Conference on Materials Science and Materials Engineering Education
Sponsored by National Science Foundation

C Singh (U. Pittsburgh), R. Hamers(U. Wisconsin) I. Robertson (U. Illinois), L. Woolf (General Atomics) NSF Program Monitor. U. Venkateswaran

GOAL: to bring together scientists from materials science and engineering and allied fields such as chemistry and physics to begin the discussion of the future of education in materials science and materials engineering.

Format: Keynote talks to establish the issues, constraints and challenges.

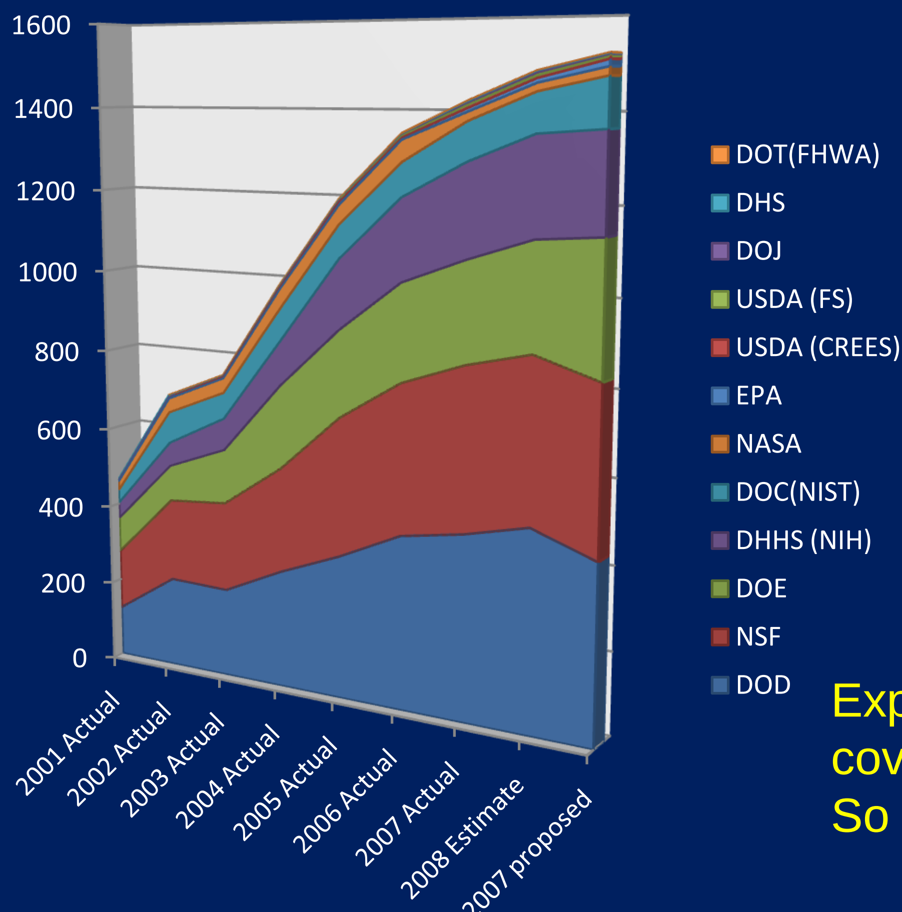
Areas explored:

Materials science and engineering education of the general public
Materials science and engineering education of K-12

Materials science and engineering education at the undergraduate level
Materials science and engineering education at the graduate level.

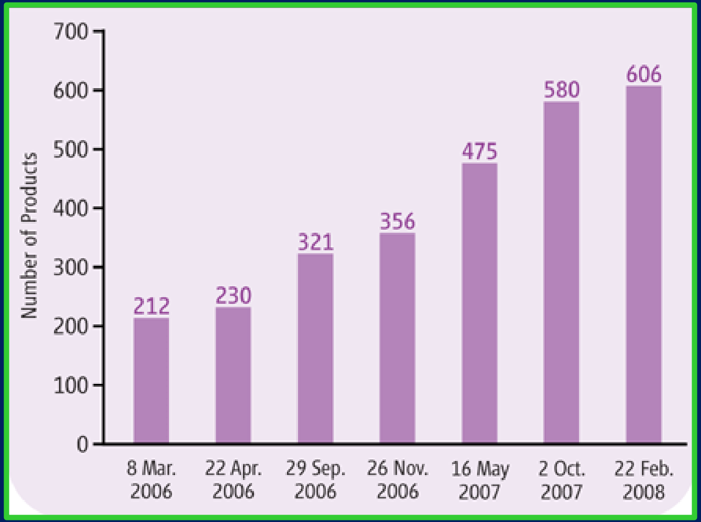
Learning public understanding of science and technology - nanotechnology

NNI Budget History by Agency (dollars in millions)



