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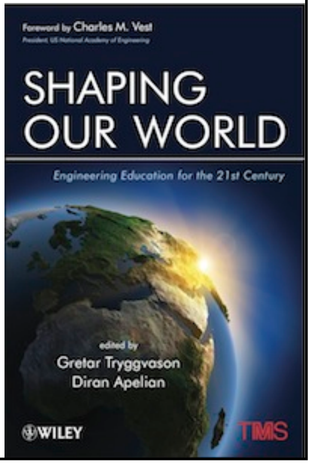
Musings on Engineering Education

Grétar Tryggvason,
University of Notre Dame

CDIO Regional Meeting
University of Notre Dame
November 14, 2012



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Transforming Engineering Education

Who am I?

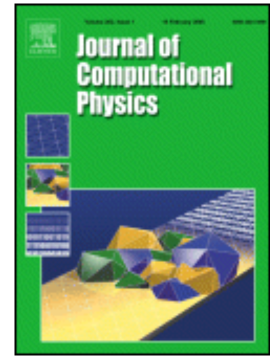
- University of Notre Dame. Viola D Hank Prof. and Chair of the Department of Aerospace and Mechanical Engineering
- Worcester Polytechnic Inst. Prof. and Head, Dept. of Mech. Engrg. 2000 -2010
- Univ. of Michigan, Ann Arbor. Prof. of Mech. Engrg. 1985 – 2000

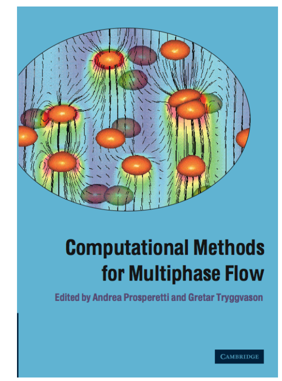
- Ph.D. Brown University, Division of Engineering, 1985

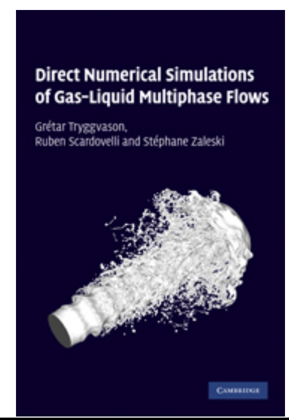
- Over 100 journal papers, over 3800 citations; h-index=30
- Over 20 PhD students
- Several million dollars in research funding from gov. agencies and corporations

- 2012 ASME Fluids Engineering Award
- The 2005 Comput. Mechanics Award from the Comput. Mech. Div. of JSME
- 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)







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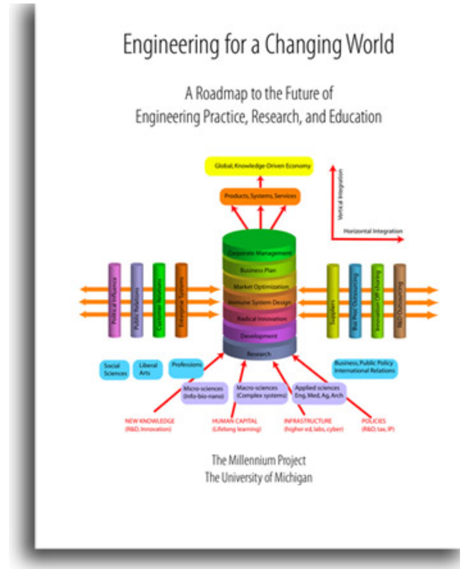
Transforming Engineering Education Challenges

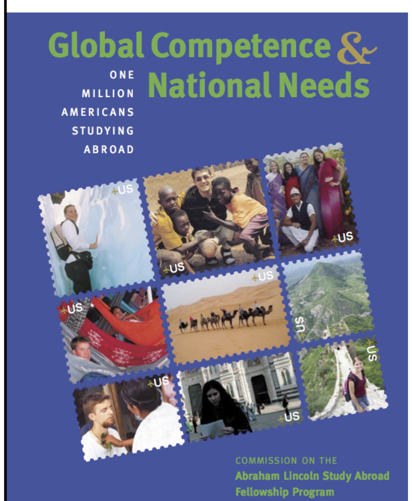
The globalization of the world economy along with unprecedented connectivity has changed the way engineering and manufacturing is being done. The global growth in education makes it now possible to locate engineering and manufacturing anywhere, usually where the cost is lowest. Many traditional advantages based on location and culture are rapidly disappearing.

