Beyond the Engineer of 2020
Whither Engineering Education?

Daniel Hastings
Professor of Aeronautics & Astronautics and Engineering Systems
October 2013
The Evolution of Engineering Education in the United States - Conclusion

• Engineering education continues to evolve in the US
  – More focus on using theories of learning
  – More focus on bringing in active learning
  – More focus on integrating design early into the education
  – Schools are using a variety of approaches to improve engineering education
  – MOOCs may be a forcing function
  – Large Challenges in demographics

• The Result: Islands of success
  – Engineering is becoming more attractive to young people (but with demographic challenges)
  – Much more needs to be done!
The Evolution of Engineering Education in the United States

- National Picture
- Innovative Approaches
  - Olin College
  - Purdue
  - RPI & Georgia Tech
  - Arizona State University
  - MIT
- The Impact of Online Education
- Continuing Challenges
NAE Great Engineering Achievements of the 20th Century - Unappreciated by the Public

1. Electrification
2. Automobile
3. Airplane
4. Water Supply & Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning & Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum & Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials
Evolution of Engineering Education

Did Engineering Science Go Too Far?

Attitudes

Skills

Knowledge

Pre WW II

Tomorrow?

Today?
US View: Call for Educational Reform

The Urgency of Engineering Education Reform and A Makeover for Engineering Education - 2003

- Change needed:
  - Curriculum and pedagogy
  - Diversity
  - Baccalaureate as first professional degree
  - Faculty reward system
  - Formalized lifelong learning
  - Preparation for K-12
  - Technical literacy in the general population

- Two fundamental and related problems:
  - Fewer students going into engineering
  - Engineering schools increasingly out of touch with engineering practice

- Students not being prepared to practice engineering for the 21st century
An Emerging Global Workforce

• “We see globalization...as an overarching “mega-trend,” a force so ubiquitous that it will substantially shape all other major trends in the world of 2020...”

• “Competitive pressures will force companies based in the advanced economies to ‘outsource’ many blue- and white-color jobs.”

• “With the gradual integration of China, India, and other developing countries...World patterns of production, trade, employment, and wages will be transformed.”
  – Competitive source of low-cost labor
  – Necessitates professional retooling, and restrains wage growth in some occupations.

From: ‘Mapping the Global Future’
Report of the National Intelligence Council
2020 Project, Dec 2004
Embracing Globalization of S&T

- Globalization of S&T is an overarching challenge
- U.S. no longer has an unchallenged, preeminent position
- U.S. lead has dwindled or vanished
  - producing researchers in science and engineering
  - technical knowledge
  - high technology exports

Source: NSF – Science and Engineering Indicators 2010
Individuals in S&E work broadly

![Venn Diagram]

Figure 3-10
Intersection of individuals with highest degree in S&E and S&E occupation: 2008

- Individuals with highest degree in S&E working in S&E occupations: 4.9 million
- Individuals with highest degree in S&E: 12.6 million
- Individuals with highest degree in S&E working in non-S&E occupations: 3.9 million


Science and Engineering Indicators 2012
the focus of the Engineer of 2020 report

Integrating what we want in the “next generation” engineer with what we know about how people learn into a field of inquiry and practice focused on engineering learning.
What are the Desired Attributes of the Engineer of 2020?

- Strong analytical skills
- Practical ingenuity and creativity
- Good communication skills
- Business, management, and leadership skills
- High ethical standards, professionalism
- Dynamic, agile, resilient, flexible
- Lifelong learner
- Able to put problems in their socio-technical and operational context
Recommendation of 2020 study

• Whatever other creative approaches are taken in the 4-year engineering curriculum, the essence of engineering - the iterative process of designing, building, and testing - should be taught from the earliest stages of the curriculum, including the first year.
Recommendation of 2020 study

• Colleges and universities should develop new standards for faculty qualifications, appointments and expectations, for example, to require experience as a practicing engineer, and should create or adapt development programs to support the professional growth of engineering faculty.

  – Has happened to some extent
Recommendation of 2020 study

- The engineering education establishment should embrace research in engineering education as a valued activity for engineering faculty as a means to enhance and personalize the connection to undergraduate students, to understand how they learn and to appreciate the pedagogical approaches that excite them.
Recommenda5ons of 2020 study

• The baccalaureate degree should be recognized as the “preengineering” degree or bachelor of arts in engineering degree, depending on the course content and reflecting the career aspirations of the student.
  – Has not happened
Trends in Response to Calls for Change

- New design-oriented model for engineering education
  - Olin College, Singapore University of Technology & Design
- Return to more holistic view of engineering education
  - Holistic Engineering – Smith, Dartmouth
- Allow for more flexible paths in engineering education
  - Stanford, MIT
- Development of Departments of Engineering Education in Engineering Schools
  - Purdue, Virginia Tech
- Development of global experiences as key part of Engineering Education
  - RPI, Georgia Tech
- Reorganize around the NAE grand challenges
  - Arizona State University
The Evolution of Engineering Education in the United States

• National Picture
• Innovative Approaches
  – Olin College
  – Purdue
  – RPI & Georgia Tech
  – Arizona State University
  – MIT
• The Impact of Online Education
• Continuing Challenges
Olin College: An Experiment in Design

- Engineering design vs. applied science
- Design of device, system, or process under constraint
- Engineering science at core, design at periphery
- How many faculty members have real design experience?

