Musings on Engineering Education

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Transforming Engineering Education

Who am I?

- University of Notre Dame. Viola D Hank Prof. and Chair of the Department of Aerospace and Mechanical Engineering
- Worcester Polytechnic Inst. Prof. and Head, Dept. of Mech. Engrg. 2000 -2010
- Univ. of Michigan, Ann Arbor. Prof. of Mech. Engrg. 1985 – 2000
- Ph.D. Brown University, Division of Engineering, 1985
- Over 100 journal papers, over 3800 citations; h-index=30
- Over 20 PhD students
- Several million dollars in research funding from gov. agencies and corporations
- 2012 ASME Fluids Engineering Award
- Fellow of the American Society of Mechanical Engineers
- Fellow of the American Physical Society
- Editor-in-chief, Journal of Computational Physics (>1300 subm./year; IF> 2.3)
- On several editorial boards
- Chair: Governing Board of the ICMF, 2007-2010.
- Chair: 2008 IMEE Conference (ASME)
The globalization of the world economy along with unprecedented connectivity has changed the way engineering and manufacturing is being done. The global growth in education makes it now possible to locate engineering and manufacturing anywhere, usually where the cost is lowest. Many traditional advantages based on location and culture are rapidly disappearing.
New corporations will continue to emerge (and old ones will die)

Of the original Forbes 100 list, published in 1917, only 18 where there in 1987 and 61 did not exist.

Wal-Mart 1969
Microsoft 1976
Oracle 1977
Apple 1976
Dell 1984
Amazon.com 1994
eBay 1995
Yahoo 1995
Google 1998
Salesforce.com 1999
Facebook 2004
Twitter 2006
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The Students are Changing

Their background is different: Students now come into engineering with little hands-on knowledge, but often with extensive computer experience.

Their attitudes are also different: Optimistic, cooperative team players, respectful of authority and more accepting of structure, close to parents, smart, believe in the future and see themselves at the cutting edge (Millennials Rising, 2000)

And their elders will continue to underestimate the new generation. Socrates wrote: “Youth today love luxury. They have bad manners, contempt for authority, no respect for older people, and talk nonsense when they should be working.”
Engineering is about creating our physical world and as our environment changes, we may have to learn new skills and adopt new attitudes. To do so we need to understand the broader role of engineering in shaping our civilization.

Engineering as a discipline

<table>
<thead>
<tr>
<th>Cultural</th>
<th>Physical</th>
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<tbody>
<tr>
<td>Humanities</td>
<td>Arts</td>
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<tr>
<td>Science</td>
<td>Engineering</td>
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Commodity Engineers

Entrepreneurial Engineers
19th and first half of the 20th century: The professional engineer
Early engineering programs focused on providing their graduates with considerable hands on training. However, mathematical modeling slowly increased as Applied Mechanics increasingly gained acceptance.

Second half of the 20th century: The scientific engineer
In the 1960s, motivated by Sputnik but probably also by the successful harnessing of nuclear energy, engineering became much more science based. In the early nineties many schools started to emphasize non-technical skills such as teamwork and communications.

The 21st century: The entrepreneurial engineer
Skill will no longer be a distinguishing feature that commands high salaries. The ability to make things happen will be required of every successful engineer.
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The Entrepreneurial Engineer

- Knows Everything— Or rather, can find any information quickly and knows how to evaluate and use those information.
- Can do Anything — Understands the basics to the degree that he or she can quickly understand what needs to be done and acquire the tools needed
- Collaborates— Has the communication skills, team skills, and understanding of global and current issues to work with anybody anywhere
- Innovates— Has the entrepreneurial spirit and the managerial skills to identify needs, come up with new solutions, and see them through

Changes are already taking place. Many universities are experimenting with new programs, new approaches and new ideas. And new players are emerging.
An educated person: Knows “things” and can Do “things”

Traditionally the focus of universities has been on the former, through lectures. Knowledge is now communal and can increasingly be developed in multitude of ways.

Traditional lecture material will continue to move to the web and the delivery and assessment will become increasingly sophisticated. Students will increasingly seek to learn in a way that is convenient and fits their schedule and learning style.

Universities must therefore increasingly focus on developing the students ability to “do things” Through projects, teamwork and open ended projects.

Today’s students often spend inordinate time learning on their own — we need to learn what motivates them!
Engineers have always learned what they needed to know to get their job done. In the 20th Century the laws of physics were usually the limiting factor.

We have, however, increasingly become very good at mastering physics and making stuff. In the new Century, the limiting factor is more and more going to be social, rather than physical.

Rapid progress is currently being made in understanding how humans behave and such knowledge will increasingly become part of engineering decisions.

For engineers, social sciences may well be the “physics” of the 21st Century.
The need to be able to collaborate effectively will take on an increased urgency. All engineering students will, in particular, need to develop the experience and attitude needed to work globally, in collaborations with people with different cultural perspectives.

Most schools now offer some kind of global experience with participation rates of up to 50%
The demand for more customization of engineering education, to suit the diverse career plans of the “Millennials,” who generally expect more from the institutions that serve them. This will increase the number of electives within disciplines and the offering of interdisciplinary degrees.

WPI introduced an undergraduate degree in robotics in 2007. It is now one of the most popular majors at the Institute.