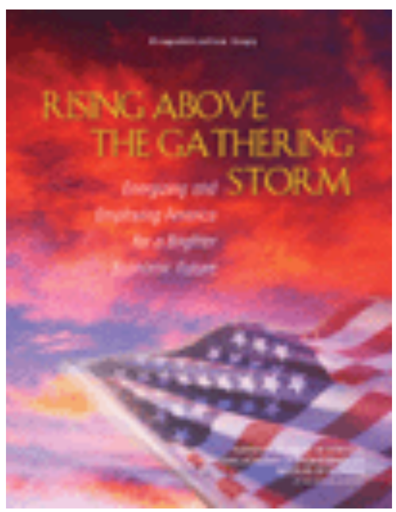


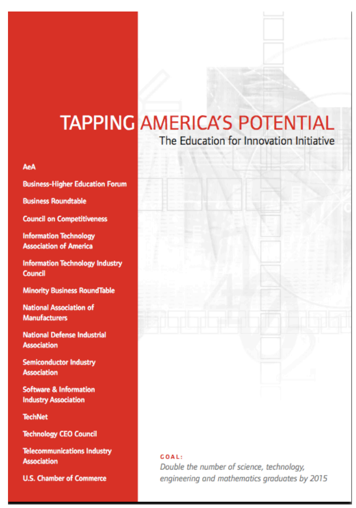
Innovate America

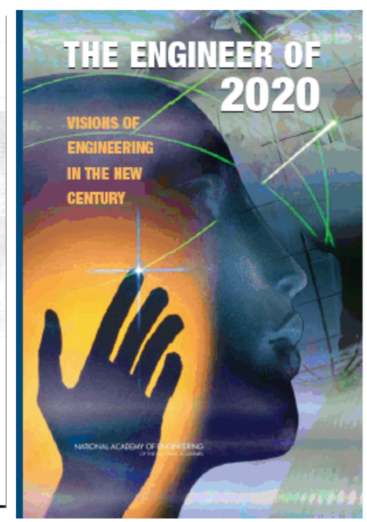
Thriving in a World of Challenge and Change

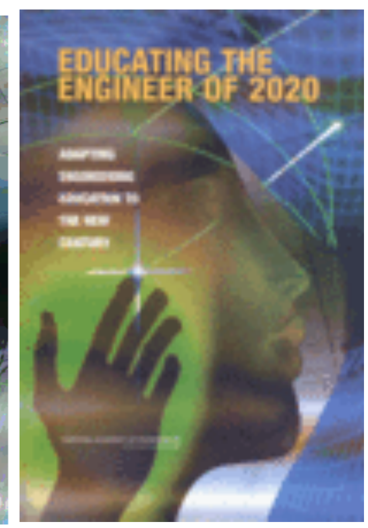
National Innovation Initiative
Interim Report
7/23/04











Transforming Engineering Education

Technology Offers New Opportunities

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.

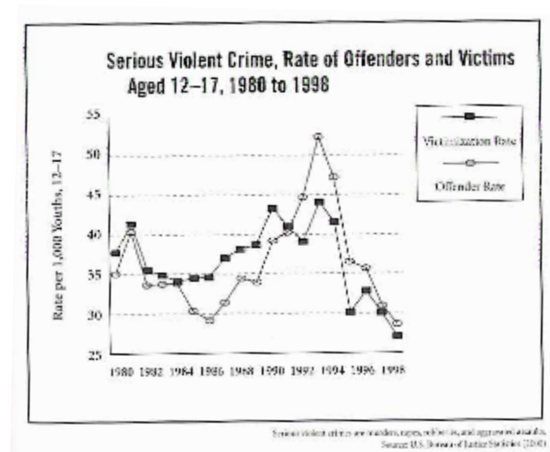
- Wal-Mart 1969
- Microsoft 1976
- Oracle 1977
- Apple 1976
- Dell 1984
- Amazon.com 1994
- eBay 1995
- Yahoo 1995
- Google 1998
- Salesforce.com 1999
- Facebook 2004
- Twitter 2006

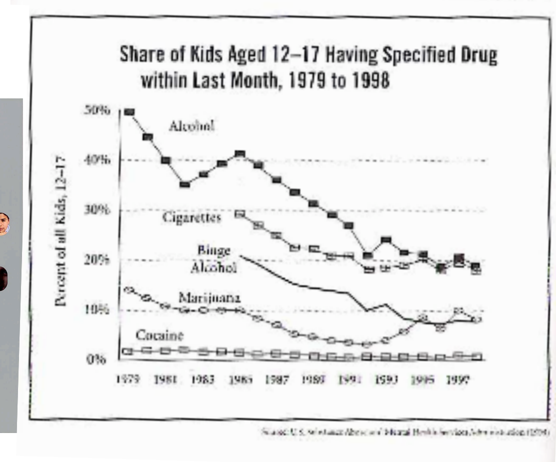
Transforming Engineering Education

The Students are Changing

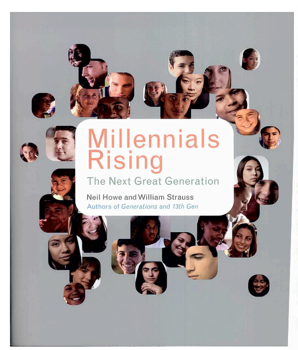
Their background is different: Students now come into engineering with little hands-on knowledge, but often with extensive computer experience.

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 them selves 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."*



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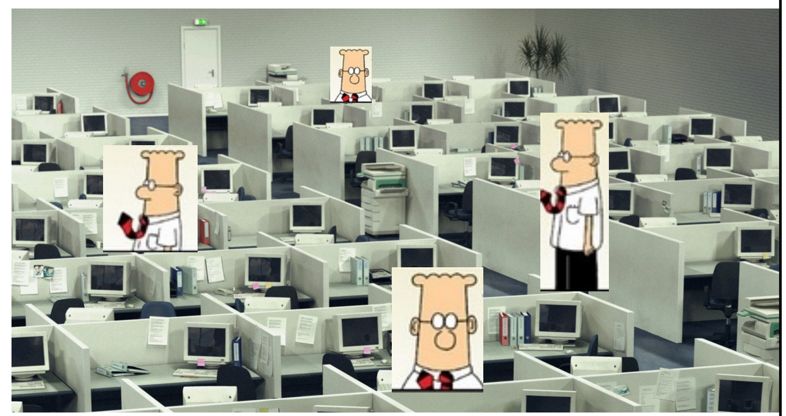
What is Engineering?