Approach at Olin:
- Design at the core, engineering science in support of design
- Design as a process, more than invention of new technology
- Design as a point of entry to the field
- Design as social dialog with non-technical colleagues
Some Features of the Olin Curriculum

- **Required Design core**
- Team design projects in 6+ semesters
- **SCOPE** senior project: corporate sponsored, year-long ($50k/project)
- **EXPO** at end of each semester: “stand and deliver”
- Integrated Course Blocks in Science, Math, and Engineering
- Study Away in Junior year
- Summer internships: REU and corporate experience
- Business and entrepreneurship: all students must start and run a business for a semester
- **Nine competencies** across all four years: quantitative analysis, qualitative analysis, teamwork, communication, life-long learning, context, design, diagnosis, opportunity assessment
- Continuous improvement: expiration date on curriculum
- BUT, the learning culture is far more important than the curriculum!
Purdue: Department of Engineering Education

• Vision:
  
  *A more inclusive, socially connected, and scholarly engineering education*

• Mission:
  
  *Transforming engineering education based on scholarship and research*

• Mission rests on three pillars:
  – Re-imagine Engineering and Engineering Education
  – Create Field-shaping Knowledge
  – Empower Agents of Change
RPI & Georgia Tech: Global Experiences

• RPI
  – Rensselaer Education Across Cultural Horizons (REACH)
  – Strongly encouraged for all engineering students
  – Semester long exchange (or more) with several universities (NTU, CUHK, etc)

• Georgia Tech
  – International Plan - integrated study abroad
  – 40% of Georgia Tech students participate
Co-Curricular Global Experiences
Empower Students to Become...

• Confident, articulate leaders
• Collaborators with the ability to recognize and solve complex problems
• Perceptive scholars who effectively function in a global society
• Citizens who are passionate about making the world a better place
• Qualified professionals with an understanding of ethical behavior and issues
Arizona State University: Reorganize Around NAE Grand Challenges

• Explicitly recognizes that the Grand Challenges interest young people and motivate them to learn

• College of Engineering
  – School of Biological and Health Systems Engineering
  – School of Computing, Informatics and Decision Systems Engineering
  – School of Electrical, Computing and Energy Engineering
  – School for Engineering of Matter, Transport and Energy
  – School of Sustainable Engineering and the Built Environment
  – School of Arts, Media and Engineering
  – School of Earth and Space Exploration
MIT Aero-Astro Flexible Engineering Degree 16-ENG

16-1 Aerospace Engineering
- Aerospace Experimental Projects Lab/Hands-on, Aerospace Capstone Design Subjects
- Choose 4 out of 9 subjects, with 2 having vehicles focus
- 4 second-level core subjects
- Unified Engineering

16-2 Aerospace Engineering with Information Technology
- Aerospace Experimental Projects Lab/Hands-on, Aerospace Capstone Design Subjects
- Choose 4 out of 9 subjects, with 3 having information focus
- 4 second-level core subjects
- Unified Engineering

SB in Engineering As Recommended by the Department of Aeronautics and Astronautics
- Aerospace Experimental Projects Lab/Hands-on, Aerospace Capstone Design Subjects
- Choose 6 subjects from one of 8 Concentrations, each containing dozens of subjects
- 2 second-level core subjects
- Unified Engineering

GIRs
MIT Rationale for a Flexible Engineering Degree: External Sources

- NAE 2020 Report [2005] and others
  - The changing practice of engineering
  - Increasingly multidisciplinary, multicultural, global, focused on large socio-technical problems

- Educational specialists
  - ABET Criterion 3 a-k not enough

- Peer schools
  - Growth of explicit focus on socio-technical themes within engineering degree programs and the development of knowledge, skills and attitudes to address these problems
MIT CDIO Initiative

• CDIO is an innovative educational framework for producing the next generation of engineers
• CDIO provides students with an education stressing engineering fundamentals set in the context of
  – Conceiving
  – Designing
  – Implementing
  – Operating
    real-world systems and products
• Schools throughout the world have adopted CDIO as the framework of their curricular planning and outcome–based assessment
• CDIO is defined by twelve standards
The Evolution of Engineering Education in the United States

- National Picture
- Innovative Approaches
  - Olin College
  - Purdue
  - RPI & Georgia Tech
  - Arizona State University
  - MIT
- Impact of Online Education
- Continuing Challenges
WHY ONLINE EDUCATION AND WHY NOW?

