Leveraging Engineering Education Innovation to Redefine Undergraduate Education

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Questions for Today

• **How did we get here?**

• What are the data telling us?

• What are the desirable learning outcomes?

• Any reflections from Olin experience?

• Can engineering education innovation be a lever for rebalancing 21st Century education?
This is not a new challenge – Washington Roebling graduated from RPI in 1857!

“…the terrible treadmill of forcing an avalanche of figures and facts into young brains not qualified to assimilate them…I am still busy trying to forget the heterogeneous mass of unusable knowledge that I could only memorize…”
1945: “Science won the war.”
*Engineering becomes Engineering Science.*
Pendulum swings too far, society and education change

30 years of calls for change follow…


Current realities - rebalance content and process

- **There will never be enough time to ‘cover’ the material.**

- **We do not retain what we do not use.**

- **Information is a means not an end.**
Teamwork, communication, creativity, leadership, entrepreneurial thinking, ethical reasoning, global contextual analysis
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Current realities – who are our students?

- Average of independence ~ 29 years old
- 31M people have partially completed college
- >40% of undergraduate population is over 25
Observations from USA undergraduate degree data (Department of Education)

- Small percentage of engineering degrees
- Balkanization of American higher education – A&S vs Engineering vs Business rather than integrated

<table>
<thead>
<tr>
<th>Total</th>
<th>2001</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.24M</td>
<td>1.89M</td>
</tr>
<tr>
<td>Engineering</td>
<td>58k/4.7%</td>
<td>98k/5.2%</td>
</tr>
<tr>
<td>Engr Tech</td>
<td>14k/1.2%</td>
<td>17k/0.9%</td>
</tr>
<tr>
<td>CS/IS</td>
<td>44k/3.5%</td>
<td>60k/3.1%</td>
</tr>
<tr>
<td></td>
<td><strong>9.4%</strong></td>
<td><strong>9.2%</strong></td>
</tr>
<tr>
<td>Business</td>
<td>264k/21.1%</td>
<td>364k/19.2%</td>
</tr>
<tr>
<td>Biology</td>
<td>61k/4.9%</td>
<td>110k/5.8%</td>
</tr>
<tr>
<td>Health</td>
<td>76k/6.1%</td>
<td>216k/11.4%</td>
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Implications - USA compared to the world
(Department of Education)

• **Tipping point for impact – societal priorities, government policy, active and informed citizenship…**

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<thead>
<tr>
<th></th>
<th>Engineering</th>
<th>Physical Sciences</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>5%</td>
<td>11%</td>
</tr>
<tr>
<td>Poland</td>
<td>11%</td>
<td>10%</td>
</tr>
<tr>
<td>Japan</td>
<td>16%</td>
<td>7%</td>
</tr>
<tr>
<td>Finland</td>
<td>20%</td>
<td>9%</td>
</tr>
<tr>
<td>South Korea</td>
<td>24%</td>
<td>12%</td>
</tr>
<tr>
<td>China</td>
<td>32%</td>
<td>13%</td>
</tr>
</tbody>
</table>
Sample implication – government policy

- 113th Congress (2015) – Engineers: 1.4%, No college: 5.0%

The ax falls on research
Numerous federal science programs would see major cuts from 2016 levels under President Donald Trump’s 2018 budget request, with the National Institutes of Health (NIH) getting a $6 billion, 20% cut, a preliminary analysis suggests. Nuclear weapons funding would surge.

% change
- ARPA-E: -100
- NOAA research office: -52
- EPA R&D office: -48
- DOE energy programs: -44
- EPA: -30
- NIH: -20
- DOE Office of Science: -17
- NOAA satellites: -16
- NIST: -13
- USGS: -10
- NASA earth science: -5
- NASA: -1
- USDA competitive grants: 0
- DOE nuclear weapons (NNSA): 11

Graph: David Malafronte/Science
Data: Matt Hounihan, AAAS R&D Budget and Policy Program
Gallup data –
Disconnected of the academy and non-academic world

- 98% of Provosts/CAOs say their institutions effective/somewhat effective at preparing students for work life.
- 11% of business leaders strongly agree that graduating students have skills and competencies needed for success.
Gallup data –
Undergraduate experience affects quality of life

- **Purpose** – what you do and how much you like it
- **Social** – relationships, love of life
- **Financial** – reduced stress, security
- **Community** – engagement with others
- **Physical** – health and well-being
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Learning outcomes for Foundational Engineering Education(?)