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

	Study	Create
Cultural	Humanities	Arts
Physical	Science	Engineering

Engineering as a discipline

Commodity Engineers



Entrepreneurial Engineers

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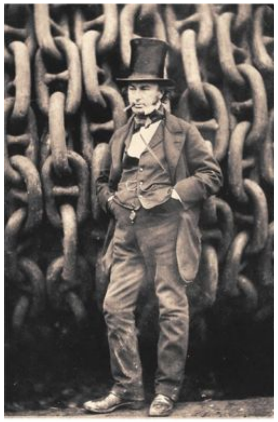
Transforming Engineering Education

First the Context

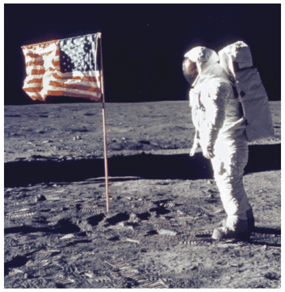
<u>19th and first half of the 20th century: The professional engineer</u>

Early engineering programs focused on providing their graduates with considerable hands on training. However, mathematical modeling slowly increased as Applied Mechanics increasingly gained acceptance.



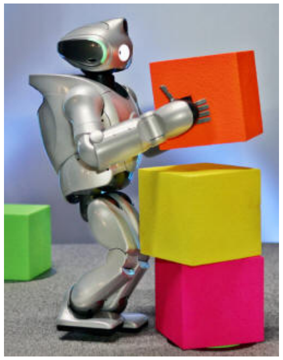
<u>Second half of the 20th century: The scientific engineer</u>

In the the sixties, 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



<u>The 21st century: The entrepreneurial engineer</u>

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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Transforming Engineering Education
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

Source: Tryggvason and Apelian, Journal of Metals, V.58, No.10, pp. 14-17 (2006)

Changes

Changes are already taking place. Many universities are experimenting with new programs, new approaches and new ideas. And new players are emerging

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Transforming Engineering Education
Education in a new century

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!

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Transforming Engineering Education

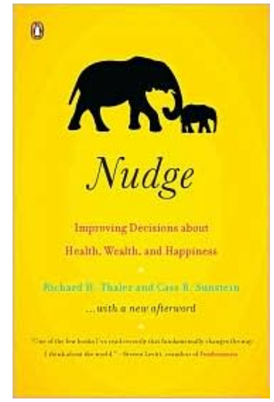
New Things to Learn

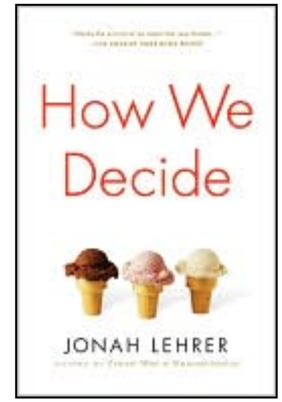
Engineers have always learned what they needed to know to get their job done. In the 20th Century the laws of physics were usually the limiting factor

We have, however, increasingly become very good a 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





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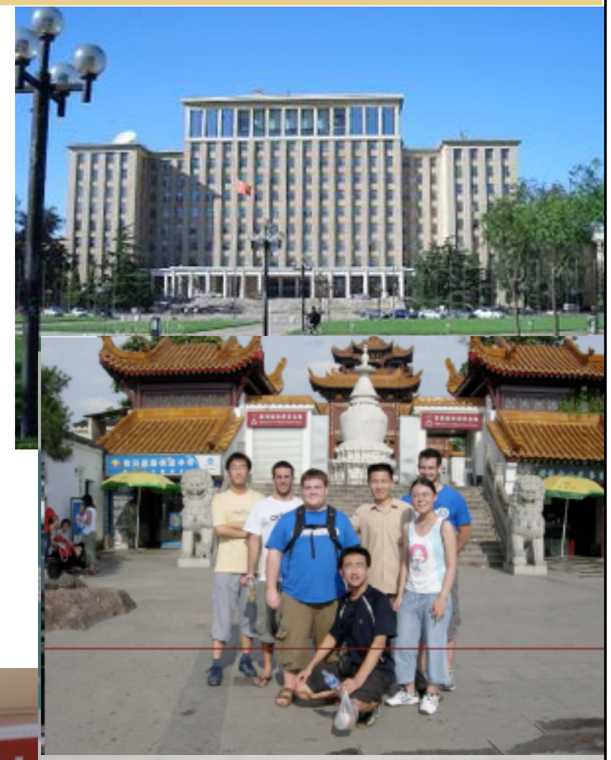
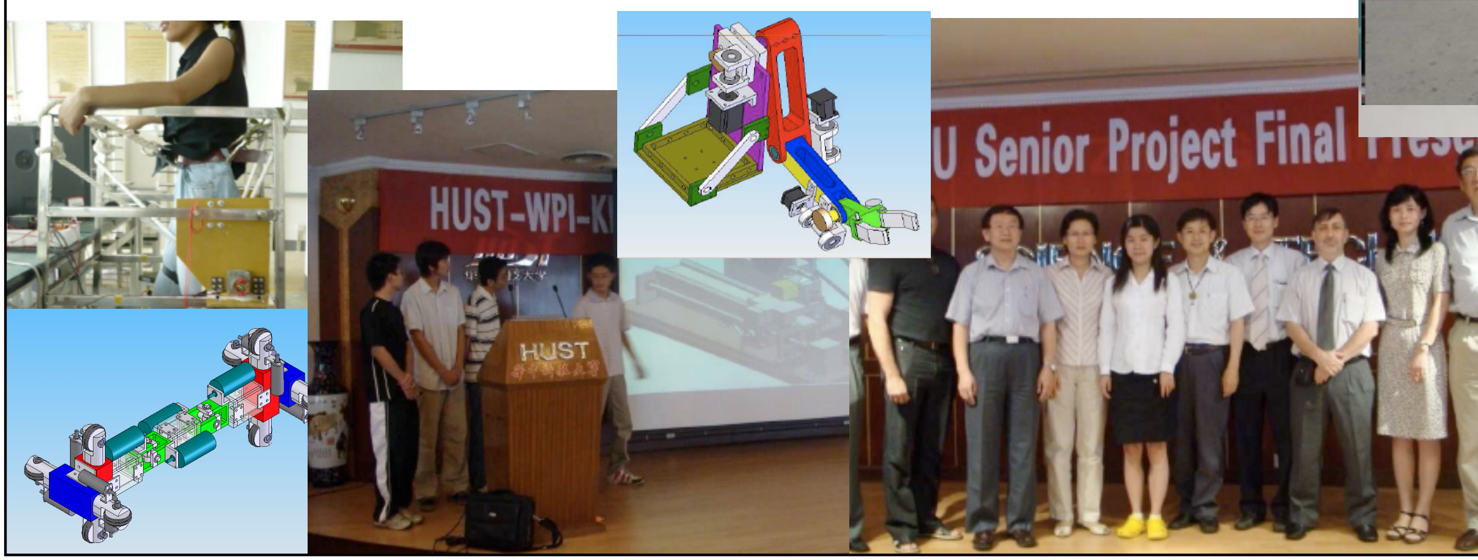
Transforming Engineering Education
Working in a Flat World

