The Innovation Imperative

Research and Education That Transforms

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What Country Is This?

- Average life expectancy: 47;
- Only 14% of households had a bathtub;
- Only 8% of homes had a telephone;
- 3-min. call between cities cost $11;
- There were only 8000 cars & 144 miles of paved roads;
- Speed limit in most cities: 10 mph;
- Average wage: 22 cents/hr;
- Average worker earned $200-$400/yr.

“This seems a very small and/or poor country.”
By Any Standard of Today, the U.S. of 1901 Would Be an Under-Underdeveloped Country

- Average life expectancy: 47;
- Only 14% of households had a bathtub;
- Only 8% of homes had a telephone;
- 3-min. call from Denver to NYC cost $11;
- There were only 8000 cars & 144 miles of paved roads;
- Speed limit in most cities: 10 mph;
- Average wage: 22 cents/hr;
- Average U.S. worker earned $200-$400/yr.

We’ve come a long way!
Engineers and Scientists Made A World of Difference in the 20th Century: Some Examples of Innovations*:

- **Transportation** – Vehicles, Infrastructure, Speed, Range;
- **Aerospace and Satellite Technologies** – Moon Landing & Back;
- **Agricultural, Food, and Pharmaceutical Technologies**;
- **Bioengineering & Healthcare Technologies** – Imaging, Lasers, etc.;
- **Smart Materials, Synthetics, Petroleum and Petrochemicals**;
- **Energy and Power Systems** – Nuclear Technologies;
- **Smart Household Appliances**; AC and Refrigeration;
- **Nanotechnology, Micro-/Opto-electronics, Entertainment, etc.**;
- **Computation and Telecommunication** – Cellphones, PDAs, etc.

Just imagine you we’re an ET on your first return visit to Earth since 1900. Wouldn’t you suspect that you might have landed on the wrong planet? Also, what do we do for an encore in the 21st Century?

*See [http://www.greatachievements.org](http://www.greatachievements.org) for a more authoritative list.
However, as Yogi Berra said...

Making predictions is a risky business, especially if it is about the future.
“I think there is a world market for maybe five computers.”

*As reported in the Business Section

*Kansas City Star; January 17, 1995
“Computers in the future may weigh no more than 1.5 tons.”

*As reported in the Business Section Kansas City Star; January 17, 1995
Ken Olson, President, Chairman, and Founder Digital Equipment Corporation, 1977*  

“There is no reason why anyone would want a computer in his home.”  

*As reported in the Business Section Kansas City Star; January 17, 1995
Some Watershed Inventions – That Have Turned into Innovations (1)

- Flush Toilet (Bramah, UK, 1778; self)
- Cotton Gin (Whitney, US, 1793; self)
- Vulcanized Rubber (Goodyear, US, 1839; self)
- Telegraph (Morse, US, 1843; self)
- Refrigeration (Gorrie, US, 1850; self)
- Telephone (Bell, US, 1876; self)
- Ketchup (Heinz, US, 1876; self)
- Int. Combustion Engine (Otto, Germany, 1876; self)
- Phonograph (Edison, US, 1877; self)
- Incandescent Light (Edison, US, 1879; self)

Source: Robert C. Dean, Jr.
Some Watershed Inventions –
That have Turned into Innovations (2)

- **Kinescope (Movies)** (Edison, US, 1889; self)
- **Wireless Radio** (Marconi, UK, 1895; self)
- **X-Ray** (Roentgen, Germany, 1895; self)
- **Airplane** (Wright Bros., US, 1903; self)
- **Assembly Line** (Ford, US, 1908; self)
- **TV** (Zworykin vs. Farnsworth, US, 1929; RCA/self)
- **Nylon** (Carothers, US, 1937; Du Pont)
- **Helicopter** (Sikorski, US, 1939; self)
- **Microwave Oven** (Spencer, US, 1945; Raytheon)
- **Transistor** (Bardeen, et al., US, 1948; Bell Labs)

Source: Robert C. Dean, Jr.
Creativity and Innovation

Innovation is the successful implementation of creative ideas....creativity by individuals and teams is a starting point for innovation; the first is necessary but not sufficient condition for the second.