http://www.nano.gov/html/about/funding.html

Growth in the number of products containing nanotechnology

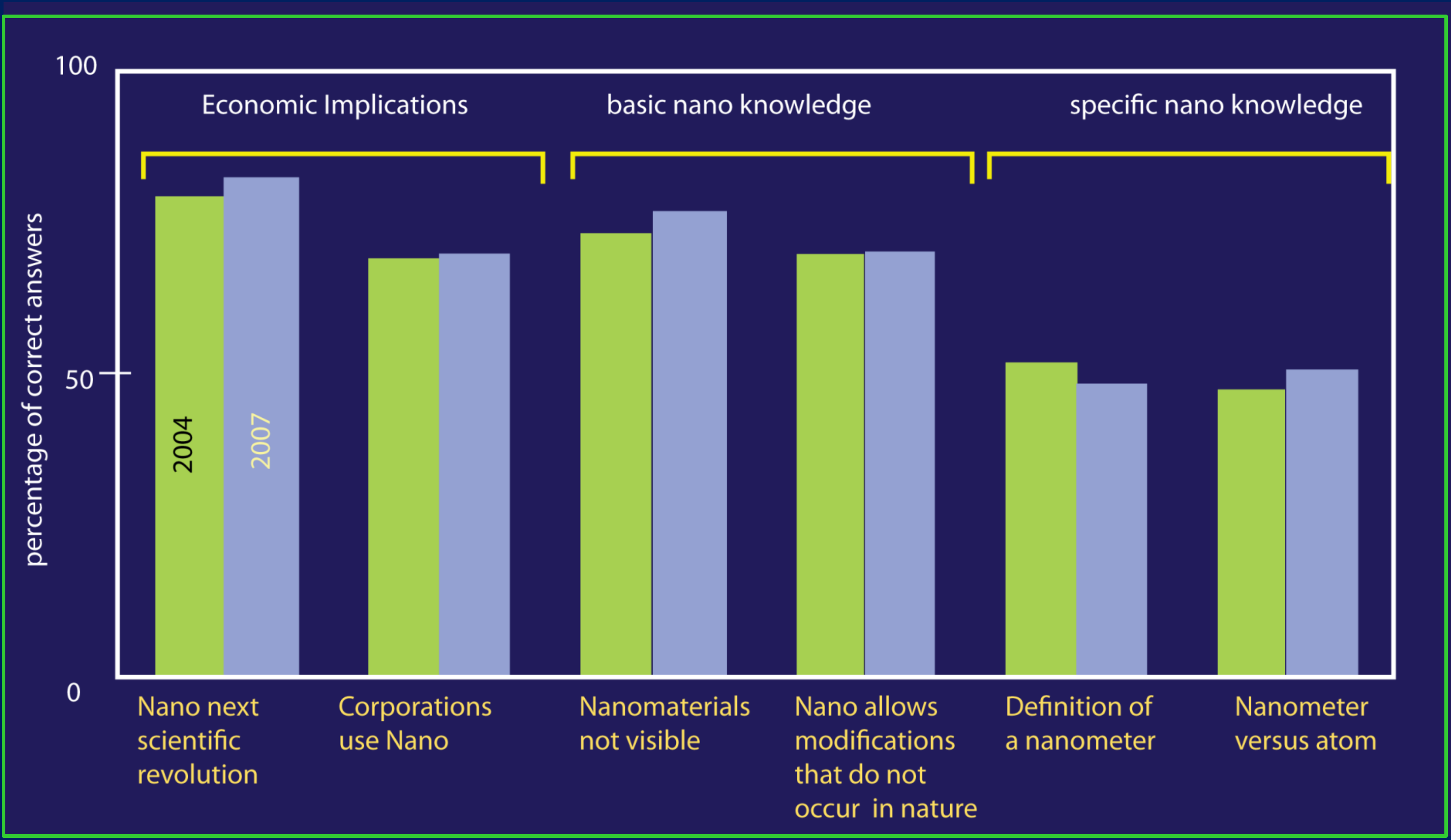


Science 22 August 2008:
Vol. 321. no. 5892, pp. 1036 - 1037
DOI: 10.1126/science.321.5892.1036

Exponential growth in media coverage since 2000.
So what do they understand about nano?

