Engineering Entrepreneurship and Enterprise Education

NAE Bernard M. Gordon Prize 2014 Lecture
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Dartmouth College, Thayer School of Engineering

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context: a decade of discussion of the STEM challenge

• National need for STEM-education for global competitiveness

• Reports issued 2004-2006, 2010 cite need for STEM funding, lead to COMPETES

• Less noticed, also cite need for transformation of undergraduate education, better translation of invention out of laboratories

• “Ensure that the United States is the premier place in the world for innovation” - the context for programs in engineering entrepreneurship
history of engineering at Dartmouth

1867: Founded (Thayer Endowment), Overseers Named

1871: Robert Fletcher, 1st Dean and Professor, begins instruction. Professional school – must first complete liberal arts education

**Engineering Sciences** model – *no engineering departments*

Founded as a school of civil engineering; EE, ME later added

Transformation in 1958 to a 5 year, AB plus BS (BE) program
  - transition in early 1960s to ENGS from ME, EE, CE
  - Integrated engineering systems approach, with emphasis on open-ended design and innovation from start

Concentrations to learn fundamentals

One of largest interdisciplinary (BS) BE programs in the US

ONLY one *requiring* AB prior to BE
outward focus from the beginning

“To prepare the most capable and faithful for the most responsible positions and the most difficult service”

Sylvanus Thayer, Father of West Point and Founder, Thayer School of Engineering, Dartmouth College, 1867
Myron Tribus, dean of engineering (1961-1969), introduces foundation of open-ended design and project work into curriculum

“...experience the hands-on fun of actually doing something creative and useful before undertaking the abstract theoretical courses required for advanced practice...”

Robert (Bob) Dean, faculty member in 1960s, oversaw development

“...produce engineers who could stand with one foot in each world, who would be technological entrepreneurs.”

Approach: combining this foundation, developed through 1980s, with new pathways for Master’s level (1990s) and PhD (2000s)
first element -
undergraduate programs,
the AB and the BE
undergraduate introduction to engineering: ENGS 21

Professors choose theme, providing guidance yet latitude. Students choose problem.


“Introduction to Engineering” – a true introduction to entrepreneurship

Now 3x per year. Enrollments approaching 200 per year in Dartmouth class of ~ 1,000; > 20% are non-majors
themes intentionally broad to help facilitate creativity and leadership

Saving Water

Mobility and Portability

Engineering in Medicine

Timesaving Technology

Improve the Quality of Life in Winter
peer learning a core element – fully “flipped,” coached classroom
peer learning a core element
ENGS 71, structural analysis, all for one
ENGS 146, computer-aided design

... go beyond the patent literature – in just 4 weeks
ENGS 146, May 2014, from twist cars to di-wheels...
5th year capstone design course, fully interdisciplinary

past 3 years, > 85% submissions, 80% selections - non-profits and startups or very small businesses

Collegiate Inventors Competition, BMEStart – finalists 4 of 5 years, 2009-2013; 2 first place awards
second element, master’s level – Master of Engineering Management (MEM)
the master of engineering management (MEM) program

• program prepares BS engineering students for engineering leadership and management in a corporate environment

• created in 1989 as a professional, project-based masters program in partnership with the Tuck School of Business

• 15 month curriculum combines engineering (taught by Thayer faculty) and business (taught by Tuck faculty)

• Tracks of electives include Entrepreneurship; Health Care; Energy; early course in Technology Assessment

• Business entrepreneur competitions
ENGM 178: data-centered technology assessment

structured approach to assessing technology readiness – “if I were the CEO, should I invest or choose alternatives?”

multi-step process

- understand the problem; craft need statement
- search for competing and complementary technology
- develop cost / performance / environment criteria
- consult experts, conduct economic analysis and technology readiness review
- assess regulatory environment, current and future
- recommend and justify

Improved IGCC for Power Generation; Emerging Technologies in Thin Film Solar Cells; Recovery of Methane Hydrates...
Dartmouth team one of forty-two selected to compete in Rice Business Plan Competition (1800 entries)
April 13, 2012
Litherland, Morris MEM ’13, and Camila Hernandez