Types of Innovation

- **Product** - e.g., iPhone
- **Process** - manufacture
- **Service** – e.g., FedEx
- **Market and marketing**
- **Paradigm** - business model
- **Raw material** - supply chain
- **Organization**
## S. vs. E. Innovation

<table>
<thead>
<tr>
<th>Scientific</th>
<th>Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Be the first</td>
<td>• Be first and foremost</td>
</tr>
<tr>
<td>• Curiosity or even theology</td>
<td>• Largely utility (even theology) driven</td>
</tr>
<tr>
<td>inspired</td>
<td>• Create, design, build, manufacture, etc.</td>
</tr>
<tr>
<td>• Mainly discovery</td>
<td>• Ideas, devices, tools, systems, and methods</td>
</tr>
<tr>
<td>• Mostly theories, ideas, methods, etc.</td>
<td>• Mainly integrative process</td>
</tr>
<tr>
<td>• Mainly analytic process</td>
<td></td>
</tr>
<tr>
<td>Scientific</td>
<td>Engineering</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Value-neutral;</td>
<td>Value-centered; “b/c people need it”</td>
</tr>
<tr>
<td>“because it’s there”</td>
<td></td>
</tr>
<tr>
<td>Relatively free</td>
<td>Sensitive to societal, legal, cultural, and political climate; acceptance factor</td>
</tr>
<tr>
<td>of political,</td>
<td></td>
</tr>
<tr>
<td>societal,</td>
<td></td>
</tr>
<tr>
<td>cultural, and</td>
<td></td>
</tr>
<tr>
<td>legal constraints</td>
<td></td>
</tr>
<tr>
<td>Scale does not</td>
<td>Quantity and economics important</td>
</tr>
<tr>
<td>matter</td>
<td></td>
</tr>
<tr>
<td>Originality</td>
<td>Entrepreneurship req’d</td>
</tr>
<tr>
<td>required</td>
<td></td>
</tr>
</tbody>
</table>
Transformative Research
NSB\(^1\) and FacTIR\(^2\) Definition

- Research driven by ideas that have the potential to radically change our understanding of an important existing scientific or engineering concept or leading to the creation of a new paradigm or field of science or engineering.
- Such research also is characterized by its challenge to current understanding or its pathway to new frontiers.

1. National Science Board
2. NSF Working Group on Facilitating Transformative and Interdisciplinary Research
In the Past 25 years, NSF has supported many Initiatives to boost the innovation potential in our R&E enterprises

Examples:

- Engineering Research Centers (ERCs)
- Ind./Univ. Cooperative Res. Centers
- Science and Technology Centers (STCs)
- Engineering Education Coalitions
- Action Agenda for Eng. Ed. Reform
- Eng. Ed. Scholars Workshops (EESWs)
- Integrative Graduate Education and Research Traineeship (IGERT)
Some Other Non-NSF Initiatives

- Dartmouth ES-21 Freshman Design
- Comm. on Eng. Ed. - Design Ed. Workshop
- Catholic U. of America - Institute of Creative Engineering Methodology (for USAID)
- National Taiwan U. – Eng. Methodology
- Harvey Mudd College Engineering Clinic
- Many “Problem-Based Learning” courses
- Int’l EESWs – HK, ROC, S. Africa, ROK, etc.
- (Being discussed) Global Innovation Camps

Most entails cultural change & paradigm shift
Driving Forces Leading to the Creation of NSF’s Engineering Research Centers*

- In the early 80’s, US under threat from foreign industrial competitors despite consistent scientific excellence;
- Globalization of industry and markets;
- Disconnect between academe and industry;
- Academic engineering has lost its focus on systems, integration, & engineering practice;
- New graduates took too long to be productive.

