NANOTECHNOLOGY WORKFORCE DEVELOPMENT & EDUCATION

Moderators: Bob Chang (Northwestern U.) and Carl Batt (Cornell U.)

Short statements:
Steve Fonash (PSU - NACK)
Sheryl Hale (OK Dept Career & Tech. Education)
Srinivas Sridhar (Northeastern IGERT with NIH)

Nano workforce development & education

R.P.H. Chang, Northwestern

Carl Batt, Cornell

Workforce Development and Education

- What is needed to accelerate workforce development and education?
- Where are the needs most urgent?

- What should be done in the immediate future to meet these needs, and at what level? (Fed, state, regional, local)

Science Education Priorities Timeline

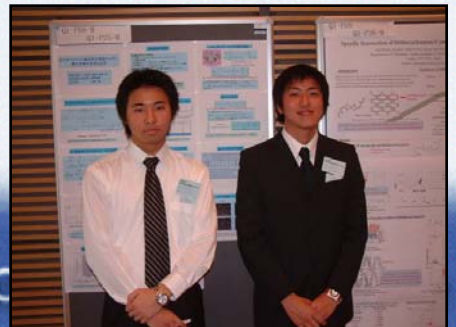
+ 15-20 years | **+ 10-15 years** | **+ 5-10 years**

Pre-college level

Exciting new content and professional development models are being developed worldwide

Undergraduate level

Expand ***access to research facilities*** for hands-on experience; cascade approach across levels



Graduate level

Young researchers must develop ***global leadership capabilities*** in order to lead future education initiatives!

Falling U.S. Rankings Among Developed Nations

US Rankings in TIMMS Study: Trends in International Mathematics & Science Study

	8th Grade	10th Grade	11th Grade
Science	9	20	27
Math	15	25	28

TIMSS 2003 International Benchmarks of Math and Science Achievement

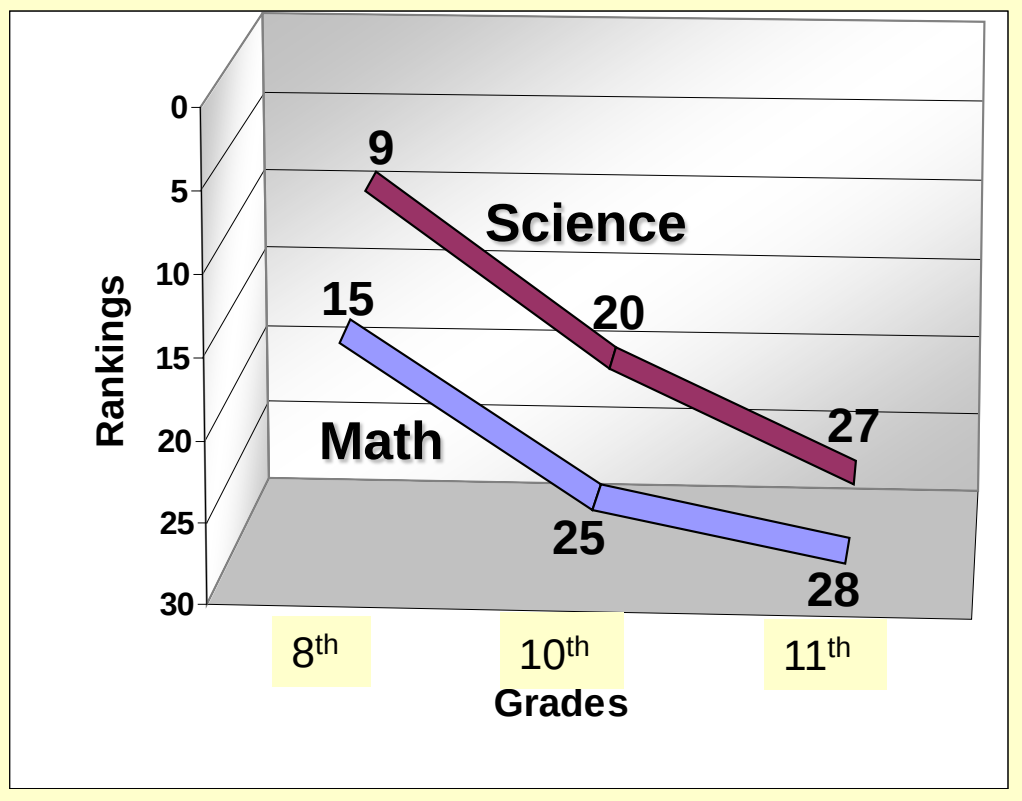
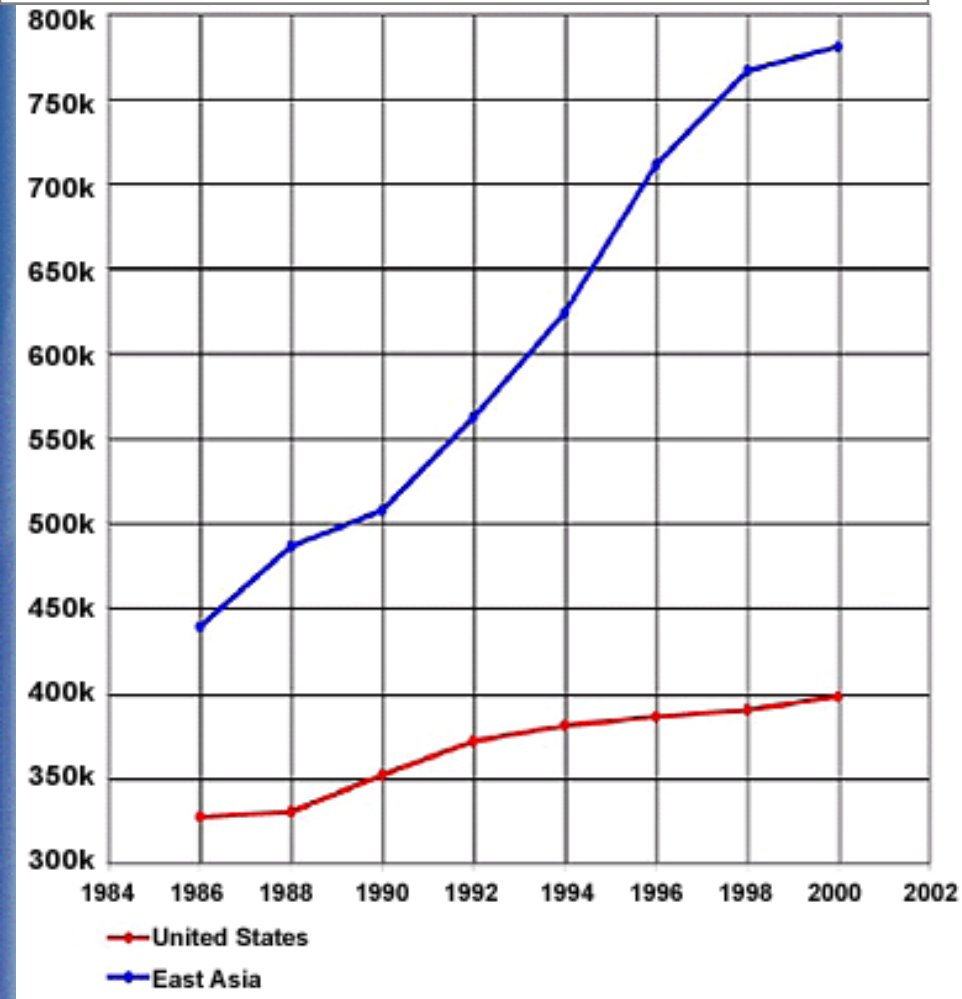
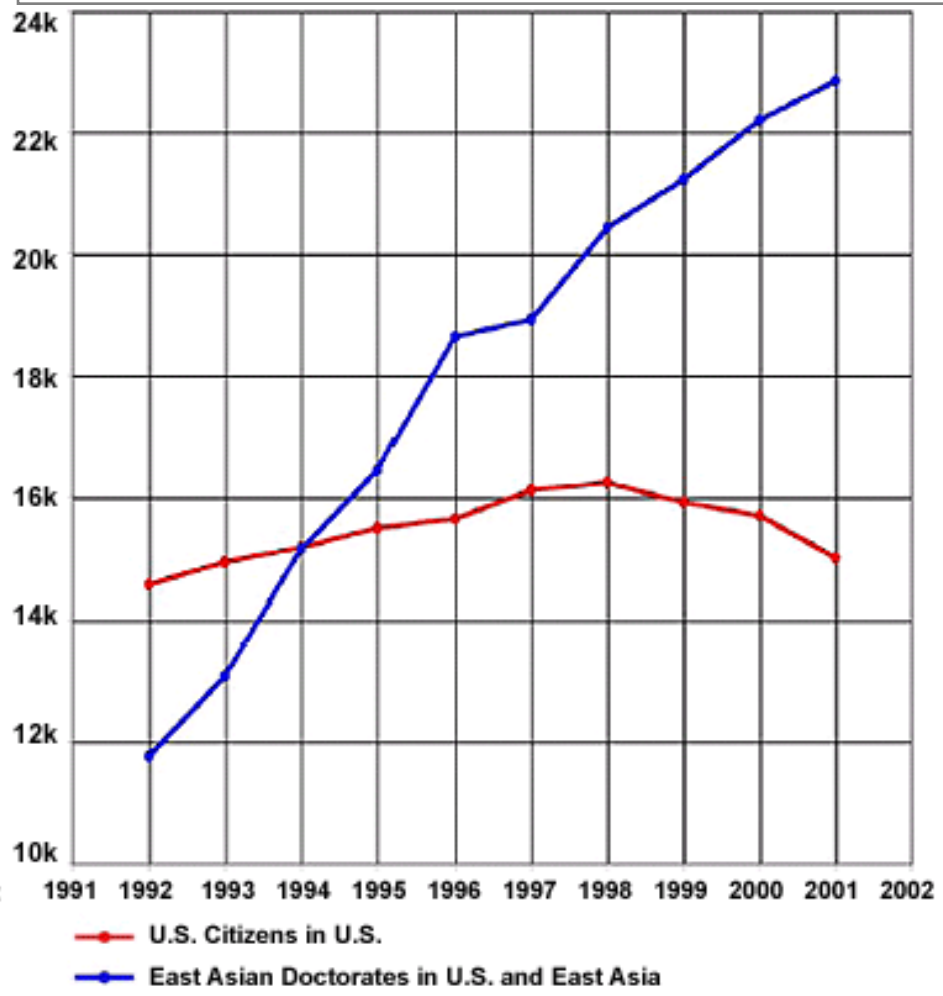