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%





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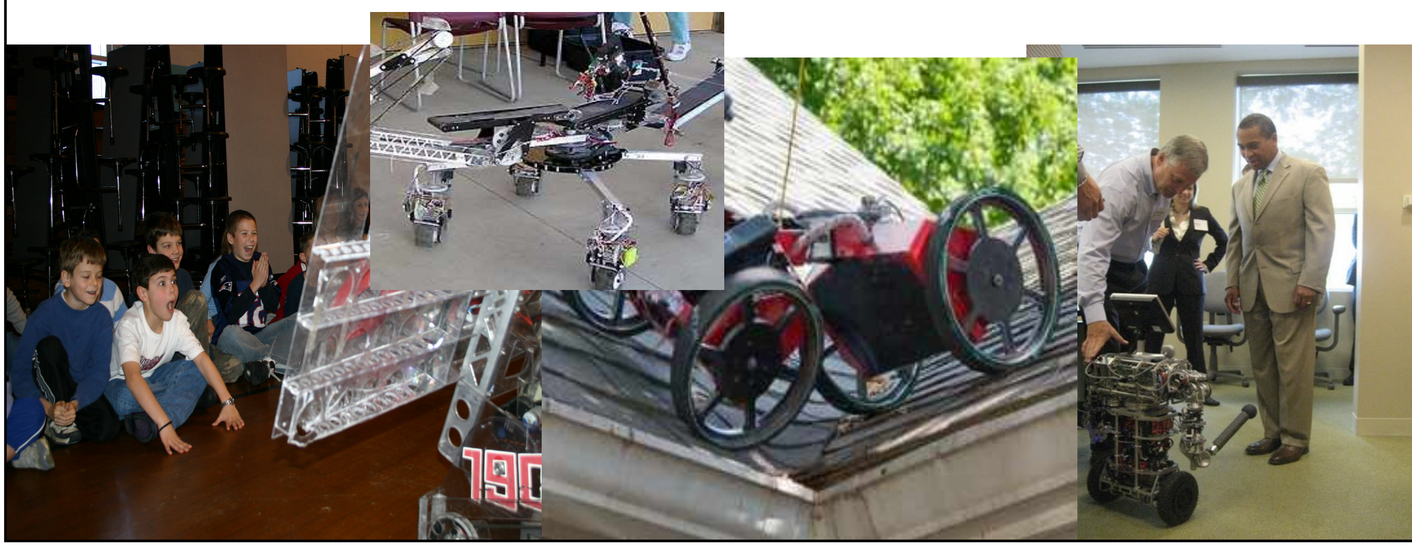
Transforming Engineering Education

New Programs

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

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Transforming Engineering Education
Graduate Education

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.