*ERC idea was initiated in 1982 in the White House Science Advisor’s office and program actually began in 1984-85 a la NAE recommendation (1983).
NSF Engineering Research Centers Guiding Strategic Goals

- Develop centers to *integrate* disciplines, research and education to produce next-generation *innovations in engineered systems*;
- *Cultivate* new generations of engineers, more effective in industry, better positioned to *lead* in a Global economy;
- *Build partnerships* among academe, industry, & government to strengthen *competitiveness* of US industry and the Nation
NSF Engineering Research Centers

Unique* or Special Characteristics

- Highly cross-disciplinary
- Extensive industrial participation
- Intensive/active technology transfer
- Education coupling and innovations*
- Competitiveness orientation
- Engineering systems integration**
- Strategic planning*
Notes: (1) Darker labels denote current ERCs; lighter labels denote graduated centers.
(2) Many centers are multi-university partnerships; University shown is lead institution.
<table>
<thead>
<tr>
<th>Institution</th>
<th>Project Title</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>U. of Washington</td>
<td>Bioengineered Materials</td>
<td>1996</td>
</tr>
<tr>
<td>Georgia Tech with Emory University School of Medicine</td>
<td>Engineering of Living Tissue</td>
<td>1998</td>
</tr>
<tr>
<td>Johns Hopkins U. with CMU and MIT, Brigham Women’s Hospital and JHU Hospital</td>
<td>Computer Integrated Surgical Systems</td>
<td>1998</td>
</tr>
<tr>
<td>Vanderbilt U. with Harvard, MIT, Northwestern U. and U. of Texas-Austin</td>
<td>Bioengineering Educational Technologies</td>
<td>1999</td>
</tr>
<tr>
<td>U. of So. California with Caltech and UC-Santa Cruz</td>
<td>Biomimetic Microelectronic Systems</td>
<td>2003</td>
</tr>
<tr>
<td>U. of California, Berkeley with Harvard, MIT, Prairie View A&amp;M, and UCSF</td>
<td>Synthetic Biology</td>
<td>2006</td>
</tr>
</tbody>
</table>
NSF Engineering Research Centers
FY 2008 - Manufacturing & Processing

- U. Michigan - Reconfigurable Machining Systems, 1996
- Clemson U. with MIT - Advanced Engineering of Fibers and Films, 1998
- Rutgers University with Purdue, New Jersey Institute of Technology and UPRM, Structured Organic Composites for Pharmaceutical, Nutraceutical, and Agrochemical Applications, 2006
NSF Engineering Research Centers FY 2008 - Microelectronics, Optics, and IT Systems

- Princeton with CUNY, JHU, Texas A & M, UMBC, & Rice, Mid-Infrared Tech. for Health and Env., 2006
- Carnegie Mellon & Pittsburgh, Quality of Life, 2006
NSF Earthquake Engineering Research Centers - FY 2008

- University of California at Berkeley - Pacific Earthquake Engineering Research Center, 1997
- University of Illinois at Urbana-Champaign - Mid-America Earthquake Center, 1997
- State University of New York at Buffalo - Multidisciplinary Center for Earthquake Engineering Research, 1997
NSF Engineering Research Center Funding

- NSF funding $1/3/4M per ctr per yr; w. industrial contributions $4/10/25M;
- In a typical ERC’s budget
  - ~30% comes from NSF;
  - ~30% from industry;
  - ~20% from other Federal agencies
  - ~10% from the host university; and
  - ~10% state, local and other sources.
## Intellectual Property Outputs, FY 1985–2007*

<table>
<thead>
<tr>
<th>Category</th>
<th>FY 1985–2006 (38 ERCs)</th>
<th>FY 2007 (15 ERCs)</th>
<th>FY 1985–2007 (38 ERCs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Per Center</td>
<td>Per Year</td>
</tr>
<tr>
<td>Inventions Disclosed</td>
<td>1,322</td>
<td>35</td>
<td>1.7</td>
</tr>
<tr>
<td>Patents Awarded</td>
<td>484</td>
<td>13</td>
<td>0.6</td>
</tr>
<tr>
<td>Patent Applications Filed</td>
<td>950</td>
<td>25</td>
<td>1.3</td>
</tr>
<tr>
<td>Licenses Issued</td>
<td>1,836</td>
<td>48</td>
<td>2.4</td>
</tr>
<tr>
<td>Spinoff Companies</td>
<td>109</td>
<td>3</td>
<td>0.1</td>
</tr>
<tr>
<td>Spinoff Employees</td>
<td>1,292</td>
<td>34</td>
<td>1.7</td>
</tr>
</tbody>
</table>