Figure 1: Science and Engineering First University Degrees in the U.S. and East Asia



Between 1986 and 2000, the annual growth in first university degrees in science and engineering increased by more than 75% in East Asia, and less than 19% in the U.S. In this plot, East Asia represents the combined total of Japan, China and South Korea. [54]

Figure 2: Science and Engineering Doctorates awarded to U.S. and East Asian Citizens



In this plot, East Asia represents China, Japan, South Korea, and Taiwan. Data for South Korea in 2001 are estimated. [57]

Barriers to rapid introduction of new science concepts

- **Lack of well-trained teachers**
- **Diverse science curricula and learning standards**
- **Lack of student interest in math and science**
- **Course content rapidly out-of date**
- **Lack of researcher involvement in pre-college science education**
- **Crowded curricula**
- **Limited education budgets**

How can we take on these challenges to quickly introduce new science concepts into secondary and tertiary classrooms?

Goals

1. **Horizontal Integration (across disciplines and communities)**
   Examples: Eliminate Departmental Barriers; Offer cross-cutting, theme-based courses; Create interdisciplinary degree programs; etc.
2. **Vertical Integration (across levels)**
   Examples: Partner with teachers & schools to integrate new content into existing curricula; Involve university faculty; Offer excellent professional development and research experience for teachers; etc.

Goals

3. Motivate student interest in science and engineering

Examples: Engage students early; Offer sustained access to science education; Create exciting, engaging programs that are relevant to them!

Use Inquiry-and Design to stimulate their natural curiosity & creativity!

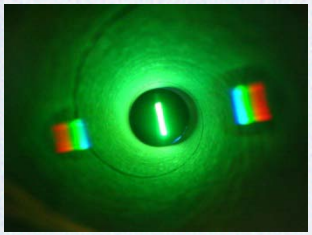
National Center for Learning and Teaching in Nanoscale Science and Engineering

R.P.H. Chang

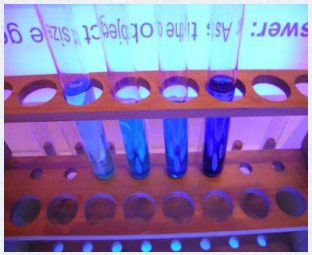
Center Mission & Vision

Mission: ***Build national capacity*** in Nanoscale Science & Engineering (NSE) Education (grades 7-16)

Vision: **Develop a *globally competitive*** NSE workforce and train a national cadre of leaders in NSE education



Learning and teaching through inquiry and design of nanoscale materials and systems for applications



Developing Curricula • **New Learning Standards** • **NSEE Knowledge Base**

Center Goals

- Develop fundamental research in nano science and engineering education (NSEE).
- Develop knowledge base and model for teaching NSE, equipping future leaders in NSEE.
- Develop proto-type curricula for teachers and students.
- Equip Teachers/Professors in NSE learning and teaching.
- Establish NCLT as a national and global leader in NSEE.

