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

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- *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 for a more authoritative list.**

However, as Yogi Berra said…

Making predictions is a risky business, especially if it is about the future.

Thomas Watson
Chairman of IBM, 1943*

"I think there is a world market for maybe five computers."

***As reported in the Business Section**
***Kansas City Star*; January 17, 1995**

Popular Mechanics, forecasting the relentless march of science, 1949*

“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.

Luecke and Katz (2003)

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

Scientific

- *Be the first*
- *Curiosity or even theology inspired*
- *Mainly discovery*
- *Mostly theories, ideas, methods, etc.*
- *Mainly analytic process*

Engineering

- *Be first and foremost*
- *Largely utility (even theology) driven*
- *Create, design, build, manufacture, etc.*
- *Ideas, devices, tools, systems, and methods*
- *Mainly integrative process*

S. vs. E. Innovation *(cont'd)*

Scientific

- *Value-neutral; "because it's there"*
- *Relatively free of political, societal, cultural, and legal constraints*
- *Scale does not matter*
- *Originality required*

Engineering

- *Value-centered; "b/c people need it"*
- *Sensitive to societal, legal, cultural, and political climate; acceptance factor*
- *Quantity and economics important*
- *Entrepreneurship req'd*

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.*

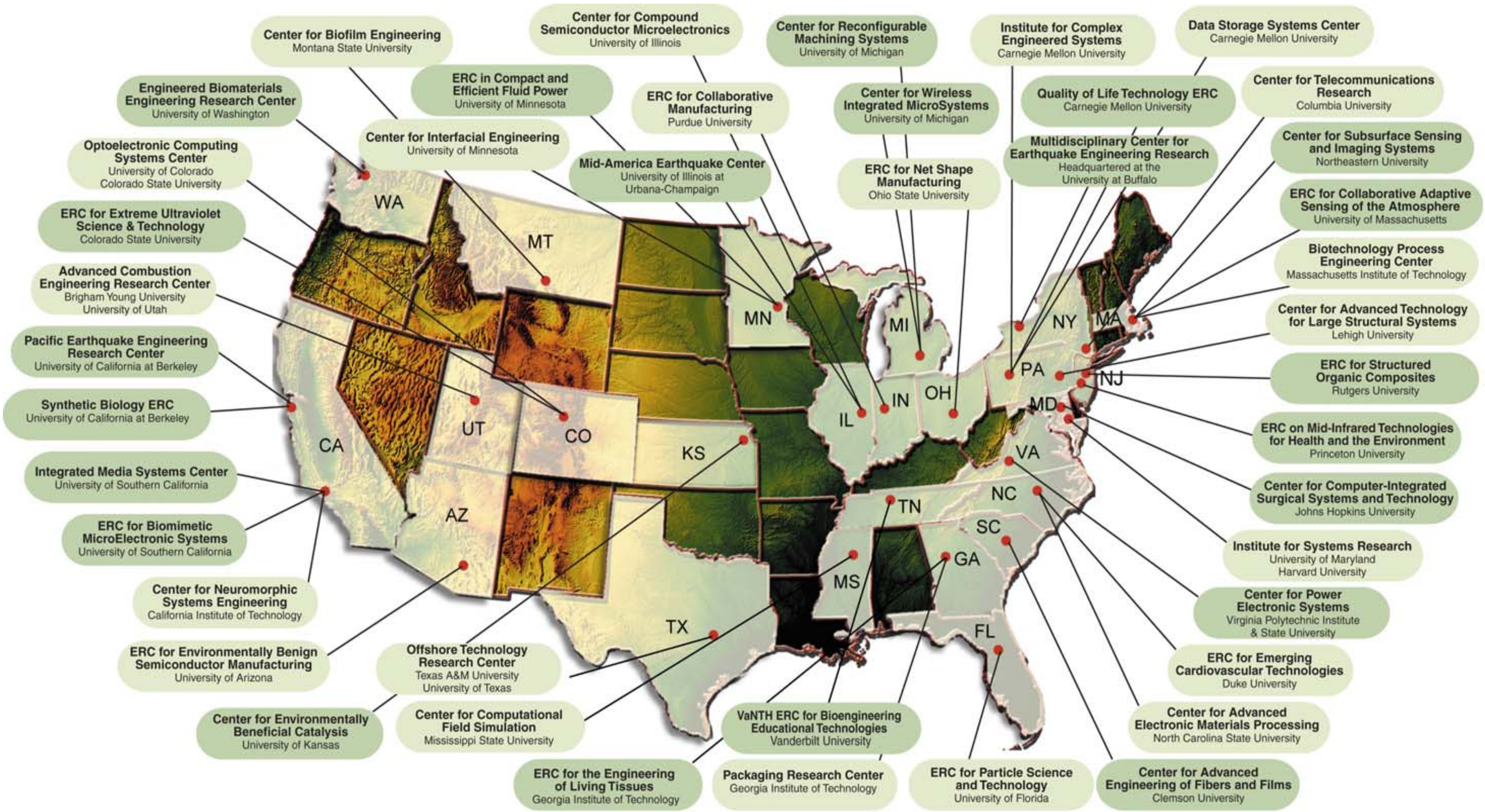
***ERC idea was initiated in 1982 in the White House Science Advisor's office and program actually began in 1984-85 a la NAE recommendation (1983).**