MEMs win Oliver Wyman Case Competition
March 5, 2012
Shen, Bao, Rathi, and Zhang, all MEM 2013

Medical/Business and Engineering Students Win Dartmouth Business Plan Competition  May 25, 2011
Bendich, Kwei MEM ‘12, Gigliotti

40% of MEM survey respondents 15 years out had started company (38% response rate)
third element, doctoral level –
Engineering PhD Innovation Program
context: national doctoral enrollments and degrees

full-time engineering PhD enrollments

25% growth, 2008-2013

engineering PhD degrees granted

19% growth, 2008-2013

source: ASEE Profiles of Engineering and Engineering Technology Colleges, 2013
PhD employment 1993-2013

employed US-educated PhDs

engineering: >30% growth each decade

pct employed by 4-yr universities

engineering: absolute growth each decade, but less than overall;

percentage declining

only 1 in 4 ENG PhDs in academia

source: NSF Survey of Doctorate Recipients, September 2014, NSF14-317, and earlier versions
academic opportunity?

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<th>2008</th>
<th>2013</th>
<th>Pct Chg</th>
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<tbody>
<tr>
<td>Number of PhD Graduates</td>
<td>9,086</td>
<td>10,764</td>
<td>18.5</td>
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<tr>
<td>Tenure track faculty</td>
<td>24,207</td>
<td>25,628</td>
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<td>Tenure track Assistant Prof</td>
<td>5,610</td>
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</tbody>
</table>

estimated number of annual Assistant Professor openings: 950 – 1000

source: ASEE Profiles of Engineering and Engineering Technology Colleges, 2013 and 2008
academic opportunity?

US engineering PhD programs – work exceptionally well to train researchers

- fundamentals in the discipline, followed by qualifying exam
- coursework or seminar study to support research project
- deep exploration of original research question

little attention paid to...

- teaching teaching
- breadth PLUS depth often valued by industry
- educational elements of entrepreneurship

yet data suggest that, at most:

- 1 in 4 engineering PhDs work at universities
- 1 in 10 engineering PhD graduates will obtain tenure track positions
- < 1 in 10 become faculty at 108 “Very High Research Activity” (RU/VH) institutions
PhD Innovation Program – launched in 2008

designed to be SMALL, SELECTIVE, FOCUSED – 5 student / yr limit

Different curriculum, approach; REVERSE FELLOWSHIPS

Beyond PhD - COURSEWORK, BUSINESS PLAN, INTERNSHIP

Broad FACULTY PARTICIPATION:  > ¼ of faculty

RECOGNITION for company spun out of university

noted as PROVIDING NEW PATH for PhD
transformational OUTCOMES v existing Dartmouth PhD program

- **domestic IP filing**
- **post-doc**
- **establish or join startup**

Figures represent percentage of PhD graduates. PhD-I, since 2008 start. Baseline PhD – past three years of graduates
“For creating an integrated program in engineering innovation from undergraduate through doctorate to prepare students for engineering leadership”
experiments in engineering PhD education

MIT PhD in Chemical Engineering Practice

Trinity College Dublin, University College Dublin, Queen’s University, Belfast. Ref. McNabola and Coughlan, 41st SEFI Conference, 2013

are certainly others. but the list is not long.

if we think about outcomes and PhD pathways – shouldn’t there be more?
back to the beginning – a national imperative

engineering enrollments and degrees

full-time undergraduate enrollments

7% growth, 2003-2008
35% growth, 2008-2013

Bachelor’s degrees granted

2014 prediction: 97,000-100,000
2015 prediction: 105,000-108,000

source: ASEE Profiles of Engineering and Engineering Technology Colleges, 2013
broad goal – technology leadership

goal – create next generation of technology leaders who understand and lead the innovation and commercialization process

• Can you create a leader? Perhaps not.

• But, we can *inspire* students to be leaders, *nurture* latent interests and abilities, and *prepare* them for opportunity

• Current BS enrollments unthinkable 5 yrs ago. PhD growth is also occurring

• Will we have the research funding to support their scholarly work?

• Do we have the right programs in place to educate them, not “just” to be researchers, but to be technology leaders?