Some "Big" nano concepts and learning goals, relating to materials

A. **The scale of matter determines its nature and properties.**

B. **Dominant forces in the nanoworld are different from those in the macro world.**

C. **Materials and phenomena in the nanoscale may or may not behave the same way as in the macroscale.**

D. **The unique properties of nanomaterials can be used to advance technology and improve quality of life.**

E. **New concepts can be derived from interdisciplinarity and complexity at the nano level.**

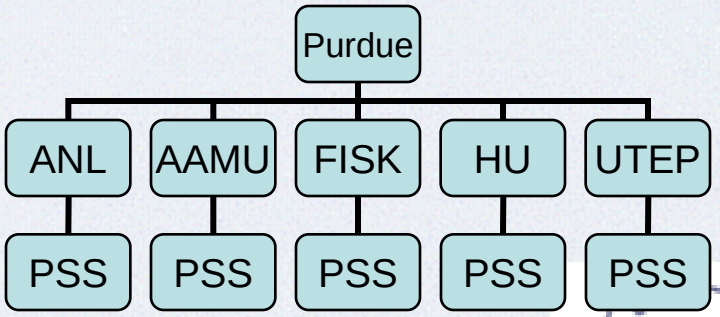
F. **Geometry can have an impact on nano materials design and applications.**

Link to National Standards: **(A, C)** NSES/5-8/B/1/a, **Properties and changes of properties in matter**; 2061/6-8/4D/1, **The structure of matter**; 2061/6-8/11D/1, **Scale**; 2061/6-8/12B/9, **Computation and estimation**; 2061/9-12/11D/2, **Scale**. **(B)** 2061/6-8/4G/1, **Forces of Nature**; NSES/9-12/B/4/d, **Motions and Forces**. **(D)** NSES/5-8/F/5/d, S**cience and technology in society**; NSES/9-12/E/2/b, **Understanding about science and technology**; 2061/9-12/8B/3,4, **Materials and manufacturing**. **(E)** NSES/5-8/F/5/d, S**cience and technology in society**; NSES/9-12/G/1/a, **Science as a human endeavor**. **(F)** 2061/9-12/9C/2, **Shapes.**

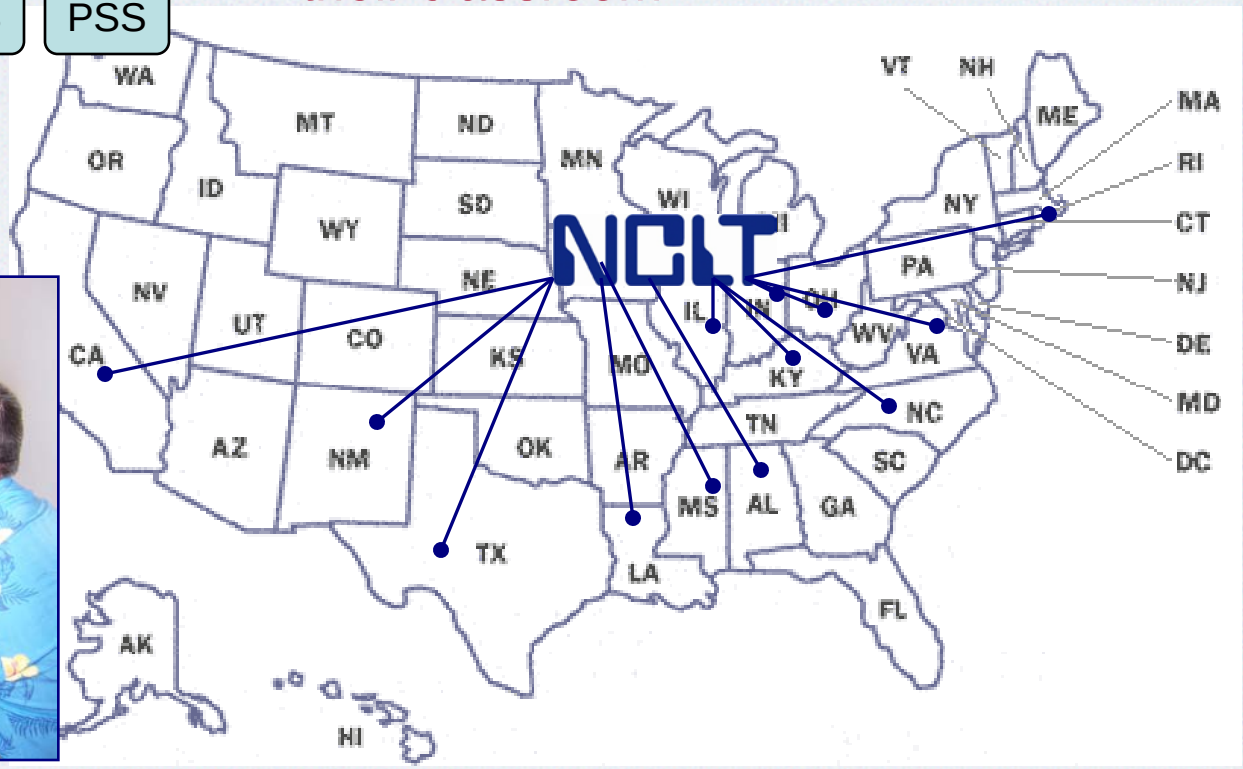
Highlights: NSE Learning Research

- Big Ideas in NanoScience
- Learning Progressions
- Concept Inventories
- Professional Development Research
- Higher Education Learning Research
- Impact of NCLT Learning Research on science education

NCLT Professional Development



100+ Network of Schools & Teachers being trained to incorporate NSE into their classroom

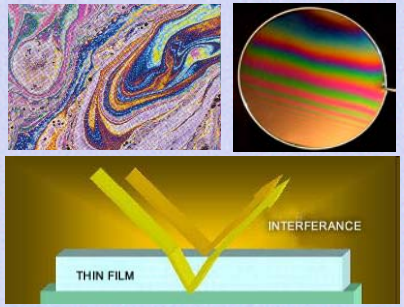


Manipulating Light in the Nanoworld

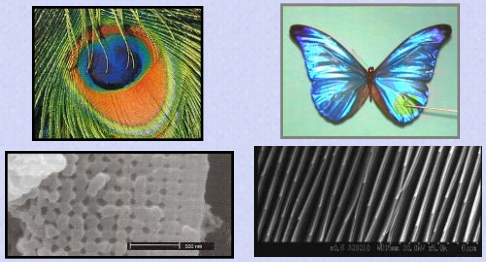
INVESTIGATION: Light Interacting with Nanostructures