* Excludes EERC data
## Degrees Granted to ERC Students, FY 1985–2007*

<table>
<thead>
<tr>
<th>Degree Type</th>
<th>FY 1985–2006 (38 ERCs)</th>
<th>FY 2007 (15 ERCs)</th>
<th>FY 1985–2007 (38 ERCs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Per Center</td>
<td>Per Center</td>
</tr>
<tr>
<td>Bachelor’s</td>
<td>3,461</td>
<td>91</td>
<td>4.6</td>
</tr>
<tr>
<td>Master’s</td>
<td>3,140</td>
<td>83</td>
<td>4.1</td>
</tr>
<tr>
<td>Doctorate</td>
<td>3,066</td>
<td>81</td>
<td>4.0</td>
</tr>
<tr>
<td>Totals</td>
<td>9,667</td>
<td>254</td>
<td>12.7</td>
</tr>
</tbody>
</table>

* Excludes EERC data
## ERC Influence on Curriculum, FY 1985–2007*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Per Center</td>
<td>Per Center Per Year</td>
</tr>
<tr>
<td>Degree Programs</td>
<td>122</td>
<td>3</td>
<td>0.2</td>
</tr>
<tr>
<td>Degree Minors Programs</td>
<td>10</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Certificate Programs</td>
<td>6</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>New Courses</td>
<td>690</td>
<td>18</td>
<td>0.9</td>
</tr>
<tr>
<td>Modified Courses</td>
<td>1,168</td>
<td>31</td>
<td>1.5</td>
</tr>
<tr>
<td>Textbooks</td>
<td>180</td>
<td>5</td>
<td>0.2</td>
</tr>
<tr>
<td>Textbook Chapter</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Course Modules</td>
<td>241</td>
<td>6</td>
<td>0.3</td>
</tr>
</tbody>
</table>

* Excludes EERC data
**ERC Information Dissemination, FY 1985–2007***

<table>
<thead>
<tr>
<th>Articles in—</th>
<th>FY 1985–2006 (38 ERCs)</th>
<th>FY 2007 (15 ERCs)</th>
<th>FY 1985–2007 (38 ERCs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Per Center</td>
<td>Per Center</td>
</tr>
<tr>
<td>Peer-Reviewed Conference Proceedings</td>
<td>11,520</td>
<td>303</td>
<td>15.2</td>
</tr>
<tr>
<td>Peer-Reviewed Journals</td>
<td>12,479</td>
<td>328</td>
<td>16.4</td>
</tr>
<tr>
<td>Trade Journals</td>
<td>538</td>
<td>14</td>
<td>0.7</td>
</tr>
<tr>
<td>Co-Authored With ERC Students</td>
<td>3,046</td>
<td>80</td>
<td>4.0</td>
</tr>
<tr>
<td>Seminars and Colloquia</td>
<td>9,121</td>
<td>240</td>
<td>12.0</td>
</tr>
<tr>
<td>Workshops, Short Courses to Industry</td>
<td>4,448</td>
<td>117</td>
<td>5.9</td>
</tr>
</tbody>
</table>

* Excludes EERC data
Productivity at 15 ERCs, FY 2007:
Graduate Employment*

ERC Graduates Hired by:

Industry
- ERC Member Firms: 45
- Other U.S. Firms: 119
- Foreign Firms: 12
- Academia: 98
- U.S. Government: 9

ERC graduates, by employment sector

* Excludes EERC data
Women* Working in ERCs, FY 2001–2007

* FY 2005, FY 2006, and FY 2007 data include women working on ERC projects funded by awards made to ERC faculty members' departments, not just projects supported by funds controlled by centers. In addition, FY 2005, FY 2006, and FY 2007 data include female students participating in Research Experiences for Undergraduates (REU) activities.