Department of Materials
Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

Learning public understanding of science and technology - nanotechnology

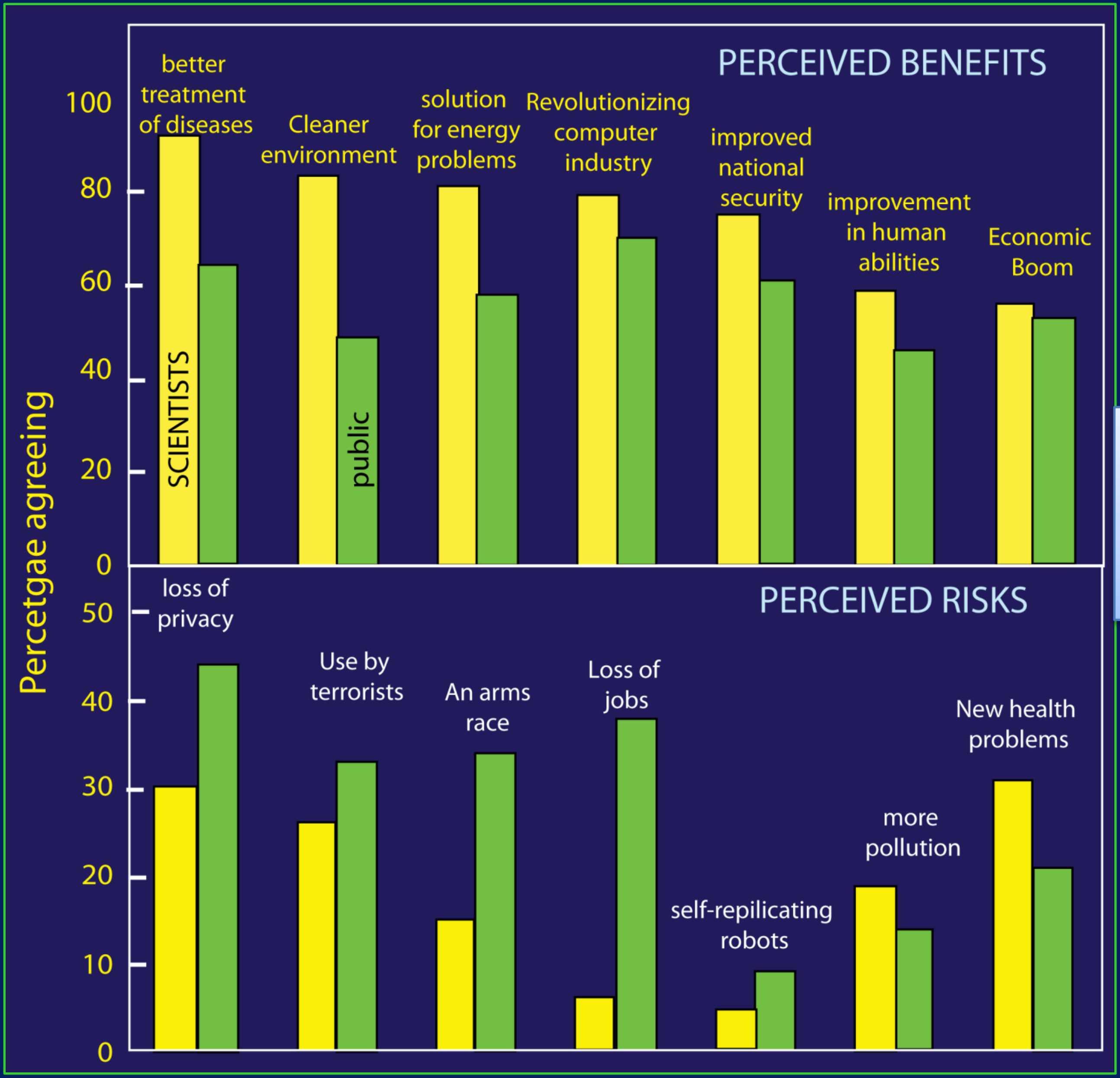


Despite increase use of nanotechnology in consumer products and the accompanying growth in media coverage there has been negligible improvement in understanding

Scheufele

Department of Materials
Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

Scientists vs. Public



Scientists more optimistic about the beneficial uses of nanotechnology than the public.

Public more concerned than the scientists about potential risks.

Difference not all attributable to more knowledgeable but how information is presented, discussed and how it is processed.

We need to be aware of this information as we propose new approaches for educational outreach

Dietram A. Scheufele, et al. *Nature Nanotechnology* **2**, 732 - 734 (2007)

Department of Materials Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

Public outreach

Recommendation: When creating public education materials and strategies, emphasis needs to be placed upon communicating the significant social and economic effects MSE has had, and will continue to have, on society.

Recommendation: the MSE community must think carefully about how to present evidence that connects with the public's prior knowledge and mindset. Researching and appreciating public preconceptions relevant to MSE will improve the efficacy of our education efforts.

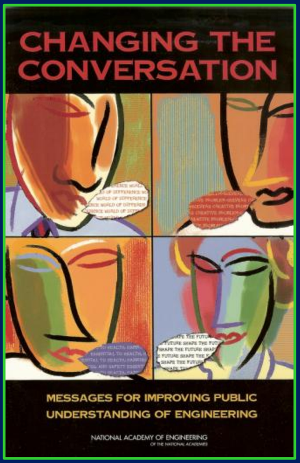
Recommendation: Research will need to be conducted to determine which slogan(s), message(s), medium(a) work. Some initial progress has been made in the report, *Changing the Conversation*. Is a separate effort in materials science and engineering warranted?

Recommendation: Know the intended audience. Scientists and engineers need to be engaged with public audiences and open to their ideas, concerns, fears, and values. It is important to be considerate of what public audiences already know and care about.


Playing with materials!

Department of Materials
Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

Public outreach



Recommendation: Choosing and crafting an effective message will require collaboration with professionals from outside science and engineering, including journalism, marketing, graphic design, education, psychology, etc. Industrial partners. In other words, we may be the wrong people to crafting and designing the materials we use for educational outreach efforts!

Strange matter

Mr. Fluid

Recommendation: Interactive web-based MSE education efforts should continue to be explored. Additionally, web-based used by tomorrow's students should be exploited: YouTube, TeacherTube, Podcasts.

Recommendation: Ground work needs to be done to determine what resources already exist (although this list cannot and should not presume to be comprehensive), the effectiveness and scientific accuracy of these resources, and best (and worst) practices these resources demonstrate.

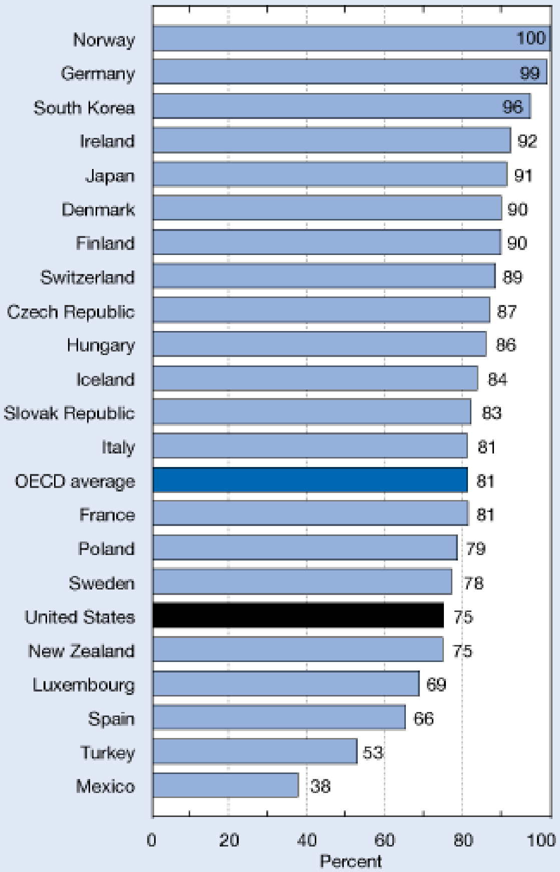
Recommendation: Whatever form of outreach effort is undertaken, collaborations and interactions between MSE faculty and professionals focused on producing, distributing, and marketing high-quality, effective educational materials should be developed.

Recommendation: Professional societies need to get involved in a collaborative and coordinated manner.