• Online Education
  – Opportunity to rethink the pedagogy of (engineering) education
  – a huge source of data
  – Opportunity to share (engineering) education with the world
    • E.g BLOSSOMS
  – Opportunity to change the cost paradigm for (engineering) education

• Why now – Technology has advanced enough to make high quality delivery available at scale
  – The convergence of
    • Video on demand (and the ability to make it cheaply)
    • Widespread connectivity
    • Automated assessment/feedback (Radically scalable)
    • Social media
    • Semi-synchronous delivery
    • Crowd sourcing (Radically scalable)
    • Acknowledgement of certification
Through educational technology, universities can...

- Address the varied abilities (capacity, preparation, interests, motivation) of its students by providing alternative pathways to learning, delivery and resources including leveraging resources elsewhere.
- Redefine the model of a semester from being a fixed-time or fixed-content construct to being one in which learning occurs in modules of varying durations with opportunities for varied experiences.
- Increase the quantity and quality of interaction between all of a universities’ constituents—students, faculty, staff and alumni.
A POSSIBLE TWENTY YEAR VISION FOR A VASTLY IMPROVED RESIDENTIAL EDUCATION

• Blended education
  – Intelligent combinations of the physical and virtual
  – Intelligent combinations of formal and non-formal

• Seamless integration of learning for UGs to Alums
  – UGs in residence, Alums periodically sample via cyberspace with customizable learning modules

• Shift frames of reference
  – Scarcity to Abundance (of easily available knowledge)
  – Learner to Participant - demand pull learning
Unlocking Knowledge
Inspiring a Movement

The OpenCourseWare Consortium

- ~250 institutions
- 100 live OCW sites
- ~13,000 courses

http://ocwconsortium.org
BLOSSOMS provides a free online repository of “interactive” video lessons for high school math and science classes.
Seems like all MOOCs all the time
at a glance

Began May 2012 by MIT and Harvard

27 institutions

60 courses

1 million course enrollments with students from 192 countries

Source: edX Media Kit https://www.edx.org/sites/default/files/mediakit/2013/06/03/edx_Media_Kit_June.pdf

http://web.mit.edu/newsoffice/2013/6002x-data-offer-insights-into-online-learning-0611.html
Circuits and Electronics (6.002x)

- “Khan Academy-like” videos
- Questions between video segments
- Tutorials
- Discussion forum
- Wiki
- Assessments (problem sets, labs, midterm, final)
H1P2: DECOMPOSITION OF AMMONIUM NITRATE

Solid NH₄NO₃ (ammonium nitrate) decomposes on heating to 400°C, forming N₂O gas and water vapor, H₂O.

(a) Write a balanced chemical equation.

(b) Calculate the number of grams of H₂O that will form on decomposition of 0.10 mole of ammonium nitrate.
Sources of data for TLL study

Clickstream data
230 million interactions*
IP addresses, interactions with course components, assignments and exams

Threads on discussion forum
12,696 threads/96,696 posts
Questions, answers, or comments

End-of-course survey
7,000+ [matrix sample]
Research questions

1. Who are the students in 6.002x?

2. What relationships can be seen between background and achievement?

3. What relationships can be seen between use of resources and achievement? Use of resources and persistence?
Some insights from the data

- Collaboration matters.
- Prerequisite knowledge is key.
- Time on task is related to success.
- Students will make use of multiple forms of the material presented.
Goals (from Princeton)

• Gain first-hand knowledge
• Encourage innovation in teaching at Princeton
• Advance our mission “in the nation’s service, and in the service of all nations”

To date, seven offerings across five disciplines

- Introduction to Sociology
- Networks: Friends, Money, and Bytes
- Computer Architecture
- A History of the World since 1300
- Statistics One
- Algorithms
- Analytic Combinatorics
Early Observations

• Collaboration (McGraw Center for Teaching and Learning)
• Production values and costs (Broadcast Center)
• Public benefit (“in the service of all nations”)
• Potential to enhance teaching on campus
  – flipping the student and the professor
  – importing the global perspective

• Research
• Provocation

I had begun worrying about how I could bring the New Jersey campus experience to [the world]; I ended by thinking about how to bring the world back to the classroom in Princeton.