Excludes EERC data
ERCs Provide Significant Benefit to Their Member Firms

Percentage of ERC member firms’ representatives rating the former ERC students/graduates hired by their firm as “Better Than” or “Much Better Than” equivalent hires without ERC experience.
The Innovation Problem

Among other difficulties,

- The typical curriculum is mostly analysis- and not integration- oriented;
- We have failed to emphasize and impart “higher-order” skills in our students;
- We are losing smart and hard-working youngsters to non-innovation tasks.
Technology Leadership in the Boardrooms and Executive Suites: Examples of Needed Knowledge

- Advances in Materials
- Artificial Intelligence
- Biotechnologies
- Business Policy
- Concurrent Engng.
- Engineering Economics
- Environmental Mgmt.
- Global Bus. Strategies
- Information Systems
- Law and Ethics
- Logistics
- Mgmt. of Technology
- Manufacturing
- Marketing Strategies
- Microelectronics
- Organizational Design
- Photonics
- Robotics/Automation
- Strategic Management
- Tech. & Public Policy
- Telecommunications
- “Art of War”, Sun Tzu
- Virtual Reality
- Etc.
## Components of a Holistic Education

<table>
<thead>
<tr>
<th>Analytic (Science) Model</th>
<th>Integrative Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical (In-depth) Thinking</td>
<td>Lateral (Functional) Thinking</td>
</tr>
<tr>
<td>Abstract Learning</td>
<td>Experiential Learning</td>
</tr>
<tr>
<td>Reductionism - Fractionation</td>
<td>Integration - Connecting the Parts</td>
</tr>
<tr>
<td>Develop Order</td>
<td>Correlate Chaos</td>
</tr>
<tr>
<td>Understand Certainty</td>
<td>Handle Ambiguity</td>
</tr>
<tr>
<td>Analysis</td>
<td>Synthesis</td>
</tr>
<tr>
<td>Research</td>
<td>Design / Process / Manufacture</td>
</tr>
<tr>
<td>Solve Problems</td>
<td>Formulate Problems</td>
</tr>
<tr>
<td>Develop Ideas</td>
<td>Implement Ideas</td>
</tr>
<tr>
<td>Independence</td>
<td>Teamwork</td>
</tr>
<tr>
<td>Technological - Scientific Base</td>
<td>Societal Context / Ethics</td>
</tr>
<tr>
<td>Engineering Science</td>
<td>Functional Core of Engineering</td>
</tr>
</tbody>
</table>
Traditional Undergraduate Sequenced Curriculum

Passing Through Filters

Freshman
- Science
- Mathematics
- Humanities & Social Sciences

Sophomore
- Eng. Science
- Disciplinary Eng.
- H. & S. S.

Junior
- Disciplinary Eng.
- Design Project
- H. & S. S.

Senior
Baseball Training Schedule Modeled After Traditional Engineering Curriculum (1)
Would you train your ball team this way?

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Week 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Sports Fundamentals + Electronic Sports Laboratory</td>
<td>● Baseball Rules 2 + Electronic Baseball Laboratory</td>
</tr>
<tr>
<td>● Baseball Rules 1</td>
<td>● Sports Physiology</td>
</tr>
<tr>
<td>● Running</td>
<td>● Jumping &amp; Diving</td>
</tr>
<tr>
<td>● Physics</td>
<td>● Economics</td>
</tr>
<tr>
<td>● Calisthenics</td>
<td>● Biomechanics</td>
</tr>
</tbody>
</table>
Baseball Training Schedule Modeled After Traditional Engineering Curriculum (2)
Would you train your ball team this way?

**Week 3**
- Throwing
- Batting
- Base-Running
- Psychology
- Business Practices
- Aerodynamics

**Week 4**
- Catching
- Bunting
- Sliding/Base-Stealing
- Sportsmanship
- Management
- History of Baseball
## Baseball Training Schedule Modeled After Traditional Engineering Curriculum (3)
Would you train your ball team this way?