Department of Materials Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

Basic Challenges in K-12 STEM Education

Figure 1-24
High school graduation rates, by OECD country: 2004



OECD = Organisation for Economic Co-operation and Development

NOTES: High school graduation rate is percentage of population at typical upper secondary graduation age (e.g., 18 years old in United States) completing upper secondary education programs. OECD average based on all OECD countries with available data.

SOURCE: OECD, Education at a Glance: OECD Indicators 2006 (2006).

Science and Engineering Indicators 2008

The need to produce a globally literate citizenry is critical to the nation's continued success in the global economy

– Human capital is key to continuing S&T and S&E developments

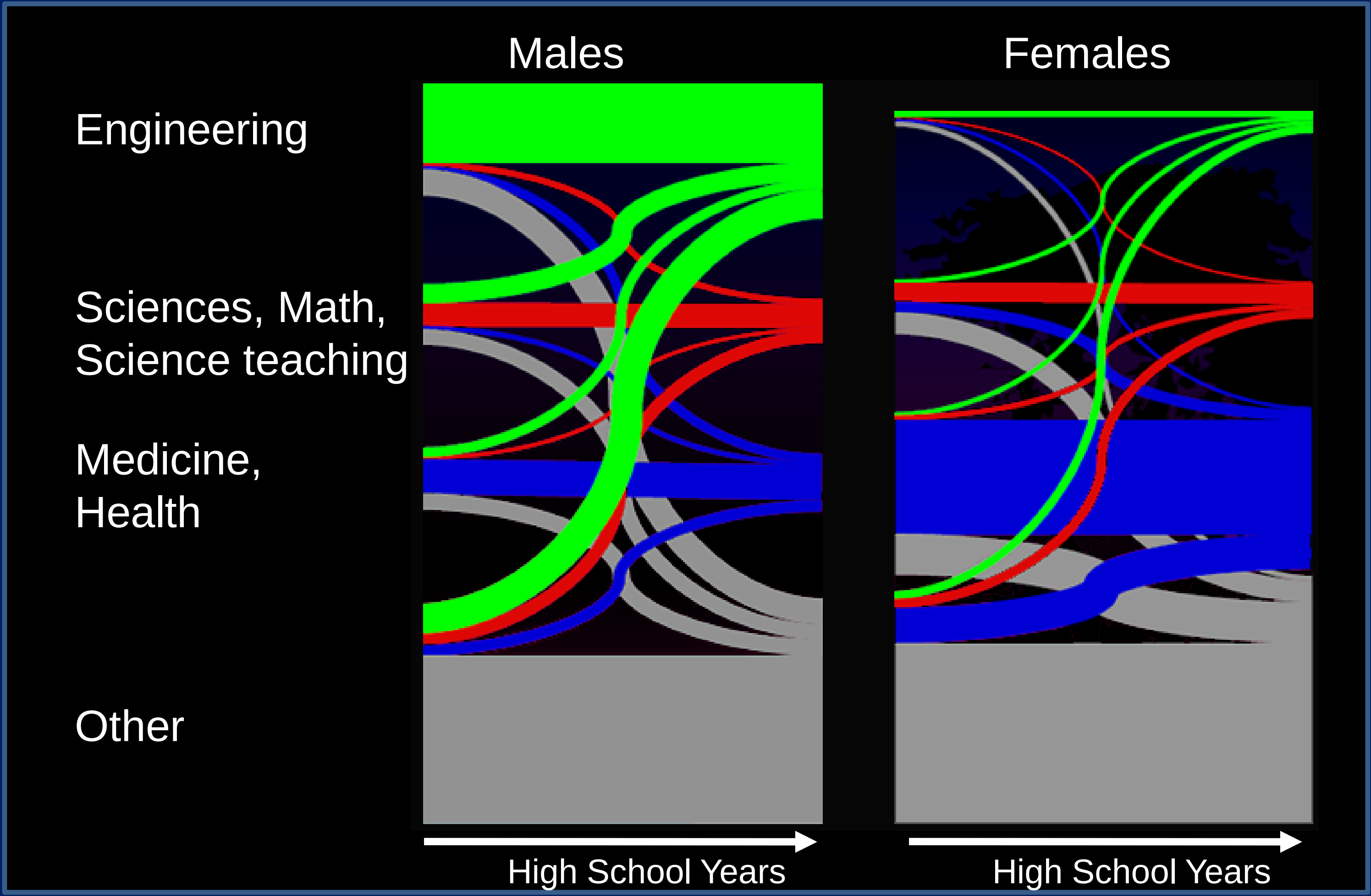
The need for secondary institutions to adapt to a world altered by technology, changing demographics and globalization

– Several national studies confirm the insufficient preparation of high school graduates for *either college-level work or the changing needs of the workforce.*

– Low proficiency performance level, only 1/3 of 4th and 8th grade, and even fewer 12th grade students, reached the proficient level for their grades

Department of Materials
Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

K-12 education and the Pipeline Problem



Females not interested in pursuing science and engineering careers.
Need to address the question of WHY and then determine the strategy to be employed to change the flow.

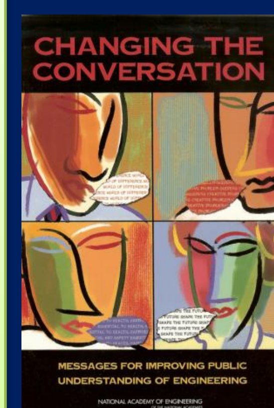
Department of Materials Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

The disconnect between our message and what motivates

The message we convey and how we convey it is important.

Need to develop strategies to reach uninvolved or hard to reach audiences and help them understand and appreciate the (societal and economic) benefits of science and engineering careers as well as research and development…

Need to convey the message that materials science and materials engineering careers impact critical societal issues such as energy independence, provision of a safe and abundant supply of water, clean air, medical advances to improve the quality of life, next generation communication technologies, advanced transportation, rebuilding the crumbling national infrastructure...