— Mitchell Duneier
Course Design

From this… to this…

…to this!
The Evolution of Engineering Education in the United States

- National Picture
- Innovative Approaches
  - Olin College
  - Purdue
  - RPI & Georgia Tech
  - Arizona State University
  - MIT
- Impact of Online Education
- Continuing Challenges
Challenges

• Further need to redo engineering curricula around what is known about effective learning
• Demographic challenges of women and underrepresented minorities entering engineering
• Unknown impact of MOOCs especially on the development of the soft skills

• Findings from learning research on the educational value of building curricula that provide
  – Context and integration across time and courses that transfer knowledge and skills to new contexts
  – Early exposure to engineering and engineers (thinking like an engineer)
  – Meaningful classroom engagement leads to deep learning (deliberate practice coupled with targeted feedback)

• Findings from learning research on the educational value of building curricula that provide
  – Opportunities for reflection to connect thinking and doing (e.g. writing to learn, e-portfolios)
  – Development of metacognitive skills to foster self-directed, lifelong learning skills (assess, evaluate, plan, apply, reflect)
  – Authentic experiential learning opportunities to put theory into practice in the real world (co-ops, service learning, internships)
Much concern over STEM shortage: BS Degrees Engineering-last decade (ASEE)

<table>
<thead>
<tr>
<th>Year</th>
<th>Bachelor’s Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010-2011</td>
<td>83,001</td>
</tr>
<tr>
<td>2009-2010</td>
<td>78,347</td>
</tr>
<tr>
<td>2008-2009</td>
<td>74,387</td>
</tr>
<tr>
<td>2007-2008</td>
<td>74,170</td>
</tr>
<tr>
<td>2006-2007</td>
<td>73,315</td>
</tr>
<tr>
<td>2005-2006</td>
<td>74,186</td>
</tr>
<tr>
<td>2004-2005</td>
<td>73,602</td>
</tr>
<tr>
<td>2003-2004</td>
<td>72,893</td>
</tr>
<tr>
<td>2002-2003</td>
<td>71,165</td>
</tr>
<tr>
<td>2001-2002</td>
<td>66,781</td>
</tr>
<tr>
<td>2000-2001</td>
<td>64,200</td>
</tr>
<tr>
<td>1999-2000</td>
<td>63,820</td>
</tr>
</tbody>
</table>
Intentions/degrees Engineering by Sex

NOTES: Data for freshmen intentions are for 2003; data for degrees are for 2009. Degrees do not reflect the same student cohort.


Science and Engineering Indicators 2012
Women Engineers

(Less) Popular Science
The three largest fields in science have lost ground in recent decades.

GENDER GAP While women lag in engineering and computer science, they dominate in biology, where pay is lower. Salaries start at $40,000 to $60,000, compared with $55,000 to $65,000 for the other fields.

Number of women for every 10 graduates, 2009-10:

1.7 engineers
5.8 biologists
1.8 computer scientists

Source: National Center for Education Statistics
Intentions/degrees Engineering by Race

Figure 2-10: Natural sciences: Freshmen intentions and degrees, by race/ethnicity

Figure 2-8: Engineering: Freshmen intentions and degrees, by race/ethnicity

NOTES: Data for freshmen intentions are for 2003; data for degrees are for 2009. Degrees do not reflect the same student cohort. Asian American/Asian includes Native Hawaiian/Pacific Islander.


Science and Engineering Indicators 2012
Women and Minority Engineering Faculty

Best way to handle gaps in Engineering education is

- Role Models
- Summer Programs
- Research Experiences
- Professional Development Activities
- Academic Support & Social Integration
- Mentoring

<table>
<thead>
<tr>
<th>Year</th>
<th>Women</th>
<th>African American</th>
<th>Asian</th>
<th>Hispanic</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>8.9%</td>
<td>2.1%</td>
<td>17.0%</td>
<td>3.0%</td>
</tr>
<tr>
<td>2002</td>
<td>9.2%</td>
<td>2.0%</td>
<td>17.8%</td>
<td>3.0%</td>
</tr>
<tr>
<td>2003</td>
<td>9.9%</td>
<td>2.2%</td>
<td>19.2%</td>
<td>3.1%</td>
</tr>
<tr>
<td>2004</td>
<td>10.4%</td>
<td>2.3%</td>
<td>20.2%</td>
<td>3.2%</td>
</tr>
<tr>
<td>2005</td>
<td>10.6%</td>
<td>2.4%</td>
<td>20.9%</td>
<td>3.2%</td>
</tr>
<tr>
<td>2006</td>
<td>11.3%</td>
<td>2.4%</td>
<td>22.0%</td>
<td>3.3%</td>
</tr>
<tr>
<td>2007</td>
<td>11.8%</td>
<td>2.5%</td>
<td>22.6%</td>
<td>3.4%</td>
</tr>
<tr>
<td>2008</td>
<td>12.3%</td>
<td>2.5%</td>
<td>22.7%</td>
<td>3.5%</td>
</tr>
<tr>
<td>2009</td>
<td>12.7%</td>
<td>2.5%</td>
<td>23.3%</td>
<td>3.5%</td>
</tr>
<tr>
<td>2010</td>
<td>13.2%</td>
<td>2.5%</td>
<td>23.9%</td>
<td>3.6%</td>
</tr>
</tbody>
</table>

