

21st-Century Engineering Education at Marquette University

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It is widely recognized that our economy, national security, and indeed our everyday lives are increasingly dependent on scientific and technical innovation. Engineering is a key component of innovation and our technological society. The quality of engineering education has a direct impact on our ability as a nation to compete in the increasingly global competitive environment of the 21st century. The National Science Board in November 2007 stated that engineering education must respond immediately to three challenges:

- The need to adapt to the changing global context of engineering
 - Basic engineering skills have become commodities worldwide. Other countries have a competitive advantage in low-cost manufacturing and services, with excellent engineers available at one-fifth of the cost of a U.S. engineer. To be competitive, U.S. engineers must provide high value by being immediate, innovative, integrative, conceptual, and multidisciplinary.
- The need to change the public perceptions of engineering
 - Ninety percent of the engineering in the world today addresses the needs of the richest ten percent of the population. What about the other 90%? In addition to addressing the nation's needs for economic growth and defense, engineers need to identify and solve social problems that benefit people, their health and quality of life, and the environment. Engineering needs a renewed human-centered focus and a face that attracts a diversity of students interested in serving people at home and worldwide.
- The need to attract and retain top students in engineering
 - Students need to be shown the difference between studying engineering and becoming engineers. Students need to experience in a hands-on, minds-on way what it is to be an engineer – to identify the needs of people, to think and solve problems using mathematics and science, to generate human-centered ideas and rapidly prototype concepts, to integrate human values and business into concepts, to work in multidisciplinary teams, and to effectively communicate results. This must happen early and often during their four-year academic career. The exclusive use of straight lecturing and the posing of questions for which there is only one correct answer must be replaced by discovery learning. Faculty must guide students to discover engineering through the process of active investigation which: nurtures curiosity, initiative, and risk taking; promotes critical thinking; develops students' responsibility for their own learning and habits of life-long learning; and fosters intellectual development and maturity.

The National Science Board also has stated that a continuation of the status quo in engineering education in the United States is not sufficient in light of the changing workforce demographics and needs. In my view, the status quo in engineering education is characterized by: lecture-mode

faculty teaching and passive student learning; the exclusive silo structure of a university College of Engineering which deprives students of exposure to all disciplines and the multidisciplinary systems nature of modern engineering; and a reward system for faculty and students that promotes marginal teaching and accepts memorization in place of true understanding.

Clearly, a transformation is needed – for faculty and how they view teaching, for students and how they view learning, for each engineering department and how it views its role in collaboration with other departments in preparing students to be 21st-century engineers, and lastly, for the reward system for both faculty and students to enable this transformation to take root. New generations of students, with different backgrounds, interests, skills, and needs, must be attracted to and enthused about the profession of engineering and better prepared, in both technical and non-technical areas, to creatively advance technology and solve the problems the 21st century will present.

Since 1908, the Marquette University College of Engineering has been blending professional engineering preparation with a liberal arts education to provide the world with well-balanced leaders in their profession. Co-developing expertise in engineering with communications and reasoning skills is absolutely critical to engaging, hearing, and reacting to the voice of the customer in ways that are both successful and sustaining. Marquette University is the largest Catholic College of Engineering in the nation with 1100 undergraduates and 300 graduate students. The College of Engineering offers five undergraduate degrees in 11 majors through four departments: Biomedical Engineering; Civil and Environmental Engineering; Electrical and Computer Engineering; and Mechanical Engineering. All five degree programs are accredited by the Accreditation Board for Engineering and Technology (ABET). All departments offer B.S., M.S., and Ph.D. degrees.

A major transformation in the College of Engineering is currently underway in response to the national challenges and needs already discussed:

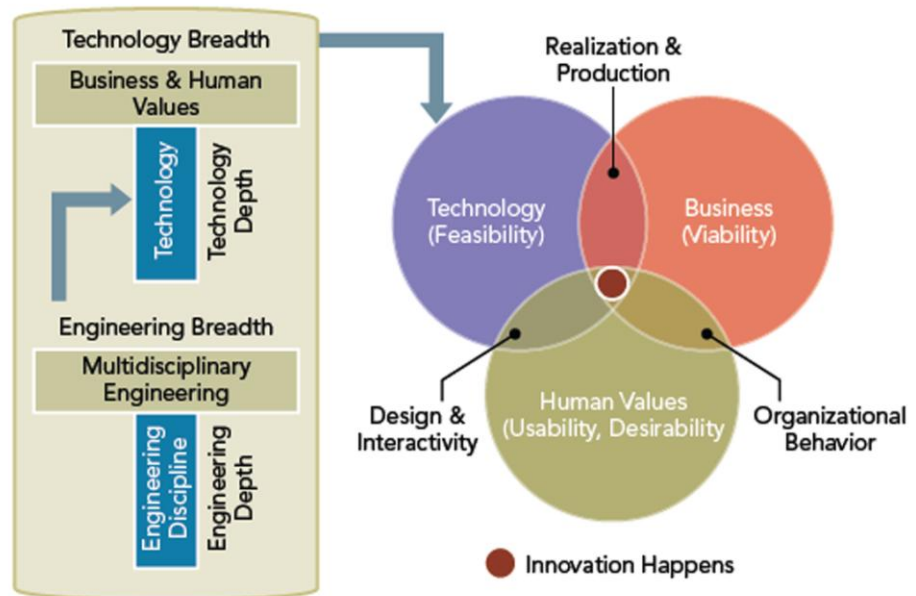
- A new 250,000 square-foot engineering building is in development with construction expected to begin in June 2009. The building will focus on discovery learning and multidisciplinary engineering systems through the transparent multidisciplinary integration of teaching and research laboratories, classrooms, presentation facilities and meeting rooms, faculty offices, teaching-assistant and research-assistant offices, and student meeting and design spaces.
- New curricula are being developed for all disciplines and across all four undergraduate years to support multidisciplinary engineering system design and discovery learning.