Career and academic motivators for girls

- ❑Enjoyment of ones work or studies
- ❑Good working environment
- ❑Making a difference
- ❑Good income
- ❑flexibility

- ❑ A challenging career
- ❑ Difficult but rewarding
- ❑ Using math and science to solve problems

The message they hear from us.

Department of Materials
Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

How to introducing materials science and engineering in K-12 education

Recommendations

Do not try to change either Federal or State standards.

Use examples from materials to bring relevance to science and to technology courses;

Use materials examples as a means to demonstrate cross – course integration

Use materials examples to illustrate the impact of science and technology has on not only daily life but societal issues.

Focus should not just be on students interested in pursuing STEM at college.

Materials examples should be accessible and implementable in a short time frame.

Need to emphasize teaching as a possible career path to our undergraduates.

Establish partnerships with College of Education to teach the teachers during the certification period.

Career sites, with up-to-date material.

Educate the teachers!

University of Illinois materials camp

Must not be a one time contact.

For information about ASM Teacher Materials camps contact

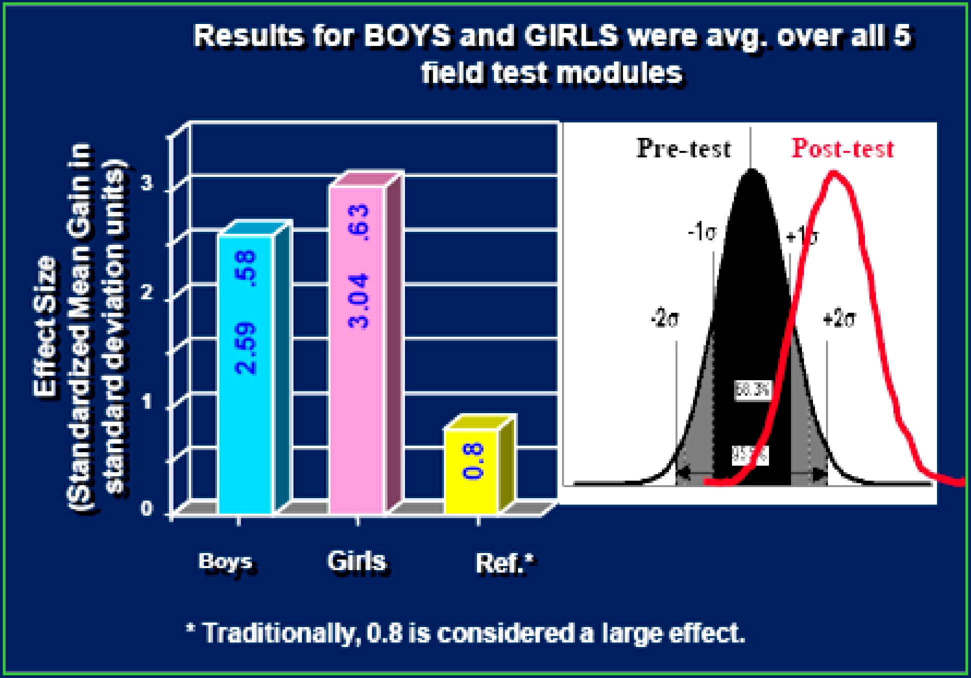
jeane.deatherage@asminternational.org

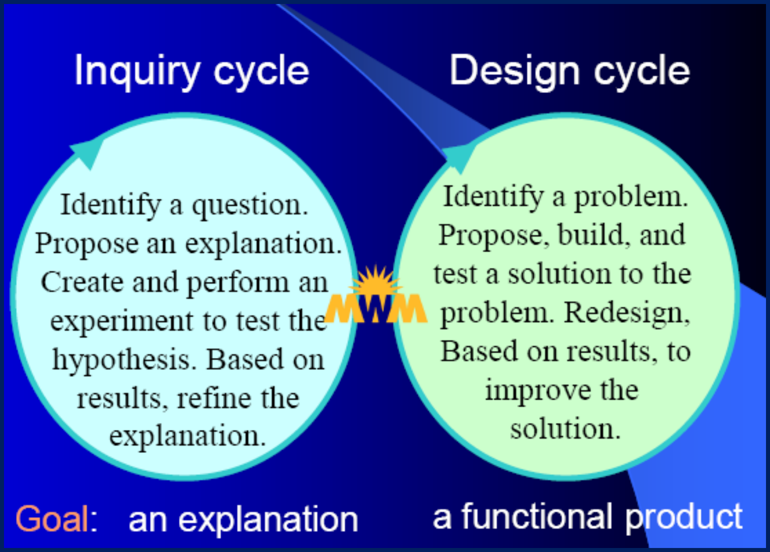
Department of Materials Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

Materials world modules program connects science and math curricula to the real world

Modules Available:

Composites	Biosensors
Concrete	Food Pkging Mat’ls
Sports Mat’ls	Ceramics
Biodeg. Mat’ls	Polymers
	Smart Sensors

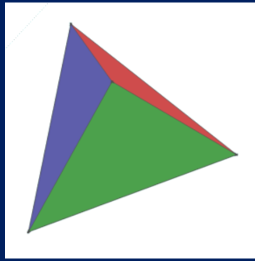




Modules used across the nation, with some 40,000 students having worked with the modules.