*Note: Includes faculty data from University of Puerto Rico, Mayaguez and Polytechnic University of Puerto Rico*
The Evolution of Engineering Education in the United States and at MIT

- National Picture
- Innovative Approaches
  - Olin College
  - Purdue
  - RPI & Georgia Tech
  - MIT
  - Arizona State University
- The Impact of Online Education
- Conclusion
The Evolution of Engineering Education in the United States - Conclusion

- Engineering education continues to evolve in the US
  - More focus on using theories of learning
  - More focus on bringing in active learning
  - More focus on integrating design early into the education
  - Schools are using a variety of approaches to improve engineering education
    - MOOCs may be a forcing function
    - Large Challenges in demographics

- The Result: Islands of success
  - Engineering is becoming more attractive to young people (but with demographic challenges)
  - Much more needs to be done!
Questions?
## Women Share of S&E degrees

### Women's share of S&E bachelor’s degrees, by field: 2000–09 (corrected July 2012)

(Percent)

<table>
<thead>
<tr>
<th>Year</th>
<th>Physical sciences</th>
<th>Biological/agricultural sciences</th>
<th>Mathematics</th>
<th>Computer sciences</th>
<th>Psychology</th>
<th>Social sciences</th>
<th>Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>41.1</td>
<td>55.8</td>
<td>47.8</td>
<td>28.0</td>
<td>76.5</td>
<td>54.2</td>
<td>20.5</td>
</tr>
<tr>
<td>2001</td>
<td>41.8</td>
<td>57.3</td>
<td>48.0</td>
<td>27.6</td>
<td>77.5</td>
<td>54.8</td>
<td>20.1</td>
</tr>
<tr>
<td>2002</td>
<td>42.7</td>
<td>58.6</td>
<td>46.9</td>
<td>27.5</td>
<td>77.5</td>
<td>54.8</td>
<td>20.9</td>
</tr>
<tr>
<td>2003</td>
<td>41.7</td>
<td>59.7</td>
<td>45.6</td>
<td>27.0</td>
<td>77.7</td>
<td>54.7</td>
<td>20.3</td>
</tr>
<tr>
<td>2004</td>
<td>42.2</td>
<td>60.1</td>
<td>45.9</td>
<td>25.1</td>
<td>77.8</td>
<td>54.5</td>
<td>20.5</td>
</tr>
<tr>
<td>2005</td>
<td>42.8</td>
<td>59.9</td>
<td>44.6</td>
<td>22.3</td>
<td>77.8</td>
<td>54.2</td>
<td>20.0</td>
</tr>
<tr>
<td>2006</td>
<td>42.4</td>
<td>59.8</td>
<td>44.9</td>
<td>20.7</td>
<td>77.4</td>
<td>53.7</td>
<td>19.5</td>
</tr>
<tr>
<td>2007</td>
<td>41.1</td>
<td>58.6</td>
<td>43.9</td>
<td>18.6</td>
<td>77.4</td>
<td>53.8</td>
<td>18.5</td>
</tr>
<tr>
<td>2008</td>
<td>41.3</td>
<td>58.2</td>
<td>43.9</td>
<td>17.7</td>
<td>77.1</td>
<td>53.5</td>
<td>18.5</td>
</tr>
<tr>
<td>2009</td>
<td>41.5</td>
<td>58.2</td>
<td>43.0</td>
<td>17.9</td>
<td>77.2</td>
<td>53.6</td>
<td>18.1</td>
</tr>
</tbody>
</table>

**NOTE:** Physical sciences include earth, atmospheric, and ocean sciences.


**Correction:** Head note was changed from "(Thousands)" to "(Percent)."

*Science and Engineering Indicators 2012*
Context for Engineering

- Breakthroughs in technology
- Demographics
- Challenges
- Economic/societal forces
Share of S&E bachelors degrees

Figure 2-15
Share of S&E bachelor’s degrees, by race/ethnicity: 2000–09

URM and Asian/Pacific Islander (Percent) White (Percent)

0 1 2 4 6 8 10 12

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009

Asian/Pacific Islander
Black
Hispanic
White

American Indian/Alaska Native

URM = underrepresented minorities (black, Hispanic, and American Indian/Alaska Native)


Science and Engineering Indicators 2012
Salaries for S&E people

Figure 3-26: Median salaries of individuals with highest degree in S&E, by degree level and years since degree: 2003

Figure 3-24: Median salaries for bachelor's degree holders, by broad field and years since degree: 2003


Science and Engineering Indicators 2012
Engineering Graduates & Occupations (1999)

- Engineering Graduates: 2.8M
- Principal Occupation Engineering: 1.7M
- Engineering graduates employed as engineers: 1.3M
- Non-engineering graduates: 0.4M
- Engineering graduates not employed as engineers: 1.5M

Source: The Education and Employment of Engineering Graduates, 2004
Share of selected region’s/country’s citations to international literature: 2000–10