The first element in this transformation, a first-year engineering experience, has been created which consists of a two-course sequence in engineering discovery (fall 2008 – spring 2009) focusing on two key engineering processes: the engineering system investigation process and the engineering system design process. This program is designed to introduce students to engineering by immersing them in the experience of what it means to be an engineer. The program objectives are:

- Students will integrate problem solving, teamwork, oral/written/graphical communication skills, and computer usage in engineering system investigations and also design projects that benefit people and society.

- Students will begin to develop the professionalism, leadership, ethical behavior, social awareness, creativity, and critical thinking essential for the practice of engineering.
- Students will recognize the relevance and importance of science and mathematics and the role of business in the practice of engineering.
- Students will understand the importance of physical and mathematical modeling, analysis (both numerical and analytical), and measurement, i.e., the essential elements in the engineering system investigation process, and how this process leads to invention and innovation.
- Students will experience engineering within the various engineering disciplines and recognize the importance of the various disciplines and their interrelationships and similarities.
- Students will gain confidence about their future career as an engineer and their learning of engineering.

Engineers today face daunting challenges. Engineering problems are getting harder, broader, and deeper. They are multidisciplinary and require a multidisciplinary engineering systems approach to solve them. Engineers in the 21st century will need depth in an engineering discipline, but also breadth among all the scientific and



engineering disciplines, as the problems they face are multidisciplinary. In addition to their technology depth, they need breadth in the important areas of business and human values, as innovation happens at the intersection of technology, business, and human values (see figure above).

Students must be transformed to become engineers poised to solve humankind's problems of the 21st century. What starts this transformation? What is the dramatic event that will put an engineering freshman on the right path to becoming an engineer? At Marquette University, new engineering freshmen – high school diplomas still fresh – will be part of a dramatic event – a three-day transformational design experience (see figure below). Students will work in teams, mentored by Marquette engineering faculty, industry engineers, and senior engineering students, on a short-cycle conceptual design focused on an urgent need of the developing world, e.g., food, water, health, energy, education, shelter. Guest presenters, discussions, and demonstrations will help inspire and inform the design teams. High school STEM (Science, Technology,

Engineering, and Mathematics) teachers will be key personnel in attuning the event to the incoming engineering students during preparation and will also participate in delivery.

Students will experience what it means to be an engineer. They will come to view their next four years – their courses, their professors, their classmates, people in need – in a very different way, a transformational way, as they will see how individually they can transform the world, one person at a time. Faculty from all engineering disciplines will work side-by-side with industry experts as together they motivate and guide these students. They will also be transformed. There will be no cost for the student. Procter & Gamble and Rockwell Automation have agreed to cover all expenses for this event and National Instruments has contributed equipment. Members of local industries and high-school STEM teachers are being engaged as design-team mentors. The entire event will be videotaped for the benefit of those first-year students who are not able to attend, as well as for assessment and dissemination purposes.

transformational design for the developing world

join a revolution



All Marquette University entering engineering students are invited to participate in a 3-day hands-on project to help invent unique ways to provide better access to food, water, shelter, health, education and energy to those who are most in need.



June 17-19, 2008
Marquette University
College of Engineering

please join us

Students will work in teams, supervised by Marquette Engineering faculty and seniors, in a short-cycle complete design experience focused on an urgent need of the developing world. Guest presenters, discussions and demonstrations will help inspire, enlighten and inform.

Please join us.

**Transform yourself.
Change the world.**

For more information or to accept our invitation, please call Kevin Craig, Ph.D. at 414.288.4427 or email kevin.craig@marquette.edu.



Make a difference.
Be the difference.
Become an engineer.

Amazing things happen when we claim responsibility for creating the seemingly impossible. In 1961, when President Kennedy called for putting a man on the moon, he didn't know how - but his vision was so compelling, his expectations of the American people so high – that they drove the moon shot well after he died. Marquette College of Engineering is taking a leadership role in addressing this national crisis in engineering preparedness. Engineering education will never be the same again.