Homemade CD-ROM spectroscope

Diffraction

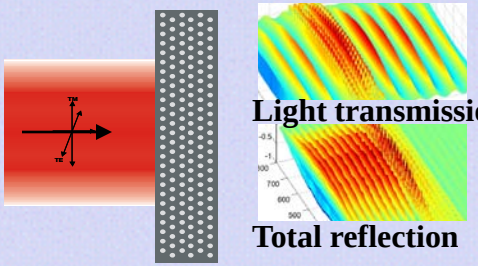


Interference

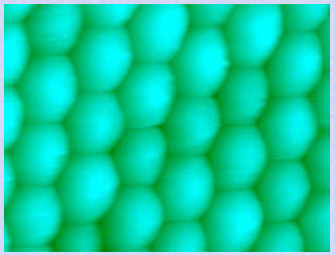


Reflection due to structure

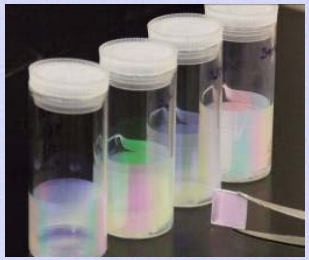
APPLICATION: Creating Opal-like, Photonic Structures



Predict structure via simulation



Self-assembly of polystyrene beads

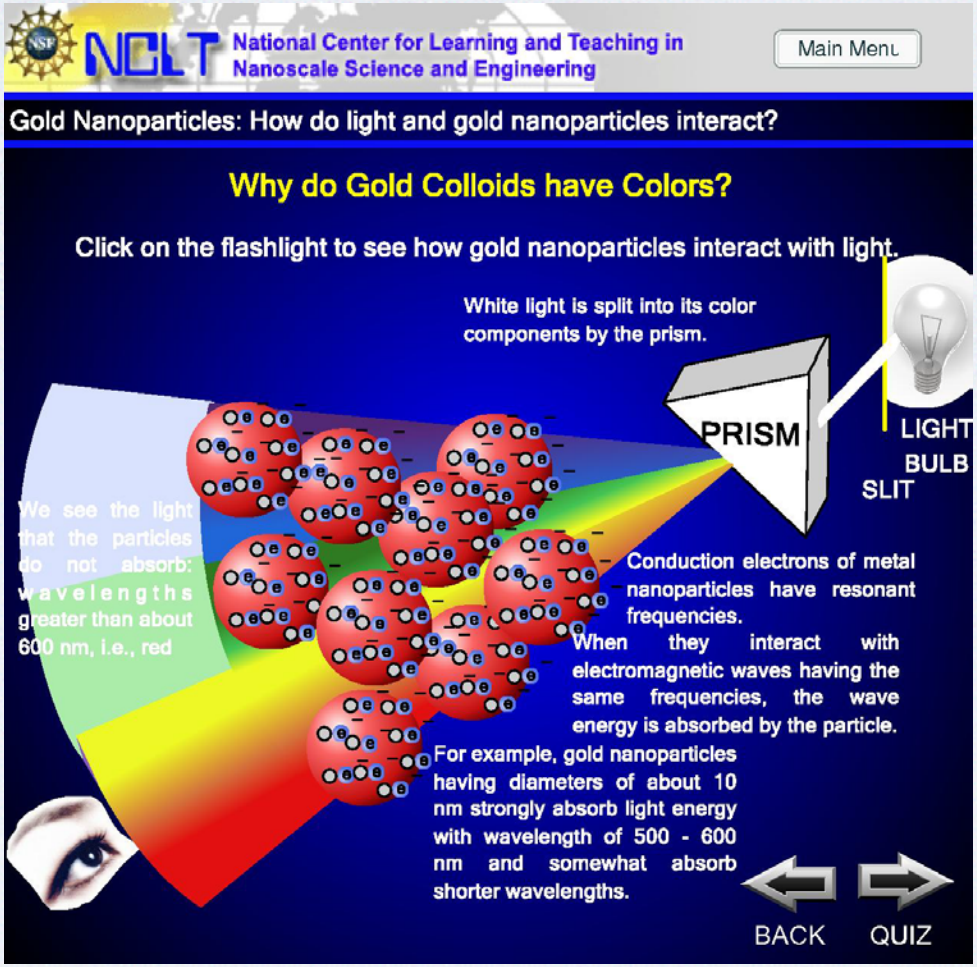


Natural opal

Artificial opal by design

Gold Colloids: Interactive Software

- Animation of light interacting with electrons of colloids
- Pre- and post-tests assess learning
- Revisions based on educator feedback & data collected at university, college, & high school levels
- Currently replacing most text w/audio



2008 NCLT Faculty NSEE Workshop

Alabama A&M University March 26-29, 2008

Workshop Participants:

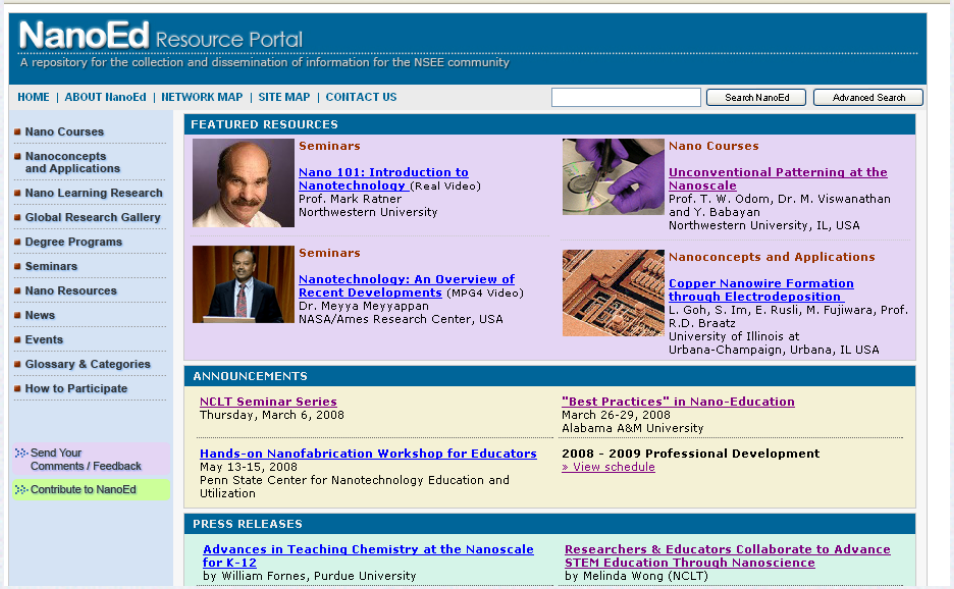
- 50 faculty participants from 35 colleges/ universities
  - 5% "Future Faculty"
  - 20% Women
  - 33 % from minority-serving institutions