- FIRST Robotic Competition reached over 30,000 high-school aged students in 2007 and FIRST Vex Challenge projects to reach over 25,000 students within a few years.
- In 2007, about ninety robotics companies in Massachusetts had sales of nearly a Billion dollars and employed about 2,500 people. On the average, the industry growth rate for 2007 was 47%.
- The military has mandated that by 2015, one third of all ground vehicles shall be unmanned.
- Robotics has been declared “the next big thing,” by industry leaders like Bill Gates.
Graduate education will become increasingly important and all students planning a career in engineering will complete a MS professional degree. The BS degree will allow an “early escape” for those using undergraduate engineering education as a springboard for other professions. The PhD degree will become more professionally focused, possibly with alternative advanced professional degrees.

### TABLE 11.1  Engineering Degrees in 2000 and 2009 [1]

<table>
<thead>
<tr>
<th>Engineering Degrees</th>
<th>BS</th>
<th>MS</th>
<th>PhD</th>
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<tbody>
<tr>
<td>2000</td>
<td>63,820</td>
<td>30,160</td>
<td>5,999</td>
</tr>
<tr>
<td>2009</td>
<td>74,387</td>
<td>41,632</td>
<td>9,083</td>
</tr>
<tr>
<td>% Increase</td>
<td>16.5%</td>
<td>38.0%</td>
<td>51.4%</td>
</tr>
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*Figure 3.5: Wages have increased for those with the most education, while falling for those with the least. Source: Acemoglu and Autor analysis of the Current Population Survey for 1963-2008.*
• Development of competencies (knowing everything and being able to do everything) will increasingly take place outside the classroom through personalized computer based learning, with time with faculty members devoted to the development of other professional skills (collaborating and innovating).

• The emphasis on innovation and entrepreneurship in societal context is increasing. All engineering students will be required to understand the role of engineering entrepreneurship in taking technologies to society through the creation of new enterprises.

• The need to be able to collaborate effectively is taking on an increased urgency. All engineering students will, in particular, need to develop the experience and attitude needed to work globally, in collaborations with people with different cultural perspectives.

• Graduate education is becoming increasingly important and all students planning a career in engineering will complete a MS professional degree. The BS degree will allow an “early escape” for those using undergraduate engineering education as a springboard for other professions. The PhD degree will become more professionally focused, possibly with alternative advanced professional degrees.

• The demand for more customization of engineering education is increasing, to suit the diverse career plans of the “Millennials,” who generally expect more from the institutions that serve them. This will increase the number of electives within disciplines and the offering of interdisciplinary degrees.
These changes—and others—are already taking place. I have attempted to put these changes in context and to examine what is likely to happen next. But, predicting the future is hard and experimentation is needed!
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Short term
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What Skills are Important?

Number of Institutions have attempted to assess the utility of specific topics for the long term success of their students. The data presented here is typical.


Data from a University of Michigan 1992 survey
The current generation of students has spent more time willingly engaging in learning and mastering new skills than any other generation before them. Of course, the skills may only apply to racecar driving, drone flying and a few other similar professions.

Video games and students “badges” for various activities suggest that the modern generation of students value recognition of the their achievements but expects to have the opportunity to try again and again.
• The emphasis on innovation and entrepreneurship in societal context will increase. All engineering students will be required to understand the role of engineering entrepreneurship in taking technologies to society through the creation of new enterprises.

• The need to be able to collaborate effectively will take on an increased urgency. All engineering students will, in particular, need to develop the experience and attitude needed to work globally, in collaborations with people with different cultural perspectives.
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Short term

**More attention to peers:** Annual Newsletter needs to reach AE & ME Department Heads/Chairs and Engineering Deans; The Department needs to have representation on Chairs/Educational forums such as ASME/AIAA and ASEE

**More effort to promote the faculty:** Fellow status; Lectureships; Awards;

**Growing research by going after large awards:** IGERTS; PSAAP; etc.

**Mentor junior faculty:** Set the expectations for junior faculty and help them succeed
New programs? ESTEEM seems to be a success; At WPI Robotics Engineering (undergrad) and Systems Engineering (graduate) did well.

Nationwide MS degrees are increasing faster than BS and PhDs. Would we benefit from growing the MS program?

Renewable energy? We are developing considerable expertise in wind power, for example.

Are there opportunities in manufacturing? No state relies as heavily on manufacturing as Indiana (25% of the economy in 2008 for a total output of about $64 Billions
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Top 10 Indiana Manufacturing Sectors, 2007 (GSP, billions) (Accounting for 86% of Indiana Manufacturing)

- Chemicals: 14.0
- Motor vehicles and parts: 11.0
- Fabricated metal products: 6.0
- Medical equipment and other misc. products: 5.4
- Machinery: 4.6
- Primary metal products: 4.2
- Food products: 3.4
- Plastics and rubber products: 2.9
- Aerospace and other misc. transportation: 1.9
- Furniture products: 1.8

http://www.nam.org/~/media/A38497E60D5A4ED29205C71FA6F8D78A.ashx

http://trade.gov/manufactureamerica/facts/tgMana_003019.asp
The Industrial Advisory Board is an invaluable resource and partner for the Department. We look to you for many things, including:

- Identifying how our graduates are meeting your needs and if those needs are changing
- Identify research opportunities at your companies for our faculty, and partnering opportunities in seeking federal funding
- Identify emerging trends in either technology or how companies conduct business that require new research or changes in how we prepare our students
- General support for the Department, College and the University
Figure 3.5: Wages have increased for those with the most education, while falling for those with the least. Source: Acemoglu and Autor analysis of the Current Population Survey for 1963-2008.
The low cost of trying out new ideas has changed how internet companies function. Similar transformation is changing how physical prototypes are made.

MS degrees focusing on developing skill in innovating may be just as valuable as preparation in the business side.