Modules require about 2 weeks to complete

Materials Science and Engineering



- Common Cores Characteristics of Different Programs
  - General Knowledge
    - Course Introduction to MSE
    - Courses on Fundamentals that allow one to understand the Processing-Structure relationship
      - Thermodynamics
      - Phase Diagrams
      - Kinetics
  - Structure /chemistry
    - Structure/Crystallography
    - Materials Characterization
  - Property
    - Courses on Properties
      - Mechanical, Electrical most common
      - Additional classes on optical/magnetic properties sometimes offered
  - Processing/Synthesis
    - Each Curricula has several classes on Processing
      - At the core level this is generally an introduction to different materials including processing of those materials

More in depth processing classes occur at the specialization level

Application/Performance

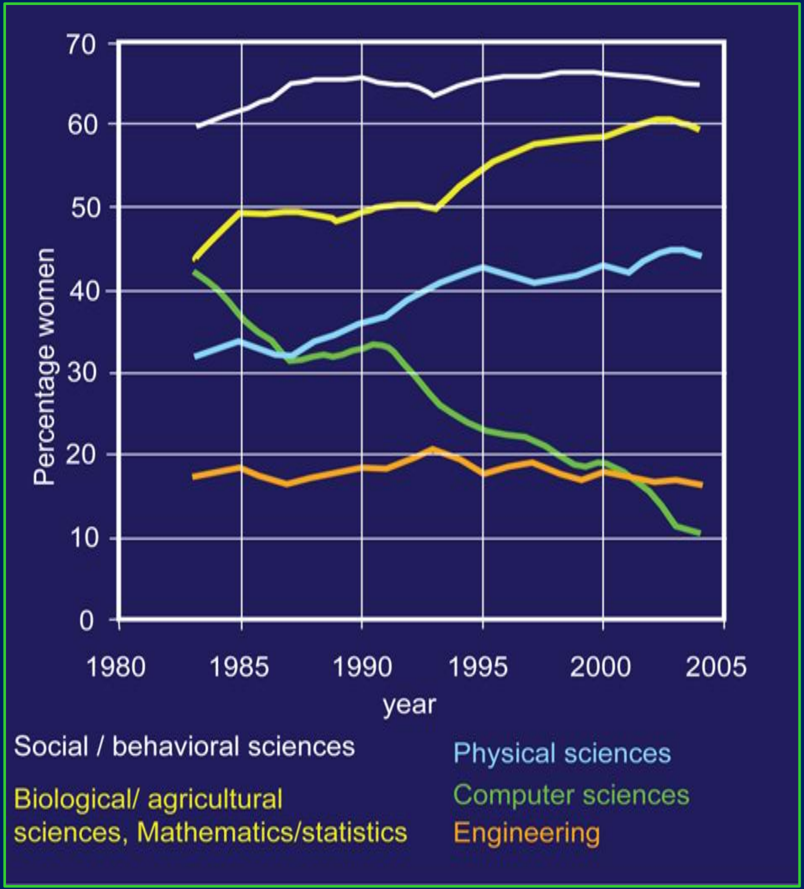
Materials Laboratory Courses
Research Classes
Corrosion/Materials Stability Course

Capstone Class

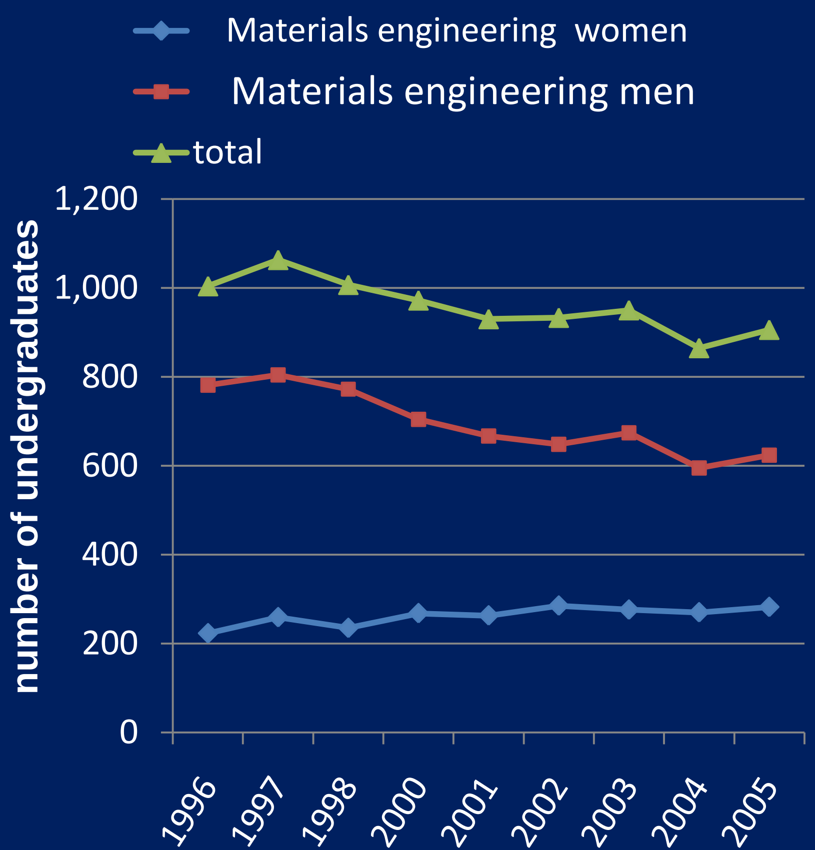
Course on Sustainable Materials Selection/Design

Department of Materials Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

STEM Baccalaureate degrees % women



Materials Science and Engineering



Flow of students into engineering disciplines has dropped overall.
Materials science and engineering dropped but rebounding to about previous numbers
Number of women students constant but low, situation worse for minorities.