Major outcomes:

- "Expert" concept-mapping of "Big Ideas" in NSEE
- Exemplars of "Construct-Centered Design" to develop nanoscience content for courses

⇨ To be posted on the NCLT NanoEd Resource Portal

NCLT NanoEd Resource Portal

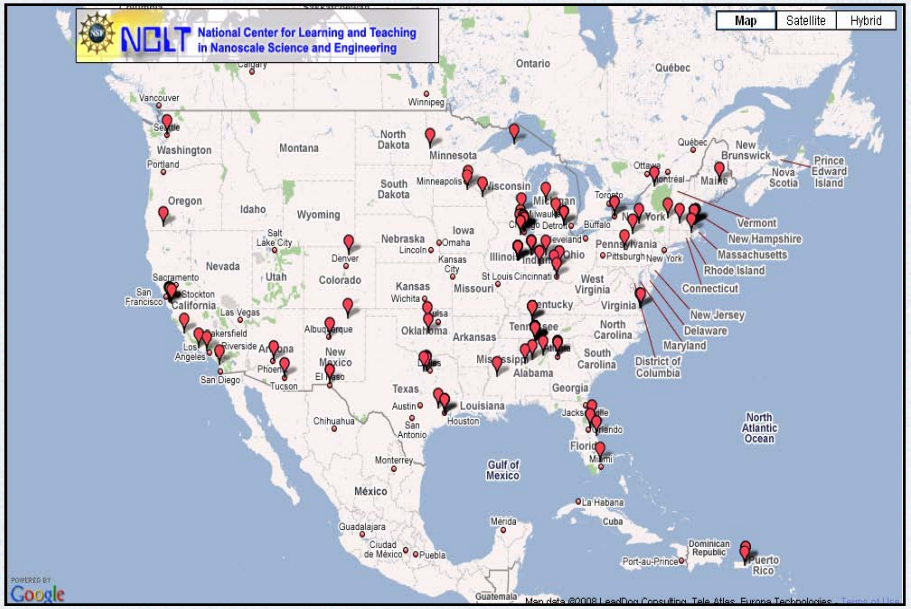


- Dynamic repository of free NSEE materials
- National & Global dissemination
- Wide range of nano-related content:
  - ☑ Courses to enhance teaching
  - ☑ Simulations to supplement teaching material
  - ☑ 7-12 grade Lessons & Activities for STEM curriculum
  - ☑ Seminars to advance NSEE community knowledge and network
- Packaged and categorized for the end-user

NCLT Seminars

Focus on both the cutting-edge nanoconcepts & educational methods for teaching NSE

Resource Gathering & Networking



Building an NSEE Community

- connect diverse stakeholders in academia, government and industry
- serving a wide rand of disciplines, instructional levels, and populations

Networking:

(1) Linking with NNI Center programs in Education

(2) Outreach & Working with School Districts

(3) National NSEE Workshops

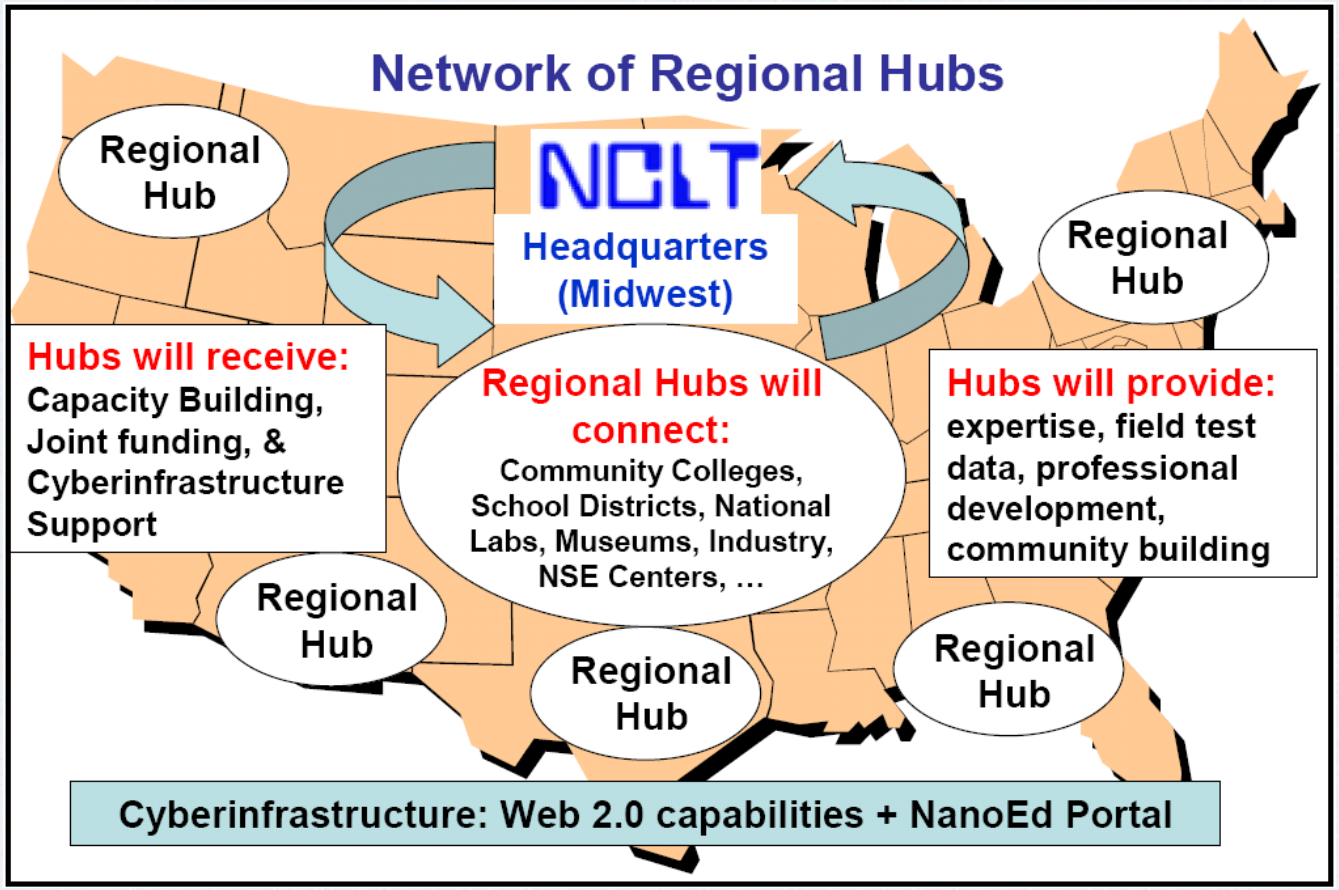
(4) NCLT Seminars

(5) Helping establish community College Nano Networks

(6) Developing Global Partnerships in NSEE

(7) NanoEd Resource Portal

Develop a New Network of Regional Hubs



New partners in Phase II

- LSU
- UCLA
- CSU
- SUNY-Albany
- (NW - TBD)
- (SE - TBD)

In time, regional hubs develop own brands of advanced NSEE capabilities, perpetuating legacy of enhanced capacity & sustainability.

Materials World Modules

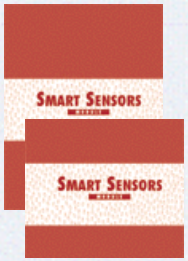
An NSF Inquiry-based Science and Technology Education Program

NU . UM . PU . UIUC . ANL . AAMU . FU . HU . MC . UTEP . PSS

Materials World Modules

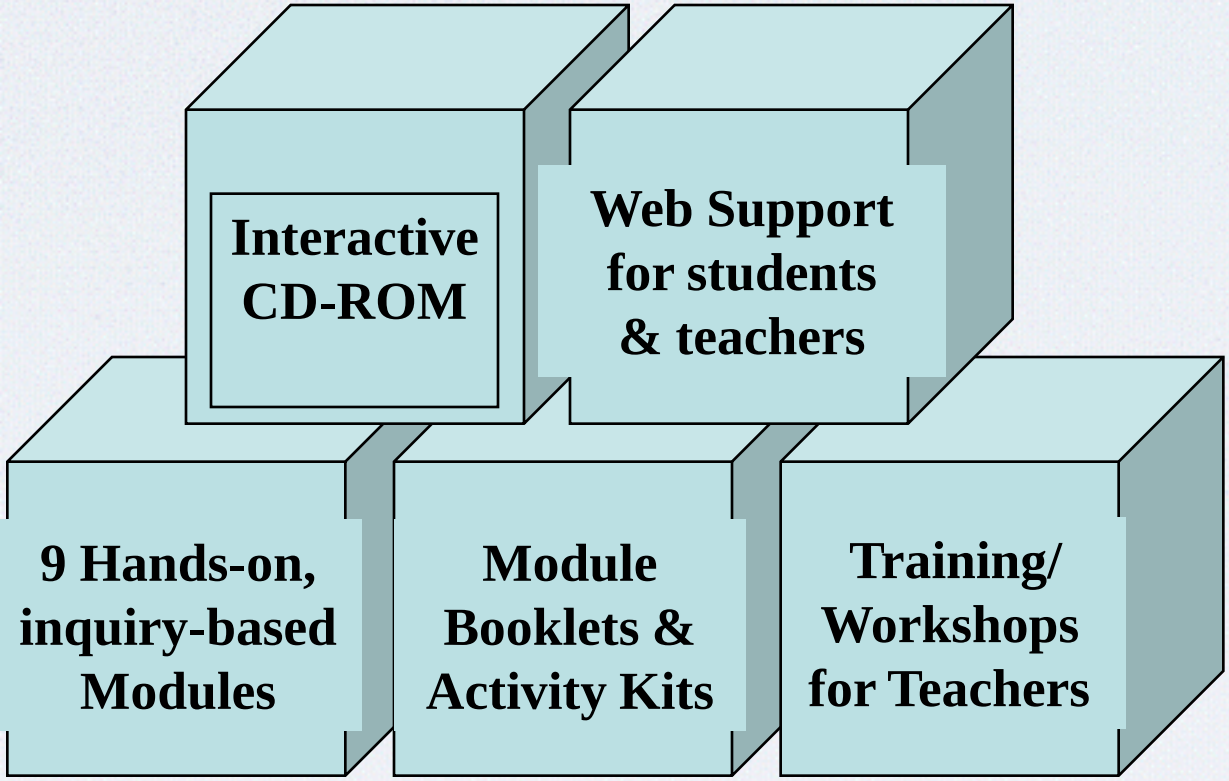
Published Modules:

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

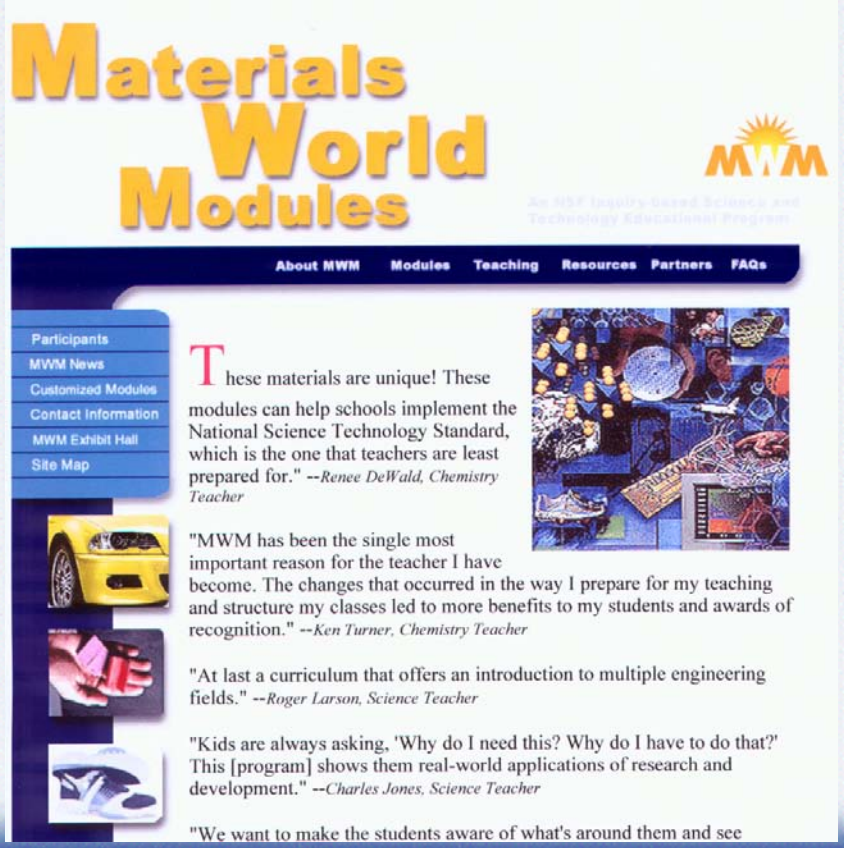


- **Light in the nanoworld**
- Conductivity
- **Environ. Catalysis**
- **Nanotechnology**