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.

Engineering Research Centers

NSF Engineering Research Centers FY 2008 - BioEngineering

- *U. of Washington - - Bioengineered Materials, 1996*
- *Georgia Tech with Emory University School of Medicine- - Engineering of Living Tissue, 1998*
- *Johns Hopkins U. with CMU and MIT, Brigham Women's Hospital and JHU Hospital - - Computer Integrated Surgical Systems, 1998*
- *Vanderbilt U. with Harvard, MIT, Northwestern U. and U. of Texas-Austin - - Bioengineering Educational Technologies, 1999*
- *U. of So. California with Caltech and UC-Santa Cruz – Biomimetic Microelectronic Systems, 2003*
- *U. of California, Berkeley with Harvard, MIT, Prairie View A&M, and UCSF - Synthetic Biology, 2006*

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*
- *U. of Kansas with U. of Iowa and Washington U at St. Louis – Environmentally Beneficial Catalysis, 2003*
- *Rutgers University with Purdue, New Jersey Institute of Technology and UPRM, Structured Organic Composites for Pharmaceutical, Nutraceutical, and Agrochemical Applications, 2006*
- *U. Minnesota with GA Tech, Purdue, U. Illinois Urbana-Champaign, and Vanderbilt, Compact and Efficient Fluid Power, 2006*

NSF Engineering Research Centers FY 2008 - Microelectronics, Optics, and IT Systems

- *U. So. California - - Integrated Media Systems, 1996*
- *VPI with NC A&T, and UPR-Mayaguez, Rensselaer, and Wisconsin - - Power Electronic Systems, 1998*
- *U. of Michigan with Mich. St., & Mich. Tech. Univ. - - Wireless Integrated Microsytems, 2000*
- *Northeastern U. with Boston U., UPR-M, & RPI - - Subsurface Sensing & Imaging Systems, 2000*
- *Colorado State U. with CU-Boulder and UC Berkeley -- Extreme Ultraviolet Science and Technology, 2003*
- *UMass-Amherst w. CSU, U. Oklahoma, & UPRM - - Collaborative Adaptive Sensing of Atmosphere, 2003*
- *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*

	FY 1985–2006 (38 ERCs)			FY 2007 (15 ERCs)		FY 1985–2007 (38 ERCs)		
	Total	Per Center	Per Center Per Year	Total	Per Center	Total	Per Center	Per Center Per Year
Inventions Disclosed	1,322	35	1.7	124	8	1,446	38	1.8
Patents Awarded	484	13	0.6	38	3	522	14	0.7
Patent Applications Filed	950	25	1.3	95	6	1,045	28	1.3
Licenses Issued	1,836	48	2.4	93	6	1,929	51	2.4
Spinoff Companies	109	3	0.1	4	0	113	3	0.1
Spinoff Employees	1,292	34	1.7	24	2	1,316	35	1.6

* Excludes EERC data

Degrees Granted to ERC Students, FY 1985–2007*

	FY 1985–2006 (38 ERCs)			FY 2007 (15 ERCs)		FY 1985–2007 (38 ERCs)		
Degree Type	**Total**	**Per Center**	**Per Center Per Year**	**Total**	**Per Center**	**Total**	**Per Center**	**Per Center Per Year**
Bachelor's	3,461	91	4.6	133	9	3,594	95	4.5
Master's	3,140	83	4.1	125	8	3,265	86	4.1
Doctorate	3,066	81	4.0	169	11	3,235	85	4.1
Totals	9,667	254	12.7	427	28	10,094	266	12.6