Sadler, NSF workshop on Future of Materials Education

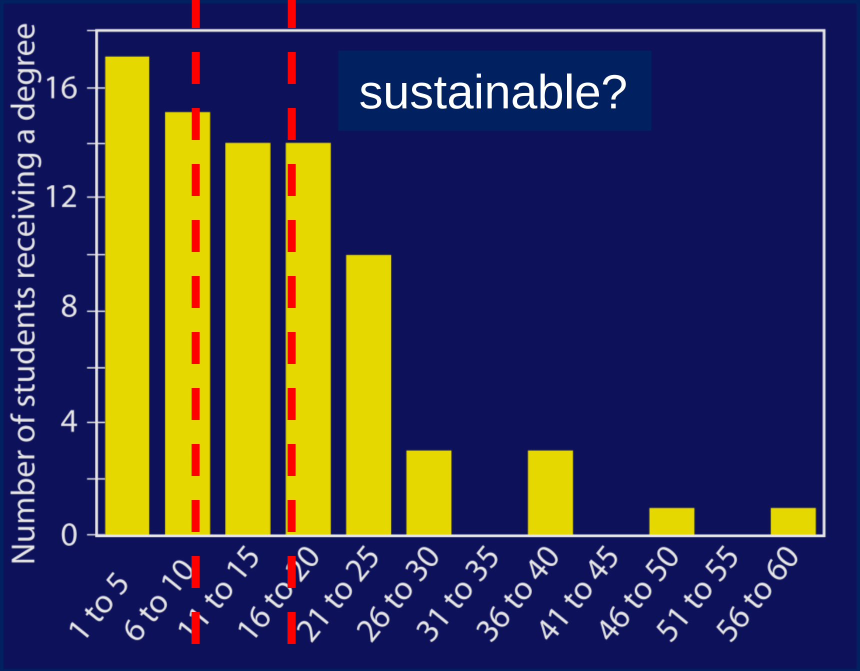
Department of Materials Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

Undergraduate education

Change in the number of materials-designated departments

	Materials Science and Engineering for the 1990s:	ASEE and UMC data
Core MSE departments. Independent materials departments granting bachelor through doctorate degrees	41	49
Independent materials departments which do not grant doctorates	2	1
Independent materials departments providing only graduate degrees	6	3
Materials departments that are joint with disciplines that are peripheral to the materials field	14	18
Materials programs embedded in departments of other disciplines or in schools	27	7
Materials specific academic departments (metals, ceramics, polymers)	14	4
Total	104	82

Degrees granted at different institutions



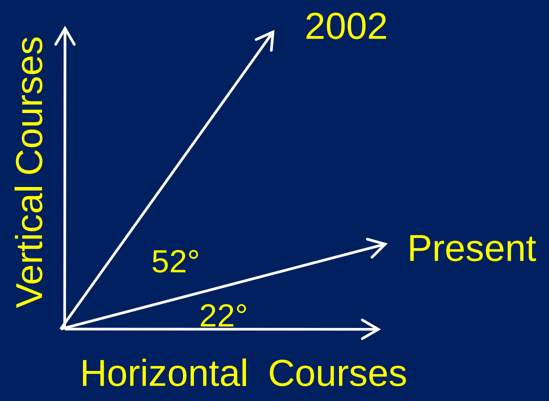
IUMRS-ICEM2008, Sydney, Australia, July 29, 2008 ***Status and Evolution of Accreditation for Materials Programs in the U.S. G. S. Cargill III and C. J. Van Tyne***

Undergraduate education

Reconsider the current curriculum in the context of the rapid expansion in scientific discovery and knowledge and of the skill sets that tomorrow's scientists and engineers must possess.

Teach the students what engineers need to know *(statics, solid mechanics, thermodynamics, etc.)*

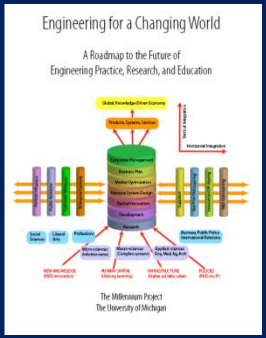
Have students start to think like engineers *(to design, be creative, understand need, long and short time cost, social and environmental impact, communications, professional ethics, etc.) (Apelian)*



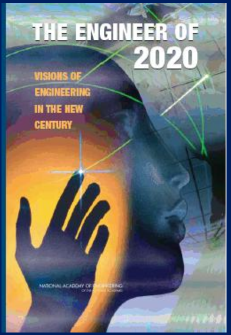
Capitalize and harness new technologies to ensure we are reaching students in a manner in which people learn. Times have changed but not our approach.

Define the body of knowledge that a materials scientist and materials engineer must know for the world of tomorrow. This body of knowledge should be presented in a manner that is meaningful and pertinent . In the words of Vest our programs should inspire and be "*exciting, creative, adventurous, rigorous, demanding, and empowering …"(C. Vest)*

Recommendations for undergraduate education:



- The community in partnership with the professional societies should seek funding to have the National Academies conduct a blue-ribbon panel study on the current status of and future needs for materials education in the USA.   A workforce with this expertise is needed to ensure national security and continued economic growth, sufficient energy and fresh water supplies in an efficient and sustainable manner, etc. These questions need to be addressed in the global context, recognizing the changing character of materials development, research and manufacturing.



- Have the professional societies with membership engaged in materials science and engineering form joint commissions to work to clarify the nature of the overlapping content and concept of the fields and to provide guidelines and recommendations that define the current status and future needs in their respective disciplines. A first step would be a detailed comparison of course content in materials options or material programs in MSE designated and non-designated departments.