MWM
A Total Educational Program



www.materialsworldmodules.org



Materials World Modules

MWM

An NSF Inquiry-based Science and Technology Educational Program

About MWM | Modules | Teaching | Resources | Partners | FAQs

- Participants
- MWM News
- Customized Modules
- Contact Information
- MWM Exhibit Hall
- Site Map

These materials are unique! These modules can help schools implement the National Science Technology Standard, which is the one that teachers are least prepared for." --*Renee DeWald, Chemistry Teacher*

"MWM has been the single most important reason for the teacher I have become. The changes that occurred in the way I prepare for my teaching and structure my classes led to more benefits to my students and awards of recognition." --*Ken Turner, Chemistry Teacher*

"At last a curriculum that offers an introduction to multiple engineering fields." --*Roger Larson, Science Teacher*

"Kids are always asking, 'Why do I need this? Why do I have to do that?' This [program] shows them real-world applications of research and development." --*Charles Jones, Science Teacher*

"We want to make the students aware of what's around them and see

Nanotechnology Workforce Development & Education

- **What is needed to accelerate nanotechnology-related education and workforce development? Where are the needs most urgent?**
- **Nanotechnology workforce development requires a broad, hands-on education that prepares technicians to work in any industry using micro- or nanotechnology**
  - Fabrication approaches **(e.g., self-assembly, chemical vapor deposition)**
  - Characterization **(e.g., scanning probe and field emission scanning electron microscopies**
- **According to a survey of 100 U.S. manufacturers carried out in 2007 with the National Council For Advanced Manufacturing (NACFAM), there is an urgent need for technicians with broad nanotechnology skills.**
- **The task of delivering the required, broad nanotechnology education and workforce development falls mainly to community and technical colleges.**
- **These institutions need the resources to be able to meet this task.**
- **The solution is resource-sharing partnerships that make the nanotechnology facilities and capabilities of research intensive universities available to community and technical colleges for nanotechnology workforce development.**
- **The NSF National Nanotechnology Applications and Career Knowledge (NACK) Center is mandated with forming such partnerships.**

Nanotechnology Workforce Development & Education

- **What should be done in the immediate future to meet these needs, and at what level (i.e. federal, regional, state, local)?**

- **What is most needed to create the required nanotechnology workforce is to encourage and sustain resource-sharing partnerships between research universities which have the facilities and expertise and the country's two-year degree-granting community and technical colleges.**
- **Local, regional, and state support are required to form (1) teaching locations or (2) regional centers that are supported (via web access or physical attendance) by research universities. The research universities have to be sustained in this resource-sharing endeavor by state and federal support.**
- **Support from state governments for nanotechnology education partnerships involving community and technical colleges on one hand, and research intensive universities with nanotechnology facilities on the other, is especially crucial.**

Oklahoma Nanotechnology Education Initiative (ONEI)

Preparing Oklahomans to Succeed in the Workplace, in Education, and in Life.

National Science Foundation (NSF)

- NSF Advanced Technological Education Grant (ATE)

- Lead Institutions
  - Oklahoma State University-Okmulgee
  - Oklahoma Department of Career and Technology Education

Workforce Needs

The United States will need between one and two million new workers trained in nanoscience, with a majority of these workers requiring only a two-year postsecondary degree.

Uldrich, Jack. *A skilled workforce: If you build it, businesses will come.* smalltimes.com, 2005

The Challenge

Secondary school students have grown up around computers in the information age. They are at home with the concept of moving information electronically but are not at home with the concept of literally moving molecules around to create and build. . .They know little about nanotechnology.

This lack of knowledge is one factor that impedes the development of a nanotechnology workforce.