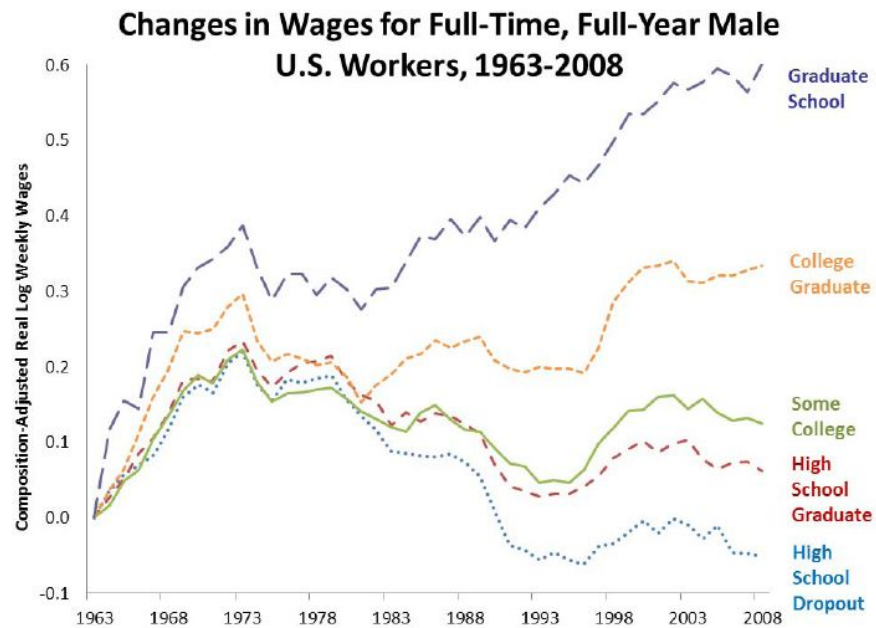

Figure 3.5: Wages have increased for those with the most education, while falling for those with the least. Source: Acemoglu and Autor analysis of the Current Population Survey for 1963-2008.

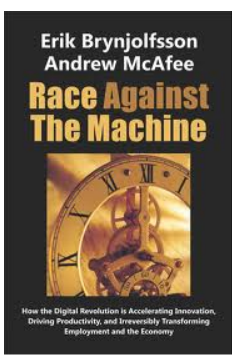

TABLE 11.1 Engineering Degrees in 2000 and 2009 [1]

Engineering Degrees	*BS*	*MS*	*PhD*
2000	63,820	30,160	5,999
2009	74,387	41,632	9,083
% Increase	16.5%	38.0%	51.4%

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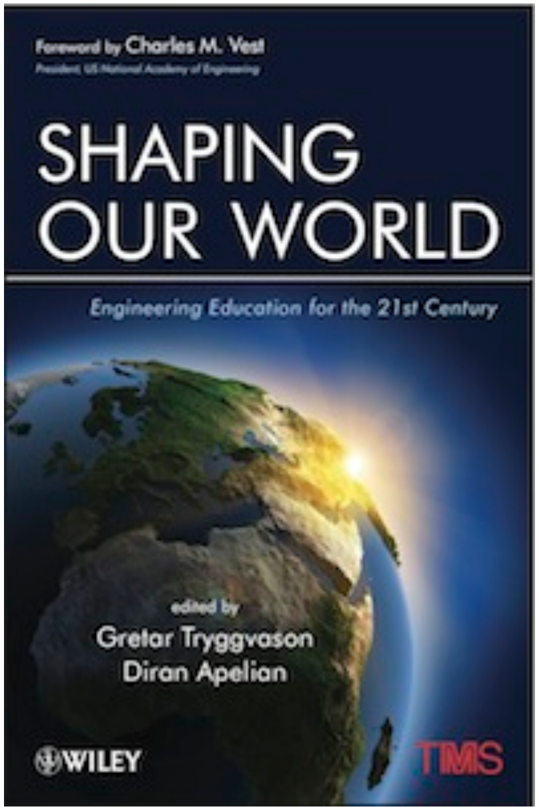
Transforming Engineering Education
Changes are already taking place

- 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.

Transforming Engineering Education

And Finally!



Opinion | Feature

Re-Engineering Engineering Education for the Challenges of the 21st Century

Gretar Tryggvason and Diran Apelian

INTRODUCTION

Engineering education and the profession are confronting a challenging crossroad. Some of us see it as a crisis, others, as an opportunity for positioning our community and our society for the 21st century. It would be fair to say, however, that none of us are very satisfied with the status quo and what seems to be facing us in the near term. As Charles Dickens cited in the opening of *A Tale of Two Cities*, "It was the best of times, it was the worst of times".

Author and journalist Thomas Friedman has declared that the world is now flat.[1] Globalization of the economy has amplified the impact of technology on modern societies in ways that could not have been predicted. The connectivity provided by the Internet has generated new markets for products and services, but has also made available labor that is often both educated and cheap. This is likely to have a profound impact on the distribution of wealth in both the developed and the developing parts of the world and may, in particular, alter the socio-economic structure of countries where the general wellbeing of the population has been taken for granted. That education plays a role in the prosperity of nations is not debated, but many authors, like Landes[2] for example, argue that it is specifically the presence of both knowledge and know-how that determines how well off societies are. The education of engineers is therefore critical to every nation to ensure the prosperity of their citizens.

The modern professional identity of engineers emerged in the early 18th century with the establishment of the Ecole Polytechnique in France and the foundation of professional engineering societies in England. The current way of educating engineers, including the structure of the curriculum, was already established by the early 20th century, but the course content has, of course, changed significantly since then. The last major shift in engineering education in the United States goes back over half a century when the role of science in the educational program increased significantly.[3] Although some evolution certainly has taken place, those changes are relatively modest and the basic structure and course content of a modern engineering program is very familiar to someone educated in the sixties.

Countless committees, task forces, panels, and commissions have already addressed the need and eloquently emphasized that the competitiveness of the country and therefore the general standard of living hinges on the ability to educate a large number of sufficiently innovative engineers.