### Week 5
- Offense Strategies + Electronic Laboratory Simulation
- (E) Pitching
- Signaling
- Baseball Business
- Teamwork

*(E) indicates electives*

### Week 6
- Defense Strategies + Advanced Electr. Lab. Simulation
- (E) Homeplating
- (E) Tagging
- Classical Games
- Coaching
Baseball Training Schedule Modeled After Traditional Engineering Curriculum (4)
Would you train your ball team this way?

**Week 7**
- (E) Pitcher-Catcher Coordination
- Business and Sports Ethics
- Substance Abuse
- (E) Infield Strategies
- (E) Umpiring
- Games 1

**Week 8**
- Sports Laws
- Contracts and Negotiations
- (E) Verbal Abuse
- (E) Baseball Management
- Baseball Greats
- Games 2

(E) indicates electives
Holistic Innovation-Oriented Curriculum

K-14 Interface

Year 1
- Functional Core of Engineering Up Front

Year 2
- Hands-on Lab, Design, System Methodologies

Year 3
- In-Depth Disciplinary Engineering

Year 4
- Research Experience In-Depth Science
- Capstone Engineering

Integrated Humanities/Social Sciences

Integrated, Unified, Science & Math As Needed

Baccalaureate Interface

BS/MS (Practice Oriented)

BS (Industry)

BS/PhD (Research Oriented)
For the 21st Century, Are We Producing Bricklayers or Cathedral Builders?

- Who will be devising crucial future strategies for the industry?
- Who will be making hire and fire decisions for our corporations - impacting engineers and the image of engineering?
- Who will be leading the society and country in this technological age?

We Need Both!
<table>
<thead>
<tr>
<th>Education &amp; Training</th>
<th>Education &amp; Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Largely</td>
<td>Largely</td>
</tr>
<tr>
<td>To think and to create*</td>
<td>To do**</td>
</tr>
<tr>
<td>To do right things</td>
<td>To do things right</td>
</tr>
<tr>
<td>To be more effective</td>
<td>To be more efficient</td>
</tr>
<tr>
<td>To lead</td>
<td>To follow</td>
</tr>
<tr>
<td>For long-term impact</td>
<td>For immediate result</td>
</tr>
<tr>
<td>Broadly based</td>
<td>Narrowly focussed</td>
</tr>
</tbody>
</table>

*To plan, integrate, discover, design, etc.; to develop conceptual skills for thinking beyond the prevailing paradigm

**To implement, build, process, etc.; to develop contextual skills to enhance immediate performance

*Both Are Needed!*
Next Generation Engineering Skills a la ABET 2000 Criterion 3. Program Outcomes and Assessment (1)

Engineering programs must demonstrate that their graduates have

(a) ability to apply knowledge of math, science, and engineering
(b) ability to design and conduct experiments, and to analyze and interpret data
(c) ability to design system, component, or process to meet desired needs
(d) ability to function on multi-discipl. teams
(e) ability to identify, formulate, and solve engineering problems
(f) understanding of professional and ethical responsibility

Technical Skills     Higher-Order Skills
Next Generation Engineering Skills a la ABET 2000
Criterion 3. Program Outcomes and Assessment (2)

Engineering programs must demonstrate that their graduates have

(g) ability to communicate effectively
(h) broad education necessary to understand the impact of engineering solutions in a global and societal context
(i) recognition of the need for, and ability to engage in life-long learning
(j) knowledge of contemporary issues
(k) ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Higher-Order Skills          Technical Skills
Why have engineers paid little or no attention to “soft skills”?

...because no engineer wants to be caught learning things that are not hard.

Higher-order skills are anything but soft or easy! They are essential and challenging.
Vision

To cultivate a new generation of engineering faculty dedicated to the life-long pursuit of excellence and integration in engineering teaching and research.