Asia-8 = India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand; EU = European Union
Student Engagement Results for Olin College

Senior-year Student Engagement

Mean Score (in Std Dev from NSSE Mean)

Level of Academic Challenge
Active and Collaborative Learning
Student-Faculty Interaction
Enriching Educational Experiences
Supportive Campus Environment

Olin College
Engineering
Liberal Arts
NSSE 2009

Franklin W. Olin College of Engineering
Olin College Overview

- Undergraduate residential engineering education
- Total enrollment of about 300
- Nearly 50% women
- BS degrees in ECE, ME, Engr
- 9-to-1 student/faculty ratio
- Founded in 1997, first graduates in 2006
- Endowment ~ $350 million
- Research expenditures ~ $1 million/yr
- Adjacent to Babson College, Wellesley College
- 75 acres and 400,000+ sq. ft. new buildings
- No academic departments
- No tenure
- Low tuition
- Continuous improvement
Expanded Design Spectrum at Olin College

**What is engineering?**

- People
- Problem
- Concept
- Specifications
- Design
- Prototype
- Product
- Market

**Narrow Definition**

- User-Oriented Design
- Design Nature
- Modeling Compartment Systems
- Fundamentals of Entrepreneurship
Our Focus is on Developing...

- Leadership and communication skills
- Understanding of global and cultural differences
- Comfort and experience applying modern and traditional technologies
- Confidence
- Judgment
- Decisiveness
- The ability to manage risk
The Evolution of Engineering Education in the United States and at MIT

• National Picture
• Innovative Approaches
  – Purdue
  – RPI & Georgia Tech
  – Arizona State University
  – Olin College

• MIT Perspective
Content Evolution: MIT Engineering

In 1950...
- Civil Engineering
- Mechanical Engineering
- Metallurgy
- Electrical Engineering
- Chemical Engineering
- General Engineering
- Sanitary Engineering
- Naval Architecture and Marine Engineering
- Economics and Engineering
- Business and Engineering Administration
- Aeronautical Engineering

In 2000...
- Civil and Environment Engineering
- Mechanical Engineering
- Material Science and Engineering
- Electrical Engineering and Computer Science
- Chemical Engineering
- Ocean Engineering
- Nuclear Engineering
- Aeronautical and Astronautical Engineering
- Biological Engineering
- Engineering Systems
Undergraduates Entering MIT

- 40% are valedictorians
- 89% are in the top 5% of their class
- 21% are recognized Academic Stars
- 20% are accomplished Art, Music or Athletic Stars
- 71% held leadership positions in high school
- 24% underrepresented minorities
- 19% first generation to college
- 55% male and 45% female

Source: MIT Admissions, Class of 2013
Task Force Goals for an
MIT Education

An MIT education is one grounded in science and technology that:

● ignites a passion for learning,

● provides the intellectual and personal foundations for future development, and

● illuminates the breadth, depth and diversity of human knowledge and experience,

in order to enable each student to develop a personal coherent intellectual identity.
# What Should an Educated Individual Know?

<table>
<thead>
<tr>
<th>Fundamental studies in HASS:</th>
<th>Rigorous fundamentals of science and math:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human cultures</td>
<td>Physics</td>
</tr>
<tr>
<td>History</td>
<td>Chemistry</td>
</tr>
<tr>
<td>Literature</td>
<td>Math</td>
</tr>
<tr>
<td>Economics</td>
<td>Biology</td>
</tr>
<tr>
<td>Government</td>
<td>Computation</td>
</tr>
<tr>
<td>Social structures &amp; organizations</td>
<td>Engineering ideas and methods</td>
</tr>
<tr>
<td>Foreign language</td>
<td>Probability and statistics</td>
</tr>
<tr>
<td>Philosophy</td>
<td>Complex systems</td>
</tr>
<tr>
<td>Writing skills</td>
<td>Neuroscience</td>
</tr>
<tr>
<td>Speaking skills</td>
<td>Earth science</td>
</tr>
<tr>
<td>Ability to analyze complex texts</td>
<td>Environmental studies</td>
</tr>
<tr>
<td>Sensitivity to artistic expression</td>
<td>Differential equations</td>
</tr>
<tr>
<td>Understanding of global systems</td>
<td>Linear algebra</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Science, Technology &amp; Society</th>
<th>Departmental Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethics</td>
<td></td>
</tr>
<tr>
<td>Diversity</td>
<td></td>
</tr>
<tr>
<td>Management</td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>
MIT SB Degree Programs: Rules

General Institute Requirements (GIRs)

- 17 subjects
- 8 Humanities, Arts and Social Sciences subjects
- 6 Science and Math
- Institute Lab
- 2 Restricted Electives in Science and Technology subjects

Departmental Programs

- 11 subjects (132 units)
- 3-subject overlap with GIRs allows up to maximum of 15.5 subjects
- 180-198 units, including 48 unrestricted electives