The time for another major re-examination of engineering education is overdue. Countless committees, task forces, panels, and commissions have already addressed the need and eloquently emphasized that the competitiveness of the country and therefore the general standard of living hinges on the ability to educate a large number of sufficiently innovative engineers [See, for example References 4–8]. Figure 1 clearly shows the concern with respect to manufacturing production, especially when one compares the production in the United States to Japan and China.[9] This is even more concerning when one considers that creation of wealth is related to a nation's ability to make products that other nations want to purchase.

That the world has changed in fundamental ways during the last decade or two is self-evident. Computers have completely altered the way we live and work. They have, in particular, transformed our ability to deal with information and data. We are now moving rapidly toward a world where, for all practical purposes, we can process information infinitely fast, store infinite amount of data, and transmit data instantaneously, to paraphrase a statement made by Henry B. Schacht, the first chairman and chief executive officer of Lucent Technologies Inc. in his commencement speech at Worcester Polytechnic Institute (WPI) in 2001.

As a result of the emergence of the Internet, knowledge has been "communalized." Everybody has access to information about anything and, perhaps equally importantly, knowledge is no longer "owned" by the experts. High school students can, and do, write articles on Wikipedia, just like the professors. This change has already transformed industries and raised fundamental questions about authorship and ownership of information and scholarly works. Computers have also empowered the average man and woman to create products that previously required large corporations

14 JOM • October 2006

中国大学教学 2008 年第 12 期

21 世纪的工程教育重构

[美]Gretar Tryggvason Diran Apelian

引 言

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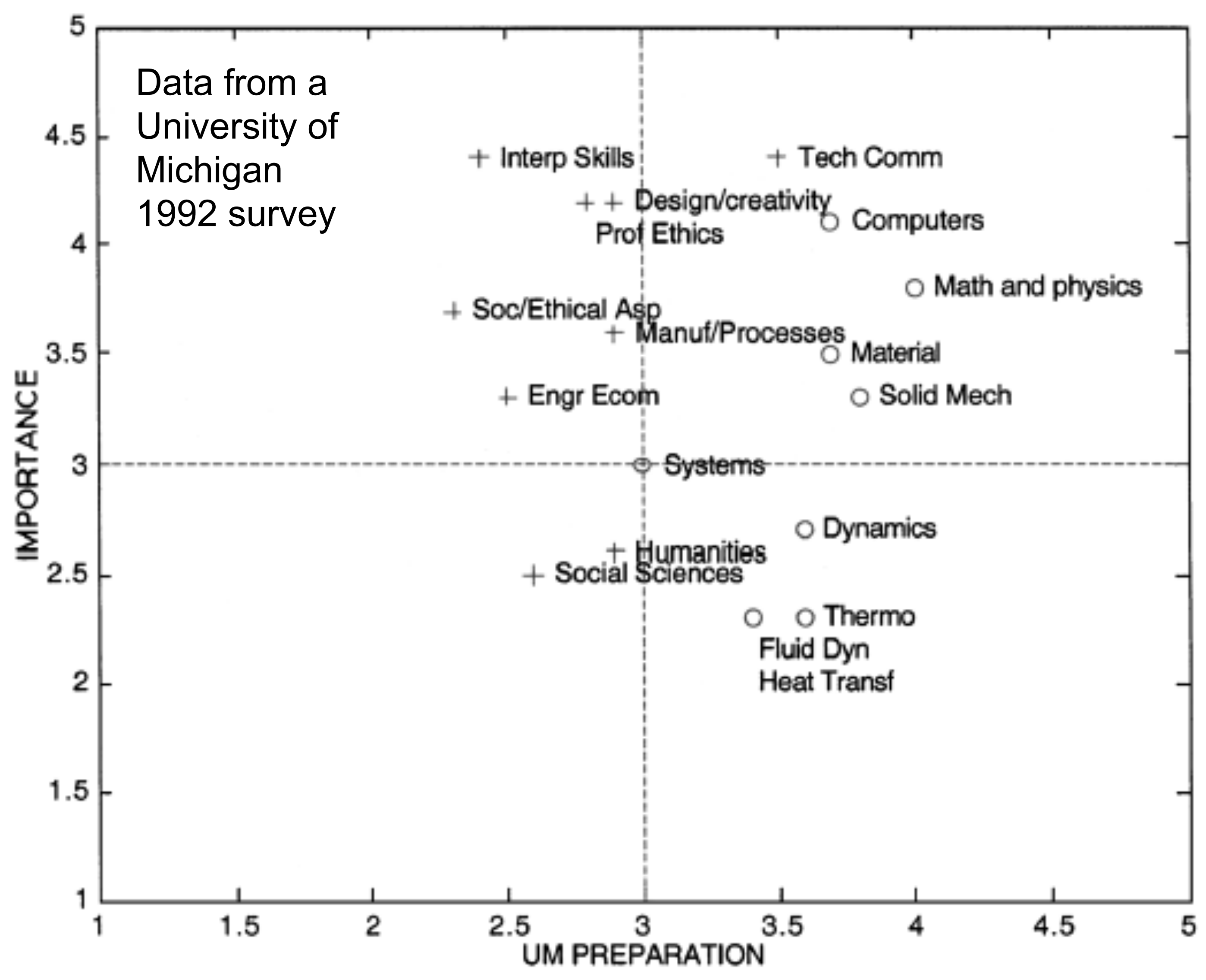
These changes—and others—are already taking place. I have attempted to put these changes in context and to examine what is likely to happen next. But, predicting the future is hard and experimentation is needed!