Recommendations for undergraduate education continued:

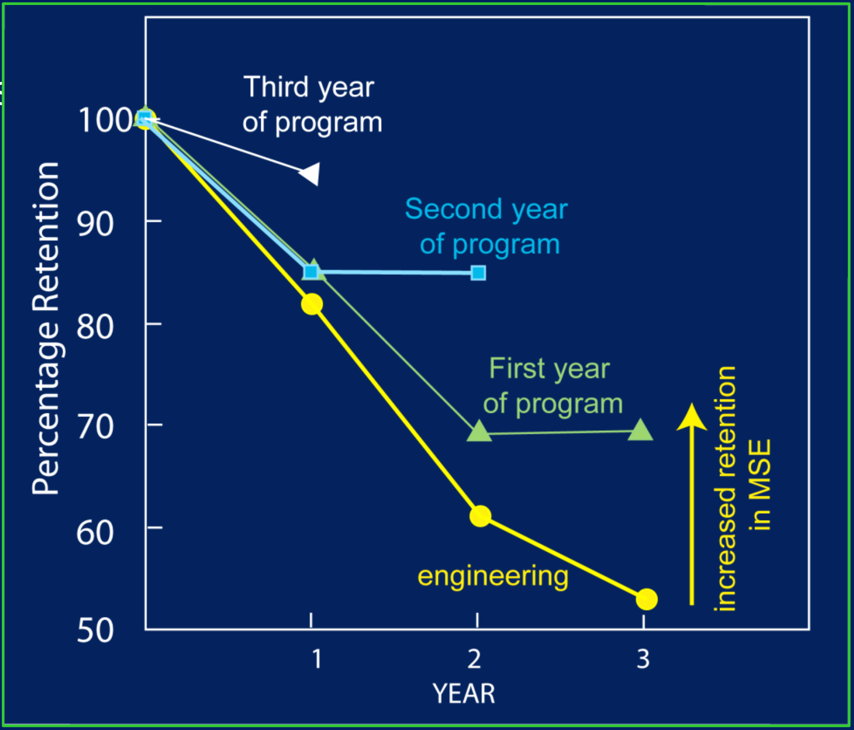
Research, internship and industrial experiences both at home and abroad are important components of preparing future materials scientists and engineers of the future. There is a need to enable research experience programs even as early as the freshman year but this requires resources, which are becoming increasingly difficult to find.

Curriculum revision to seek novel ways to include biology, computational materials science, business, project management, leadership, entrepreneurship, international experiences should be explored but the method of implementation should not be prescribed.

Explore online educational programs to enable continued teaching of “traditional” areas especially at smaller schools and for continuing education courses.

The professional Master’s degree program should not be required as the entry level degree to the profession.

Impact of research experience on retention



Jones, UF.

Department of Materials Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

Graduate programs in materials – a very limited comparison

Materials-designated departments

Structures Thermodynamics
Kinetics Processing
Properties

Sinnott's Survey of programs: Illinois, Michigan, Berkeley, MIT, Northwestern, Stanford, Cornell, U. Florida, Georgia Tech., Penn State revealed that:

- Seven of ten departments have required core classes.
- The number of classes in the core ranges from 1 to 10.
- Most students take additional classes outside the core. The courses selected is determined by students' research interest.
- Several departments require or recommend students who do not have a materials background take an accelerated introduction-style course.

Materials Chemistry Programs

University of Illinois

2 Core Courses Advanced Materials Chemistry; Physical Methods in Materials Chemistry
+ 3 from a list.

University of Wisconsin-Madison
3 required courses: Chemistry of Inorganic Materials; Chemistry of Organic Materials; Materials Chemistry of Polymers (last one may be substituted for another from an approved list.)

"4 primary components: preparation/synthesis ("How are materials made?"), structure ("How are they put together"), characterization ("How do they behave?") and applications ("What are they good for?")."

Recommendations

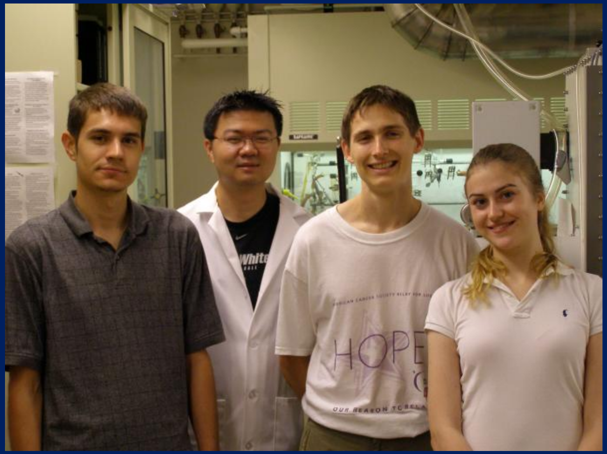
Work towards creating a common body of knowledge expected of a materials scientist and materials engineer but first need to define and agree what the common core should be.

Achieving this may hindered by institutional barriers.

May necessitate a radical change from current practices such as viewing research areas holistically – materials for advanced energy technologies, transportation, communication, medical, water purification, sustainable materials technologies, etc.

Prepare students well for their research career but programs need to be broader and more diverse than before. Need to developed methods to allow students the flexibility to build a program of their choice. Make available resources for independent research.

Graduate students mentoring undergraduates



Need to make students aware of career opportunities (and should show them the positive side of being a faculty member.)

Department of Materials
Science and Engineering
UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN

Message we deliver is important to undergraduate and graduate students too!

Grand challenges as Listed in the NAS report

Condensed-Matter and Materials Physics: The Science of the World Around Us

http://books.nap.edu/catalog.php?record_id=11967

The *grand challenges* of materials science:

- How do complex phenomena emerge from simple ingredients?
-
- How will the energy demands of future generations be met?
- What is the physics of life?
- What happens far from equilibrium and why?
- What new discoveries await us in the nanoworld?
- How will the information technology revolution be extended?

Materials science, as the report notes, is not only a broad field of inquiry itself, but advances in materials science enable advances in many other fields, and its progress has a direct impact on consumers. Our understanding of the physical and chemical properties of materials has become essential to creating various processors, sensors, light sources, etc.

http://arstechnica.com/news.ars/post/20070615-inability-to-meet-grand-challenges-of-physics-likely-to-hurt-us-competitiveness.html