* Excludes EERC data

ERC Influence on Curriculum, FY 1985–2007*

New Curricular Products	FY 1985–2006 (38 ERCs) Total	Per Center	Per Center Per Year	FY 2007 (15 ERCs) Total	Per Center	FY 1985–2007 (38 ERCs) Total	Per Center	Per Center Per Year
Degree Programs	122	3	0.2	0	0	122	3	0.2
Degree Minors Programs	10	0	0.0	2	0	12	0	0.0
Certificate Programs	6	0	0.0	0	0	6	0	0.0
New Courses	690	18	0.9	27	2	717	19	0.9
Modified Courses	1,168	31	1.5	105	7	1,273	34	1.6
Textbooks	180	5	0.2	8	1	188	5	0.2
Textbook Chapter	0	0	0.0	4	0	0	0	0.0
Course Modules	241	6	0.3	49	3	290	8	0.4

* Excludes EERC data

ERC Information Dissemination, FY 1985–2007*

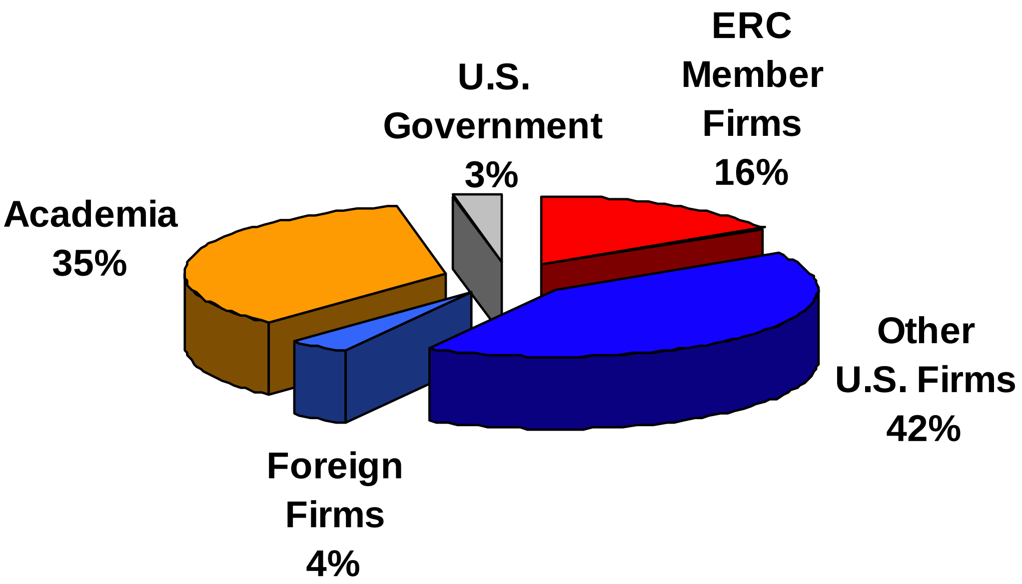
Articles in—	FY 1985–2006 (38 ERCs) Total	FY 1985–2006 (38 ERCs) Per Center	FY 1985–2006 (38 ERCs) Per Center Per Year	FY 2007 (15 ERCs) Total	FY 2007 (15 ERCs) Per Center	FY 1985–2007 (38 ERCs) Total	FY 1985–2007 (38 ERCs) Per Center	FY 1985–2007 (38 ERCs) Per Center Per Year
Peer-Reviewed Conference Proceedings	11,520	303	15.2	550	37	12,070	318	15.1
Peer-Reviewed Journals	12,479	328	16.4	454	30	12,933	340	16.2
Trade Journals	538	14	0.7	15	1	553	15	0.7
Co-Authored With ERC Students	3,046	80	4.0	804	54	3,850	101	4.8
Seminars and Colloquia	9,121	240	12.0	881	59	10,002	263	12.5
Workshops, Short Courses to Industry	4,448	117	5.9	42	3	4,490	118	5.6

* Excludes EERC data

Productivity at 15 ERCs, FY 2007: Graduate Employment*

ERC Graduates Hired by:

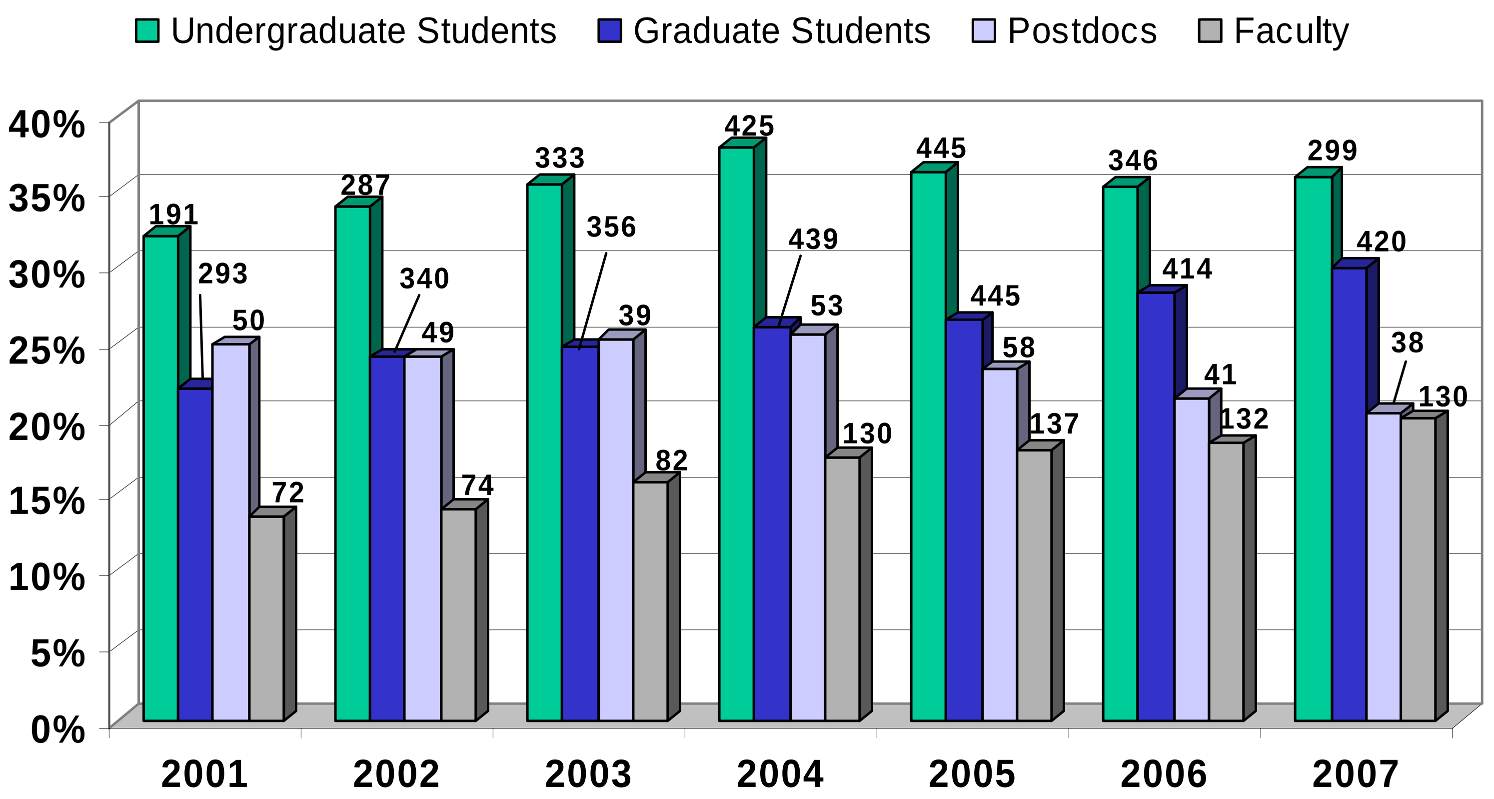
Industry	
ERC Member Firms	45
Other U.S. Firms	119
Foreign Firms	12
Academia	98
U.S. Government	9