*The term “education scholar” conveys the notion that the scholarship of knowledge transfer is intertwined with and equal in importance to that of knowledge creation.
The NSF Engineering Education Scholars Workshops (1995-2000)

- Georgia Tech, Carnegie Mellon, Stanford, Wisconsin, Syracuse-Howard-UNH; note “research schools”
- Outcomes were very positive; in addition to better classroom techniques and career path, established support network
- Also helped start similar programs in South Korea, Taiwan, Hong Kong, South Africa, etc.
Engineering Education Scholars Workshop
Examples of Topics

- Vectoring to 21st Century Academe; System Transformation
- Why Students Leave Engineering
- Does How We Teach Match How Students Learn?
- Course Design and Classroom Presentation Basics
- Test Construction and Levels of Thinking; Peer Instruction
- Role of Faculty in the Life of Students
- Frontiers in Education Technology: Why, What, & How
- Producing Instructional Multimedia - Skills and Tools
- Communication Today and Students’ Expectations
- Problem-Based Learning and Cooperative Learning
- Making a Difference; Leadership in a Challenging World
- Balancing Multiple Responsibilities; Leadership and Management
- Case Studies Exercise; Ethics
- Critique of Participant Teaching Video - Before & After
“Engineering Education Scholars”
1995-2003 Workshops* Outcome

- Enthusiastic response; value teaching as respectable intellectual pursuit, incl. research on learning process
- Basic knowledge and improved performance in various aspects of teaching; e.g., course design, classroom techniques, integration of research innovations, evaluation, etc.
- Change from teacher-centered to learner-centered
- Basis for lifelong learning and improvement, incl. integration of teaching and research aspects of career
- Common bond for future interaction and career development; E-mail connection

* Georgia Tech (95); Carnegie Mellon (96-00); Wisconsin (96-98, CIC 99-current); Stanford (98-02); Syracuse (00-02)
Engineering Education Scholars Workshops: Evolving Emphasis

- Better Preparation for Teaching - pedagogy, learning styles, cognitive foundation, test and evaluation, media technology, problem-based, active, and collaborative learning, etc.

- Integration of Research, Teaching, and Innovation

- Leadership Development

Enhancing the Effectiveness of Engineering Education - E^4
Be the Bernstein, Toscanini, and Mehta of Engineering Education!

“Teaching staff need to fundamentally rethink their roles. They do not merely impart information. They have to facilitate and orchestrate learning in a way somewhat similar to a conductor of an orchestra.”

Low Won Fook, President
Singapore Polytechnic Institute
(thru ALNTalk Forum Moderator, July 20, 1999)
“Orchestrated Learning” Means….

- Impart knowledge and insight
- Facilitate understanding & creativity
- Cultivate wisdom and character
- Inspire confidence and enthusiasm
- Maximize performance in practice
Scholarship of Innovation

- 博學  Learn broadly
- 審問  Examine and inquire
- 慎思  Think carefully
- 明辨  Distinguish clearly
- 篤行  Practice earnestly

(Borrowed from Confucius)
We now need to inject more innovation into our curricula and course contents

According to Zogby International (8046 respondents)

- ¼ Americans think China will beat US as world leader in innovation in next decade; i.e., there is significant fear
- Americans are not happy with current effort by US leaders in fostering next generation of American ingenuity;
- 70% said government is not doing enough;
- Nearly 2/3 said American business is not promoting innovation enough;
- Still, 38.5% said US will be top innovator.

http://www.zogby.com/templates/prints.cfm?id=15346
July 23, 2007 Reuters
Characteristics of Innovation

- Never before
- Widespread use
- Affordable
- Positive qualitative difference
  - Better lifestyle; healthier, safer, etc.
  - Economic growth, sustainable
  - Time saving; can do never done before
  - Quantum jump in performance
In the Engineering Context
Innovation Defined

- Act or process of introducing new idea, method, device, or system;
- Creative ideas realized or exploited, resulting in improvements;
- Transforming new ideas into tangible societal value and/or impact;
- New dimension of performance;
- Making both qualitative & quantitative differences
Scholarship Broadly Defined

Knowledge…

- **Creation** - *Research, Discovery*
- **Transfer** – *Teaching, Learning*
- **Implementation**–*Practice, Innovating*
- **Integration** – *Context, Inspiring*

*Boyer Commission Report*
The Innovation Imperative

Integrate
Integrate
Integrate
Integrate
Integrate
The Idea of Integration Is Not New

Integration is what is *higher*

in higher education.