Transforming Engineering Education
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.

Reference: G. Tryggvason, M. Thouless, D. Dutta, S. L. Ceccio, and D. M. Tilbury. “The New Mechanical Engineering Curriculum at the University of Michigan.” *Journal of Engineering Education* 90 (2001), 437-444.



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.

http://en.wikipedia.org/wiki/World_of_Warcraft

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Transforming Engineering Education

Details……..Details……Details

- 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

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Transforming Engineering Education

Discussion topics:

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 then 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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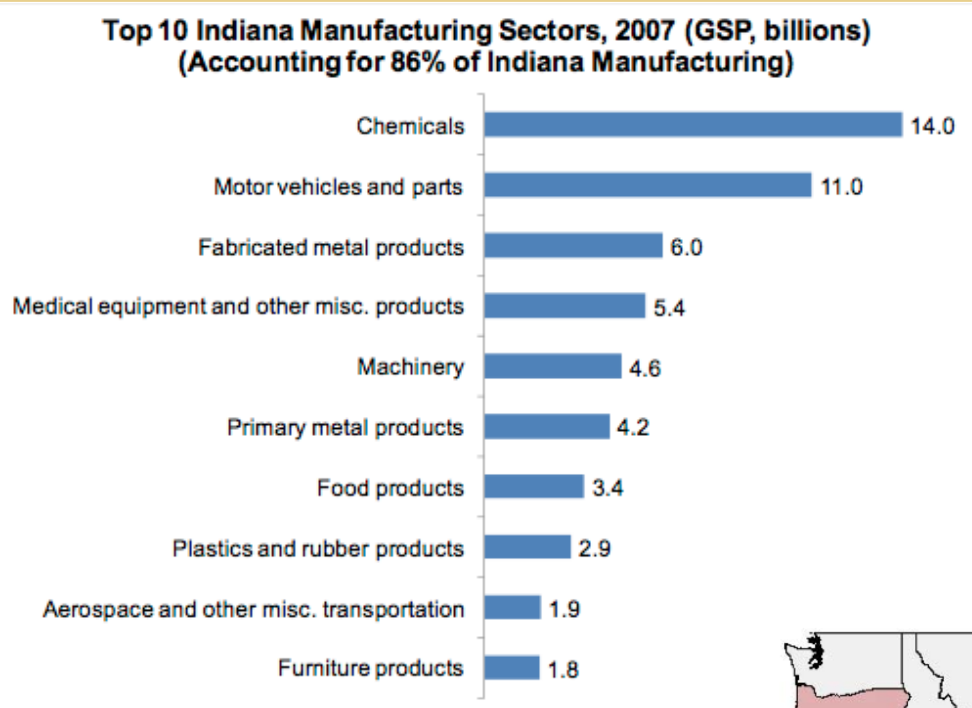
Transforming Engineering Education



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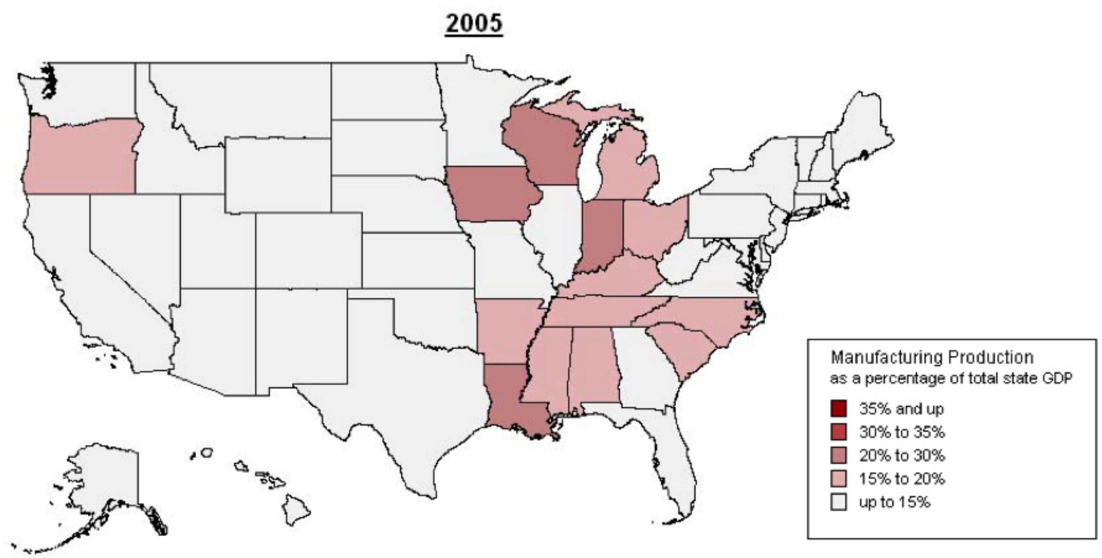