ERC graduates, by employment sector

* Excludes EERC data

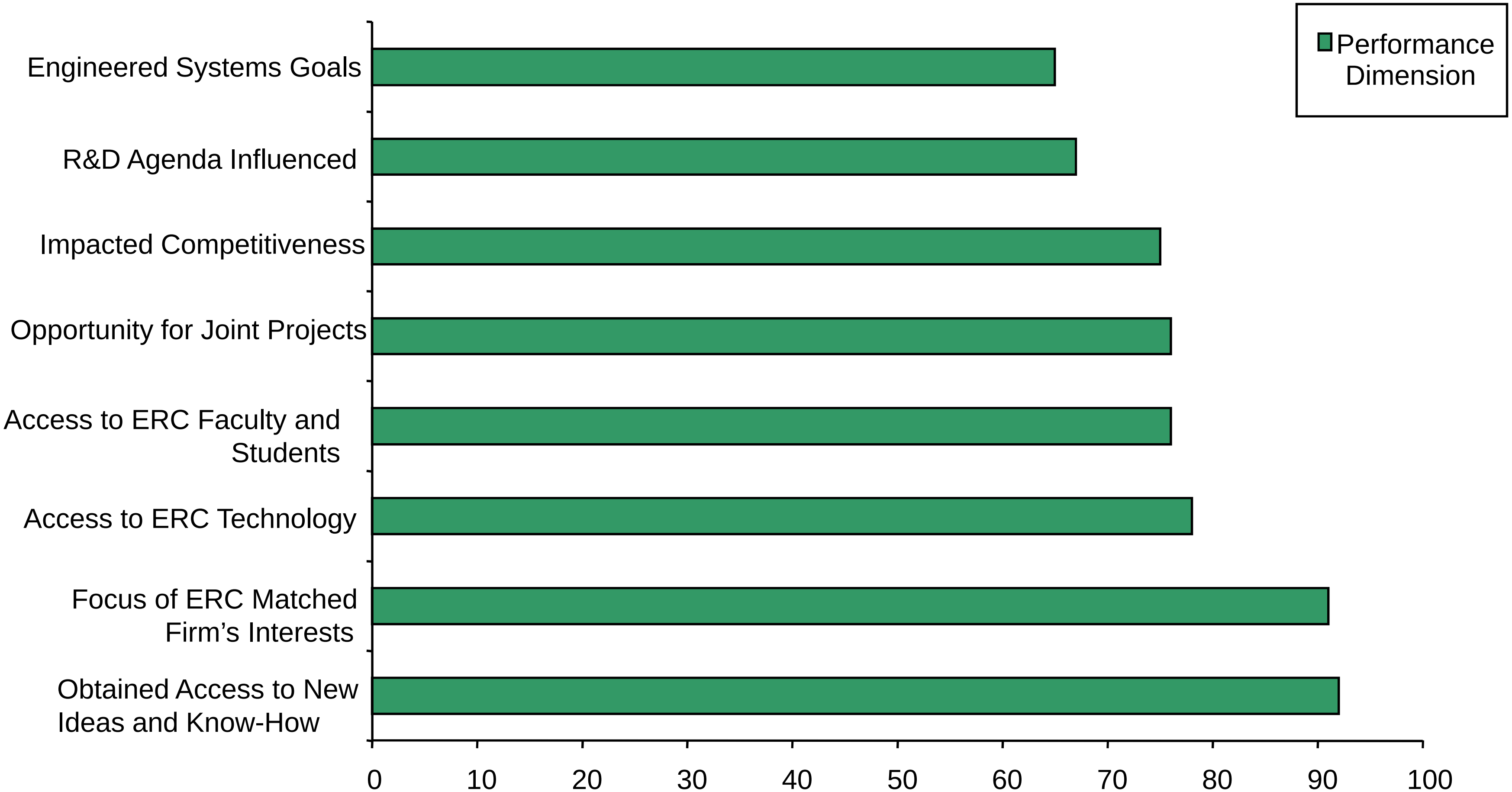
Women* Working in ERCs, FY 2001–2007



* 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

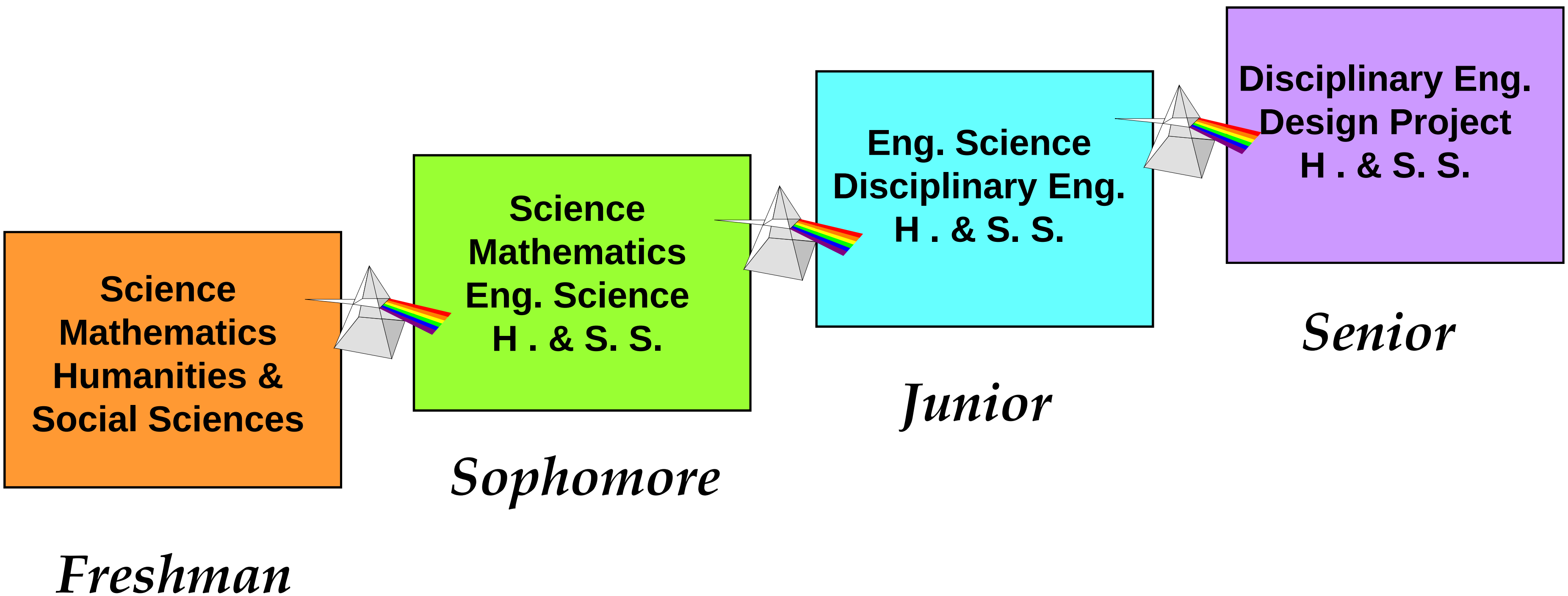
- Advances in Materials
- Artificial Intelligence
- Biotechnologies
- Business Policy
- Concurrent Engng.
- Engineering Economics
- Environmental Mgmt.
- Global Bus. Strategies
- Information Systems
- Law and Ethics
- Logistics
- Mgmt. of Technology
- Manufacturing
- Marketing Strategies
- Microelectronics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

Components of a Holistic Education

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

Traditional Undergraduate Sequenced Curriculum

Passing Through Filters



Baseball Training Schedule Modeled After Traditional Engineering Curriculum (1)

Would you train your ball team this way?

Week 1

- Sports Fundamentals + Electronic Sports Laboratory
- Baseball Rules 1
- Running
- Physics
- Calisthenics

Week 2

- Baseball Rules 2 + Electronic Baseball Laboratory
- Sports Physiology
- Jumping & Diving
- Economics
- Biomechanics