*Harlan Cleveland*
The Innovation Challenge:

The Scholarship of Integration

- Knowledge from various disciplines
- Ideas and skills from various people
- Complex parts and components
- Ever-changing socio-economic factors
- Wide-ranging needs and requirements
- Often conflicting rules and regulations
One Approach in Imparting Entrepreneurship and Innovation Concepts (1)

- Dartmouth ES-21 Intro. to Engg. (early 60’s)
- Commission on Engineering Education Design Education Workshop (1965, summer long; 6 faculty + 24 students)
  - Class divided into “companies” of 4-6;
  - Students run their own companies but advised by faculty as consultants;
  - Consultants help supply technical knowledge; students learn on a need-to-know basis;
  - Each company is given a budget, both real $$ and in-kind;
One Approach in Imparting Entrepreneurship and Innovation Concepts (2)

- A general topic is given to class---a real human/societal need to be fulfilled;
- Student companies go thru the process of defining the problem, surveying the market, generating ideas, selecting, refining, and implementing the final design;
- Final presentations are judged by real industrialists;
- Concept implemented at some schools, perhaps leading to PBL, as well as international arena; AAI-AID workshops.
Meanwhile, on the Other Coast: Engineering Clinic, Harvey Mudd College

Engineering is like dancing; you don’t learn it in a lecture hall watching slides: you learn it by getting out on the floor and having your toes stepped on.

Jack Alford
Prof. of Engg., Emeritus
Co-founder*, 1963
(*with Prof. Mack Gilkeson)
Teams of 4-5 jrs.-srs.; cross-disciplinary
$41K/team (2006-07) working for real industrial/governmental/community client
Each team is expected to devote 1200 hrs./yr.--- each student 10 hrs./wk.
Project Objective – to produce useful results in open-ended authentic problems to client’s satisfaction within time & budget constraints
Faculty – advises, coaches, and evaluates
Client – informs, guides, accepts/rejects
50-pg handbook; incl. AIChe Code of Ethics
HMC Engineering Clinic and Dartmouth ES-21: Educational Objectives

- **Authentic engineering experience** – decision-making, trade-offs, schedule and budget control, client-vendor relations, confidentiality
- **Leadership and teamwork** – authority, responsibility, accountability, delegation, conflict resolution, integration of talents and skills, personnel evaluation
- **Understanding of design process** – work plan, negotiation, contract, execution, evaluation, feasibility. Preliminary and detail design, field test, prototyping, production, service, etc.
- **Applying course material; gaining real world insights; etc.**
Examples of Important Topics To Accompany Innovation Project Learning

- **The Process of Innovation** - problem definition, idea generation, functional analysis, brainstorming, etc.
- **Invention, Patents, and Intellectual Property**
- **Technology Strategic Planning** - out-maneuvering competition, making alliances, “The Art of Warfare”
- **Learner-Centered Communication** - listening and visualization, information processing, multi-media technology; writing & speaking for different needs; etc.
- **Leadership** - how to inspire people; time and resource management; making deliberate choices; etc.
- **Cultural and gender diversity**
- **Also, individual creativity exercises**
Desirable Characteristics of an Entrepreneur

- MVP (sense of Mission, Vision*, & Passion);
- Intelligence and skills (financial & technical);
- Clarity and discernment – inspiring confidence;
- Drive and energy - independently minded;
- Charisma– Evangelistic Spirit; Dream-seller**;
- Transfer a vision into a cause and spread it;
- Willing and good at taking risks;

S/he needs to be a “born-again” person!

*An insight not yet perceptible to most people
**“Everyday Evangelism” a la Guy Kawasaki, 1991
Thank You For Your Attention.

May The Force Be With You!