- **Foundational** →
  - Provide a strong platform upon which to build a career but more importantly
  - Prepare for an engaged life

- **Engineering** →
  - Leverage intrinsic motivation, technical skills and context to create and solve
  - Practice at engineering – (self-)empowerment of realization

- **Education** →
  - Convert information to knowledge (insight?)
  - Learn how to learn and to want to learn
The Excitement of Engineering

There Must be a Better Way!  
(Analysis)

Why Doesn’t it Work?  
(Test)

Why Not…?  
(Idea)

Let’s Try It!  
(Prototype)

Empowerment
“Making universities and engineering schools exciting, creative, adventurous, rigorous, demanding, and empowering milieus is more important than specifying curricular details”
Charles Vest, NAE & MIT President emeritus
Culture trumps curriculum

- Culture needs to have a scaffold
- Student as partners – engaged and intrinsically motivated
- Continuous curriculum innovation
- Connect educational theory and practice
- Broader (contextual) definition of engineering
Attitudes and behaviors

• **Motivation** – provide opportunities for students to do something (Felder & Silverman, 1988)

• **PBL/PjBL courses**…spark some significant changes in students’ cognitive and behavioral strategy… (Lord et al., 2012)

• **Students in lecture-only courses did not connect their perceived ability to do engineering with the outcomes they would experience as engineers** (Atadero et al., 2015)
Active learning better serves the meta-goals for success in the engineering profession

**Feasibility**

Overemphasized in Engineering Education

**Desirability**

**Viability**

Embed in the programs and culture

**Innovation**
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A little bit of information about Olin
(Needham MA near Babson and Wellesley colleges)

- Founded in 1997, first graduates in 2006
- Total enrollment of about 350
- Nearly 50% women
- BS degrees in ECE, ME, E
- No academic departments
- ~40 Faculty – renewable contracts
- Merit (50% for all) plus need blind aid
- 100s of visitors and several collaborators
One faculty – one combined mission – one curriculum

Typical response:

No Tenure
No Departments

The reality:

No Tenure
No Departments

“He’s been pretty much insisting on this ever since he got tenure.”
Emphasize connectivity and why do we care

Just in time (not just in case) learning

Nearly 75% of the curriculum is independent of major.
Strong common technical foundation for all students.

- People
- Needs
- Requirements
- Specification
- Product
- People
The Learning Continuum

- Courses
- Research
- Recreation
- Passionate Pursuits
- Co-Curriculars
- Clubs & Organizations
- Post Graduate Planning
- Residence Life
- Community Service
- Service to the College
Integrate practice at engineering and ‘soft’ skills → professional skills
**Integrative learning - Competency and confidence to use ‘power tools’**

**Desired Outcome:** Competence and confidence in choosing and using the “power tools” (tools, concepts, ways of thinking) of design and analysis.
Integrative learning –
e.g. Quantitative Engineering Analysis (QEA)

- Strengthen analysis through synthesizing math, physics and engineering science in a project-based environment

- Alternative to disconnected courses embedded in the first years of engineering programs.

- Two-semester, double-wide (i.e. eight credits each term) course sequence – launched January 2016

- Created by a team of Olin faculty and students
Substantive and ‘real’ experiences

SCOPE or Affordable Design & Entrepreneurship (ADE)

**SCOPE**
- Sponsored
- Mid-burner project
- Professional mentor
- ~5 students
- No Olin IP claims/NDAs

**ADE**
- Donations
- Non-profit – international
- People, impact, humility, justice
- ~5 students
- No Olin IP claims/NDAs
(Elsewhere) **Tenure** based on demonstrated professional accomplishments in teaching, research and scholarship, and service … will continue to contribute in all of these areas at a level of excellence … through the indefinite future.

- **Teaching**
- **Research**
- **Service**

- Three Buckets – disconnected, size of each bucket?
- Individual not institution, separate not integrated, static not dynamic for the indefinite future
- No mention of mission - personal and institutional
A new model – consensus developed by faculty and administration

- Robust annual feedback, embedded faculty development
- Reappointment (looking forward) vs Promotion (retrospective)
- 19 cases so far → case law and processes evolving
- Implications for institutions with tenure systems
Can engineering education innovation be a lever for rebalancing 21st Century education?

• **YES**
  
  • *Balanced and integrated education with a foundational engineering core is best positioned in the academy to be the driver of such a system.*
  
  • *Important and positive impact on who studies engineering or who includes engineering in their studies - engineering profession, quality of life, society.*
  
  • *What does this mean about educational models? Faculty responsibilities and competencies? Academic culture, reward system, priorities? Industry role? ABET?*...
Take-away 1 - Learning to learn is hard fun

HARD WORK NEVER KILLED ANYBODY, BUT WHY TAKE THE CHANCE
Take-away 2 – Students should have goals and take responsibility
Take-away 3 - Failures will happen: Learn from them, control their size
Take-away 4 - Practice being comfortable with discomfort (It’s hard!)
We need to collaborate and co-create: Virtuous cycle and feedback loop

Curriculum Innovation

- New and innovative approaches
- Contextual opportunities
- Reflection and questioning

Virtuous Cycle

- Good Seeds
- Good Results
- Good Goals
- Good Actions

Education and facilitation

- Faculty development
- Outside perspective

Culture
These choices are ours to make – as educators, as students, as parents, as alumni, as taxpayers, as schools, as companies, society… They are the choices between the past and the future. Goldberg & Somerville, 2014.
Thank you for inviting me. What do you think?