers great promise for improving health and cleaning up the environment, and schools are scrambling to figure out how to teach it.' In *The Global Engineer*,[9] the Dean of Engineering at Purdue University stated "…that the U.S. engineer beyond 2020 will have to address a totally different set of problems from the ones we try to solve today", and "…will have to know how to address or solve a variety of problems, from creating means for communication between indigenous groups, to solving poverty, to providing transportation, to addressing the environment, to accommodating new technology breakthroughs in solutions, to becoming accustomed to a technology progress rate at a 10X to 100X of today's rate." In the *Johns Hopkins Magazine*, an article entitled 'Curriculum Changes are Key to Diversity in Engineering Education',[10] noted that "…evidence is mounting that diversity in engineering student bodies is backsliding rather than improving", and that the key to the solution "…is revamping the curriculum – for example, emphasizing engineering coursework that appeals more to women and minority students, including case studies in which engineering is used to study diseases, improve education, or clean up city toxic waste sites." At the *IEEE-USA Biennial Careers Conference*, in an article entitled 'An Action Agenda for Engineering Curriculum Innovation',[11] it was stated that we need more innovation in engineering programs with better integration of subjects; and to adopt a more innovative and entrepreneurial approach to education. Further, some changes in engineering practice that are occurring include: globalization, design for environment, concept-to-product time shortened, and frequent job and company changes. In the November issue of *PE The Magazine for Professional Engineers*, an article entitled 'Keeping Up With a Changing Universe'[12] noted that "…Engineering has always adapted to changes in technology and society. But as the pace of change reaches astronomical speeds, is the profession prepared?" Also "Report after report has focused on increased specialization, the emergence of new disciplines, and the tighter definitions of engineering disciplines. Some call the change splintering, some call it subdividing, some call it evolution."

Some Current Developments

The Pratt School of Engineering at Duke University has a 'Pratt Vision 2010'[13] which is a ten-year comprehensive plan whose "…goal is to create a culture that nurtures interdisciplinary research and breakthroughs in engineering design, the basic and applied sciences, and medicine, resulting in new products, processes, diagnostic techniques, and therapies for improving the human condition and the environment." Their research will make major investments in four cross-department strategic initiatives: Photonics and communications, bioengineering, materials engineering and sensors and simulators. Eva Pell, Vice President for Research and Dean of the graduate school at Pennsylvania State University, said that nearly 60 percent of basic research at universities funded by the federal government is now in life sciences, that funding for engineering and the physical sciences has declined, and cited a recent study showing that published papers by Western European physicists now outnumber those by U.S. authors. 'The Carnegie Mellon Engineer in the 21st Century'[14] stated that their more specific objectives include the following: "Broadly educate our students, but also…provide a flexible curriculum that allows students to make diverse choices and follow unique career paths.' 'The New Mechanical Engineering Curriculum at the University of Michigan'[15] describes the new undergraduate program in the Department of Mechanical Engineering and Applied Mechanics. The following objectives are to be addressed in the new curriculum: experience with complex mechanical devices; teamwork and communications skills; customize the undergraduate degrees; introduce a sophomore level course in Design and Manufacturing; consolidate all required laboratories into a junior and senior lab sequence; and introduce a Freshman Engineering class. At MIT, a 'New Programs Welcomed at Faculty Meeting'[16] described a new undergraduate course in biological engineering which will teach engineering entirely in the context of biology. The Department of Mechanical Engineering at the California State University-Fullerton, currently has four areas of specialization: Design and Materials for Manufacturing; Robotics, Controls and Automated Manufacturing; Thermal and Fluids Engineering; Power and Energy.

Additional Considerations

Some of the factors that may influence future engineering and engineering technology programs include:

- Prepare for political, social and economic responsibilities.
- A balanced degree will provide a springboard to other careers.
- Have project-centered courses.
- Work in multidisciplinary product design teams.
- Communicate both cross-disciplinary and cross-culturally.
- Programs should be fundamental at its core.
- More biology and interest in economics and social sciences.
- Interdisciplinary research.
- Expose students to relationships between technology and society.
- Engineering faculty should have industrial experience.
- Program should be based on industry needs.
- Use industry experts in adjunct roles.
- Major impetus on creative/brainstorming teaching.
- Consider Mechatronics, Bioengineering, Nanotechnology
- Start with an ME-based program that has a principal design function.

Program Components

The traditional forms of undergraduate education must be focused upon practical student educational development to clearly and directly serve the industrial and global environment. The following educational components may achieve those goals:

Establish a Freshman Design Experience.[17] The entering students can be exposed to a multi-dimensional course whose basic purpose is to efficiently provide not only an understanding of what is involved in the design process performed in industry, but also the opportunity to develop and employ those design functions and skills at the very outset of the student's undergraduate experience. The several components of the course can be integrated to include: use of library and other technical sources; technical report writing and oral delivery; engineering graphics activity to support design projects; research into the functions of technical societies; discussions of fundamental manufacturing processes followed by design projects that would employ a given process towards the re-design of an existing part; visits to local industries; invitations to people from industry; and discussions about current and projected technology. These activities can be integrated with the development of a wide variety of open-ended design projects within a group format. Each project can provide a creative opportunity for students along with oral and written reports that can enhance interpersonal development. This introductory freshman design experience has been found, by the writer, to nurture an awareness of and interest in further pursuing the formal course structure.

Develop a Continuing Design Program. The project design skills and learning aids developed at the onset of the student's experience can be readily adaptable in subsequent coursework. Further, the formative skills needed for the capstone design course can be implemented via open-ended design projects introduced to complement the specific topic being covered. It is, of course, exceedingly valuable to the student if the educator has had industrial experience and can provide practical design opportunities based upon those encountered in the professional world. A detailed design report may be required and would include a logical analysis, solution, design discussion and summary. The design report can include: title; table of contents; introduction; technical body with sketches, figures, tables, chronological development; results; conclusions/recommendations; appendix; and references. Preference may be given to report development on a group basis to continue to learn how to work in an effective and contributory way with other members.

Establish an Industrial-Based Capstone Design Effort. The goal at this juncture of the educational process is to create a product that will satisfy human needs with respect to function, aesthetics, quality and cost. Satisfying this goal will require an understanding of the interrelationship among concept, technical development and marketability; and integration of the technical and aesthetic skills towards development of an engineered product. A course outline and project sequence might include: a retrospective search; development of ideas; and development of an initial design proposal that would include a critical path, alternate designs, suggested specifications and prototype considerations. Project considerations may include ergonomics, human factors, design life, ethics, codes and standards, fatigue, reliability and legal responsibilities.

Conclusion

Academic and national institutions are currently engaged in a comprehensive review of engineering and engineering technology programs in light of global technological changes and developments that can markedly affect the manner and form that these programs will be taught in the near future.

Preparation for and development of new engineering and engineering technology programs will consider the many factors described herein. Many of those factors that may determine current and future educational trends would include the following additional considerations.

- Embrace continuing education.
- Control the properties of materials at the nanoscale.
- Design should be the backbone of engineering education.
- A balanced engineering degree will provide a springboard to other careers.
- Improve the human condition and environment.
- Major movement in UG curriculum to include Ethics.
- Stronger science and mathematics instruction in community colleges.
- Programs in Alternative Energy.

Finally, if it is decided to engage in a program that has current and, possibly, future limitations, we would recommend consideration for an ME-based program with a principal design function, one that closely matches that encountered by professional design engineers in our global economy.

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