Total of 32-34 subject programs
Third Task Force Goal and Outcomes

Educational Goal #3*
Every MIT undergraduate should be knowledgeable enough about the “humane culture of society” and adept enough in social interactions to participate as an effective citizen and innovator

Selected Outcome Metrics
• Successful completion of the humanities and communication requirements
• Frequency of opportunities for developing leadership and team-work
• Student-reported change in ability to function effectively as a team member
• Student-reported change in ability to relate well to people of different races, nations and religions
• Student-reported change in ability to lead others
• Alumni entrepreneurship and innovation

* This is one of the four high-level educational goals defined by the 2006 Task Force on the Undergraduate Educational Commons
Be Knowledgeable About the “Humane Culture of Society” and Adept in Social Interactions

MIT’s humanities and communications requirements are designed to meet this goal.

% of Seniors reporting “stronger” or “much stronger” ability since starting college

- Relate well to people of different races, nations, and religions
  - 2012: 53%
  - 2010: 73%
  - 2008: 66%
  - 2006: 81%
  - 2004: 66%
  - 2002: 0%

- Lead and supervise tasks and groups of people
  - 2012: 53%
  - 2010: 73%
  - 2008: 66%
  - 2006: 81%
  - 2004: 66%
  - 2002: 0%

Source: 2002-2010 Senior Survey
17% of MIT undergraduate students patent an invention within 15 years of graduation; On average, MIT alumni inventors produce six patents each.

MIT engineers are 5x more inventive than the average engineer: MIT produces .25% of U.S. engineering grads and they produce 1.2% of all U.S. engineering patents.

Source: Phan Shu, PhD Research on Innovation presented at MIT 11/22/11

1/3 of MIT SB Graduates 25 Yrs Out Report Starting a New Company

As an early employee
- 11% (2-5 years out)
- 24% (12-17 years out)
- 34% (22-27 years out)

As a founder
- 7% (2-5 years out)
- 20% (12-17 years out)
- 31% (22-27 years out)

Note: An alum can be both a founder and an early employee.

Source: 2009 Alumni Survey
Assessing Learning Outcomes

Educational Researchers

Indirect Measures
- Freshman surveys
- Alumni surveys

Direct Measures
- Standardized tests of general education skills
- Think-aloud protocols

Faculty

Grades
Concept questions, mud cards
Course evaluations (early semester and end-of-semester)

Survey of students attitudes and/or reflections on their learning
Exit interviews

Grades
Standardized tests of disciplinary knowledge

Pre-test/post-tests
Analysis of student work products
ABET accreditation data
Observations of students performing a task
Portfolios compiled over course of undergraduate study
Source of Knowledge and Skills – MIT Alumni

Source: Kristen Wolfe, B.S. Thesis, Department of Mechanical Engineering, June 2004
Knowledge and Skills – MIT Alumni
Mean Frequency of Use

Frequency of Use: 0 Never, 1 Hardly ever - a few times a year, 2 Occasionally - at least once a month, 3 Regularly - at least weekly, 4 Frequently - on most days, 5 Pervasively - for most everything I do

Source: Kristen Wolfe, B.S. Thesis, Department of Mechanical Engineering, June 2004
Changes at MIT (still wrapped around traditional core)

• Active technology enabled learning
  – TEAL Classroom

• Focus on developing engineering leaders
  – Gordon Engineering Leadership Program

• Focus on holistic development
  – CDIO Initiative

• Development of flexible engineering degrees

• Focus on undergraduate practice opportunities
Evaluation of TEAL Learning Outcomes: Increases Seen Long Term (6 months)

Gordon Leadership Engineering Program

Mission: *To educate and develop the character of outstanding MIT students as potential future leaders in the world of engineering practice and development, and to endeavor to transform engineering leadership in the nation, thereby significantly increasing its product development capability* 

Program Goals

1. To prepare all MIT engineering students to be more effective contributors to engineering innovation, invention, and implementation efforts
2. To educate and prepare the potential future leaders of engineering innovation, invention, and implementation efforts
3. To increase the focus of national engineering education on the development of leaders of engineering innovation, invention, and implementation
Gordon Leadership Program’s Strategic Approach

• Designed to demonstrate an impact on:
  
  – All MIT engineering students through systematic enrichment of departmental programs
  
  – Many MIT engineering students through a set of augmenting elective modules, subjects and learning experiences, which taken together, might be at the level of an MIT concentration
  
  – A relatively few MIT engineering students through focused mentored leadership development experiences, internships, seminars and subjects, which taken together, might be at the level of an MIT minor

• These areas are synergistically linked in that the “few” will help to lead the “many,” who in turn will contribute to the “all”

• The Program also engages a network of alumni and industrial participants who actively provide support by mentoring students and proposing projects
CDIO Standards