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

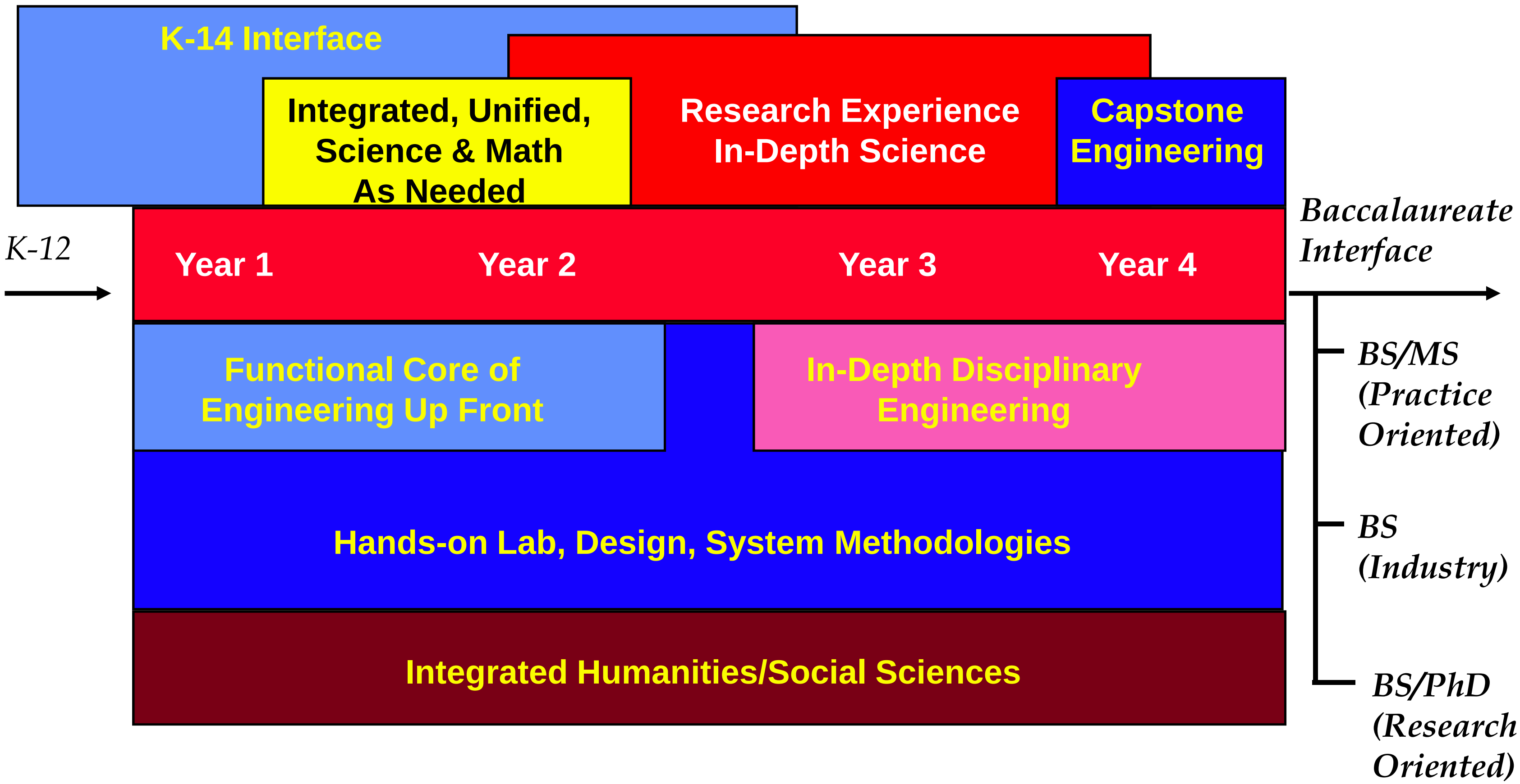
- *(E)* **Pitcher-Catcher Coordination**
- **Business and Sports Ethics**
- **Substance Abuse**
- *(E)* **Infield Strategies**
- *(E)* **Umpiring**
- **Games 1**

Week 8

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

(E) *indicates electives*

Holistic Innovation-Oriented Curriculum



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!

Education & Training

Largely	Largely
*To think and to create**	*To do***
To do right things	*To do things right*
To be more effective	*To be more efficient*
To lead	*To follow*
For long-term impact	*For immediate result*
Broadly based	*Narrowly focussed*

***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.

Changing the People: The NSF Engineering Education Scholars* Workshops (1995-2000)

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)

“Orchestrate 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/printsb.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

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 inter-national 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)

Engineering Clinic
Harvey Mudd College

- *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***

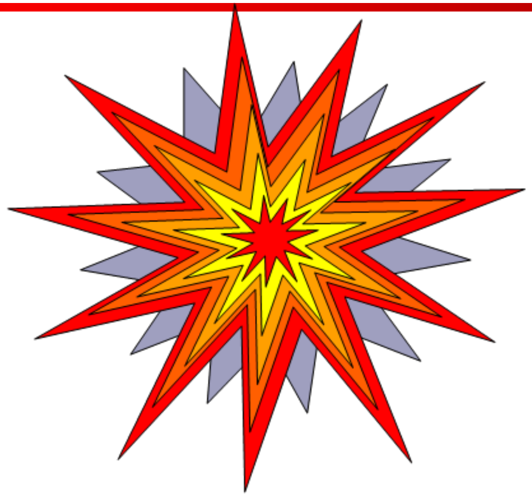
Desirable Characteristics of an Entrepreneur

- *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!