http://trade.gov/manufactureamerica/facts/tg_mana_003019.asp

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

Moving Forward

Transforming Engineering Education

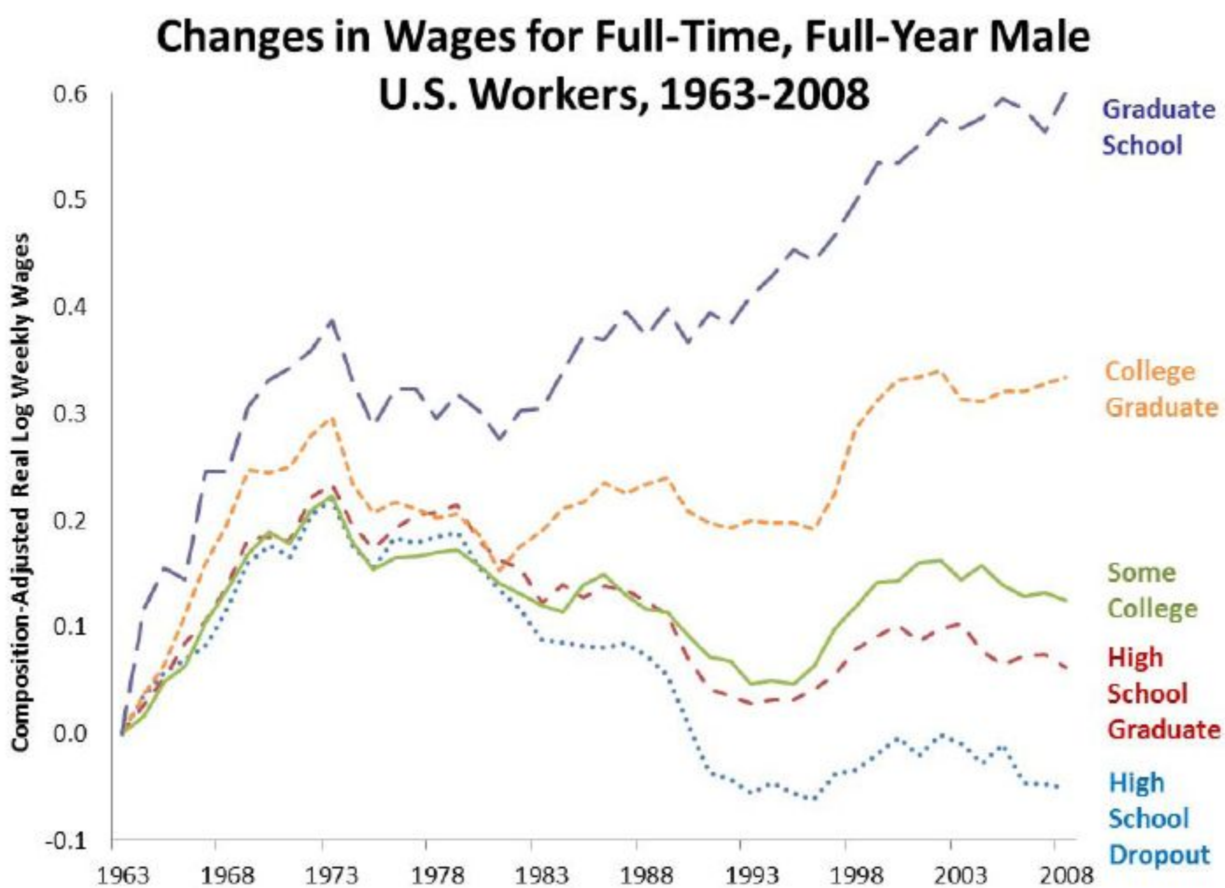
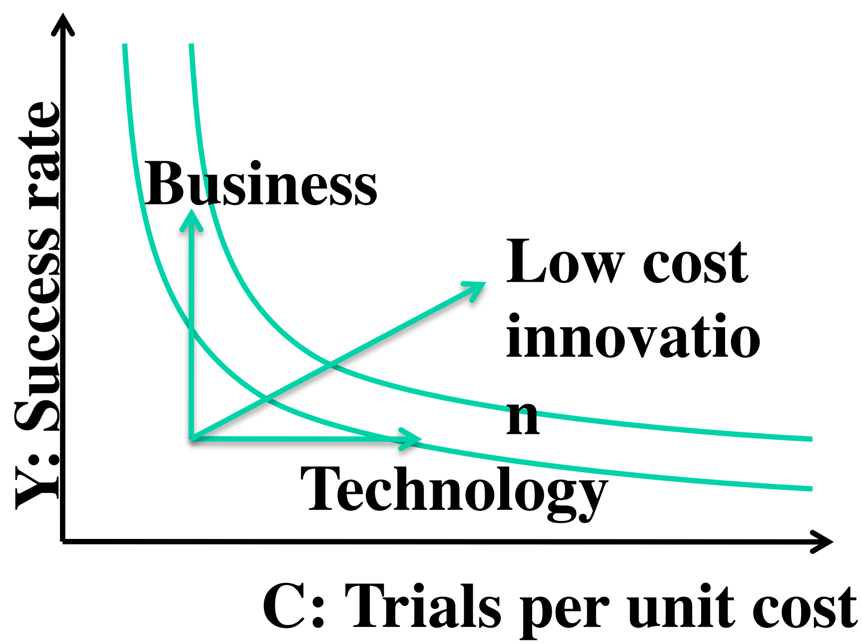


Figure 3.5: Wages have increased for those with the most education, while falling for those with the least. Source: Acemoglu and Autor analysis of the Current Population Survey for 1963-2008.

Making Innovations Possible

$$\text{Average cost of successful innovation} = \frac{\text{total cost}}{\text{total trials}} \times \frac{\text{total trials}}{\text{successful trials}} = \frac{1}{Y} \times \frac{1}{C}$$

Y: Success rate
C: Trials per dollar



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