1. CDIO as Context for Engineering Education
2. Syllabus Outcomes - Specific, Detailed Learning Outcomes
3. Integrated Curriculum
4. Introduction to Engineering
5. Design-Build Experiences
6. Workspaces that encourage hands-on learning
7. Integrated Learning Experiences
8. Active Learning
9. Enhancement of Faculty CDIO Skills
10. Enhancement of Faculty Teaching Skills
11. Skills Assessment of Student Learning
12. Program Evaluation
Features of the Flexible Engineering Degree

- Flexibility grounded in engineering fundamentals of a given discipline
- Improves students’ ability to move from disciplinary foundations of their engineering major to multidisciplinary practice.
- Responds to changes in the professional world our graduates
- Each degree would (could) meet ABET accreditation requirements for engineering degrees
- Graduates would be prepared for graduate school in engineering disciplines and other disciplines
- Implementable in current organizational framework (where departments are responsible for students)
Rationale for a Flexible Engineering Degree: SOE Students and Alumni

• In surveys, students and alums say they desire improvements in the MIT SOE program in the areas of:
  – Development of engineering leadership abilities
  – Preparation for work in global, multicultural organization
  – Opportunities for interdisciplinary study
  – Provision of more flexible engineering curricula
SOE students pursuing broader programs of study via minors and double degrees (50% with most outside of engineering)

<table>
<thead>
<tr>
<th>SB engineering Class</th>
<th>All Eng. SBs N</th>
<th>Double major N</th>
<th>Minors N</th>
<th>Double major-% graduates</th>
<th>Minors-% graduates</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>674</td>
<td>144</td>
<td>189</td>
<td>21.4%</td>
<td>28.0%</td>
</tr>
<tr>
<td>2004</td>
<td>637</td>
<td>119</td>
<td>200</td>
<td>18.7%</td>
<td>31.4%</td>
</tr>
<tr>
<td>2005</td>
<td>590</td>
<td>109</td>
<td>167</td>
<td>18.5%</td>
<td>28.3%</td>
</tr>
<tr>
<td>2006</td>
<td>572</td>
<td>101</td>
<td>158</td>
<td>17.7%</td>
<td>27.6%</td>
</tr>
<tr>
<td>2007</td>
<td>577</td>
<td>94</td>
<td>192</td>
<td>16.3%</td>
<td>33.3%</td>
</tr>
<tr>
<td>2011**</td>
<td>231</td>
<td>67</td>
<td>NA</td>
<td>29.0%</td>
<td>NA</td>
</tr>
</tbody>
</table>

** preliminary survey sampling of SOE Class 2011 sophomores only under new double degree rules. For Class 2011, % double degrees indicates intention to complete, not completion.
The world is always changing

And as a result institutions of higher educations must constantly reinvent themselves. But amidst this endless change, the founding values endure.

Course 102 — Domestic Science, with practical applications
Bottom line on current thinking

• Physical proximity most valuable for UGs
  – “bumping” into other smart people efficiently
• Speed, density of network connections is increasing
  – Click and brick are now more important then ever
• Core strategy: Must maintain our focus on innovation and transformation
• Core strategy: Must continue to attract the very best students. More and more important to draw globally
• MIT should be a place where great things happen easily. Proportion of people who make great things is high at MIT - need to keep this
Faculty Engagement

Faculty-Centered Approach

• Scaffold the development of teaching practices
• Take a long-term view of our relationships with our faculty partners
  – Consultant role
  – Our efforts are guided by faculty needs/requests
• Help faculty to identify other support needs
  – Workload management for faculty and AIs
  – Simplifying course logistics

*The feedback cards, plus some other intangibles, have made the students very interactive -- far more than last year at this time.*

-- Sam Wang
NAE Grand Challenges for 21st Century

• Make solar energy economical
• Provide energy from fusion
• Develop carbon sequestration methods
• Manage the nitrogen cycle
• Provide access to clean water
• Restore and improve urban infrastructure
• Advance health informatics
• Engineer better medicines
• Reverse engineer the brain
• Prevent nuclear terror
• Secure cyberspace
• Enhance virtual reality
• Advance personalized learning
• Engineer the tools of scientific discovery
R&D performed in the United States by U.S. affiliates of foreign companies, by investing region, and R&D performed abroad by foreign affiliates of U.S. multinational corporations, by host region: 1998 and 2008

Current U.S. dollars (billions)

Beyond The Curriculum at Olin

“Making universities and engineering schools exciting, creative, adventurous, rigorous, demanding, and empowering milieus is more important than specifying curricular details”

Chuck Vest, MIT President Emeritus

• Attitudes and Behaviors
  • “Can Do”
  • Teamwork
  • Core Values and Ethics
  • Entrepreneurial Thinking

• Motivations
  • An insatiable appetite for learning and innovation
  • Drive to become adaptive, independent, life-long learners
  • Passion to make a positive difference in the world