Fonash, Stephen. *Education training and the nanotechnology workforce*. 2001

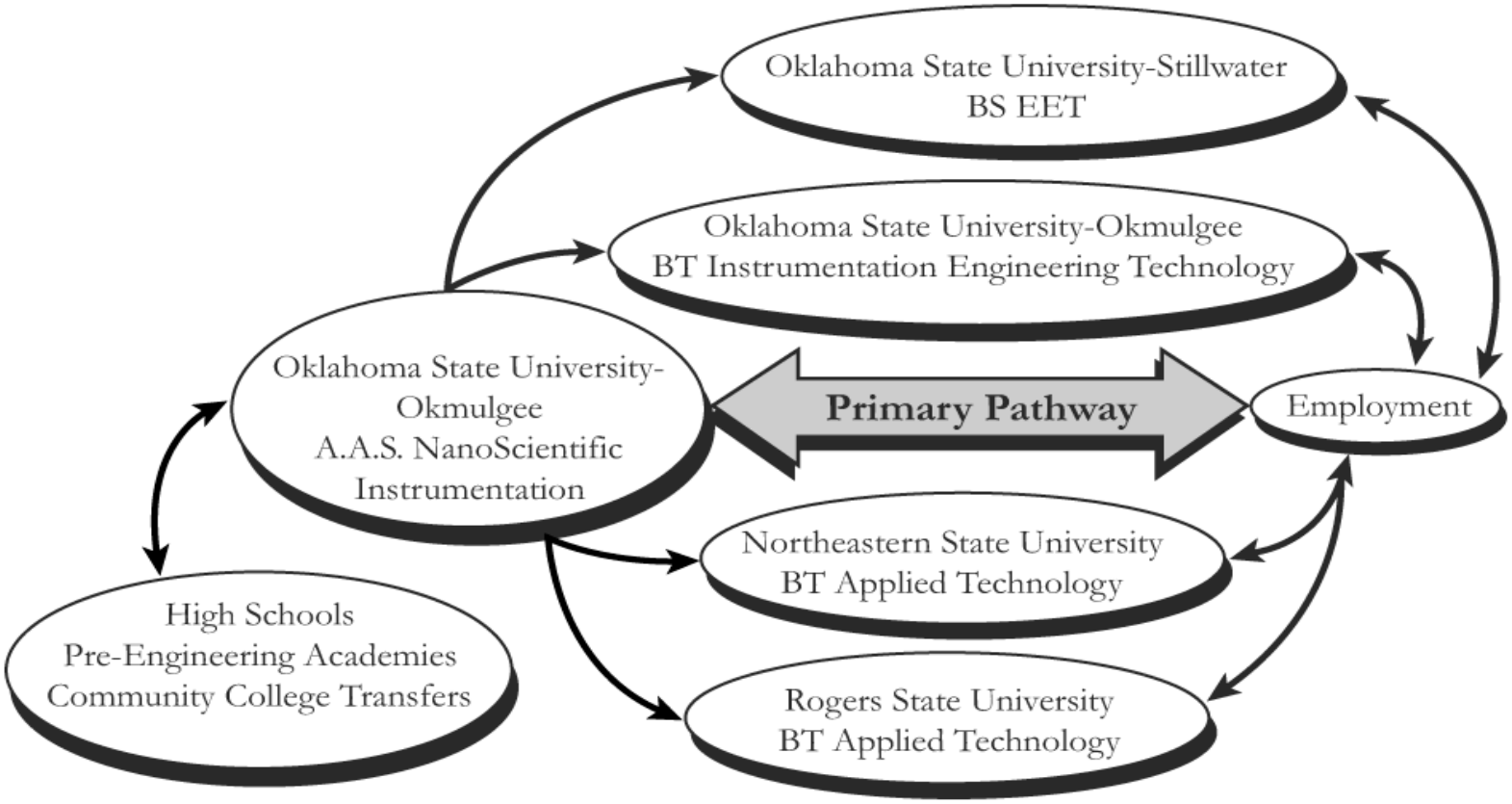
ONEI Goal

To develop a technician workforce that will advance industries' use of microtechnology and nanotechnology.

Our Approach

- Develop Career Awareness Activities
- Develop Resources to Support Career and Technology Education Programs
  - Pre-Engineering
  - Manufacturing
  - Aviation and Aerospace
- Develop Applied Associate Nanotechnology Degree – NanoScientific Instrumentation
- Provide Faculty Development
- Create Educational Pathways

Proposed Educational Pathways



Leveraging Resources

- The Regional Center for Nanofabrication Manufacturing Education (Penn State)
- Southwest Center for Microsystems Education (New Mexico)
- University of Tulsa
- Oklahoma State University

Collaborative Efforts

- Accessing Curriculum and Shareable Content Objects
- Uses Existing Experimental and Lab Modules
- Replicating Teacher Development Workshops
- Remotely Accessing Nanoprocessing Equipment
- Collaborative Student Projects

Understanding industry needs is critical to our success.

We appreciate all the support we have already received from the ONI and industry!

www.igert.neu.edu

IGERT Nanomedicine Science and Technology

@ Northeastern University

Sri Sridhar, Electronic Materials Research Institute

- IGERT grant from NCI through NSF 2005-2010
- 25 Doctoral trainees, 25 Masters and UG Associates
- > 40 research projects in diagnostics and therapeutics using nanoplatforms
- 3 new nanomedicine courses established
- Interdisciplinary seminars, guest lecturers from hospitals and industry, international collaborations
- Vigorous outreach and internship components

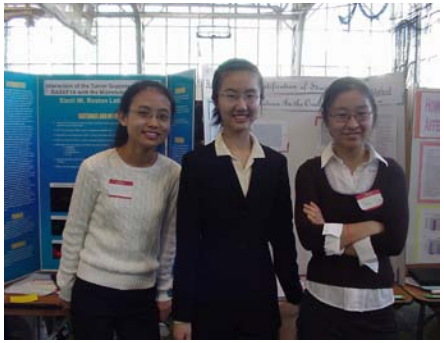
MASSACHUSETTS GENERAL HOSPITAL

Beth Israel Deaconess Medical Center

Forsyth

DANA-FARBER CANCER INSTITUTE

PARTNERS HEALTHCARE



NEXT STEPS

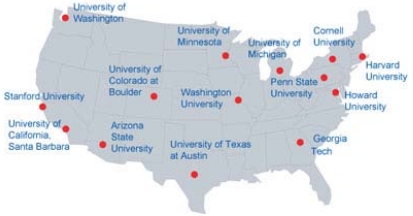
- New Ph.D., M.S., Certificate, M.D.-Ph.D programs
- Expand model to other geographic locations – U Puerto Rico, Tuskegee,….
- Extensive international interest – Expand partnership with Uni Napoli, ….

What is needed to accelerate nanotechnology-related education and workforce development? Where are the needs most urgent?

- **Develop truly integrated K-99 education programs in all geographic regions**
- **Establish more programs and curricula at universities in nanomedicine and nanotechnology**
- **Universities need to promote interdisciplinary education that is essential to this field**
- **Need adult education programs that can retrain workers for employment in this field**
- **Train the teachers to promote K-12 education in nanotechnology**
- **Develop media information outlets to enhance public awareness of nanotechnology and nanomedicine**

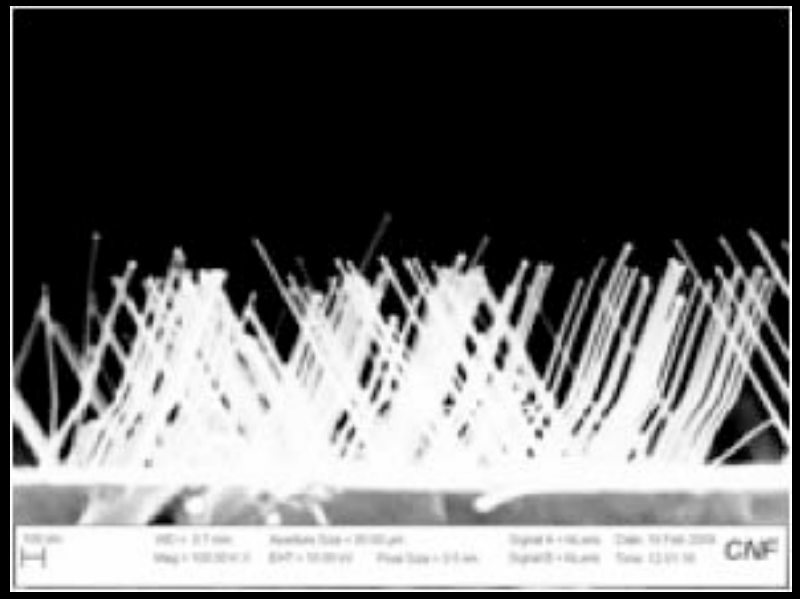
What should be done in the immediate future to meet these needs, and at what level (i.e. federal, regional, state, local)?

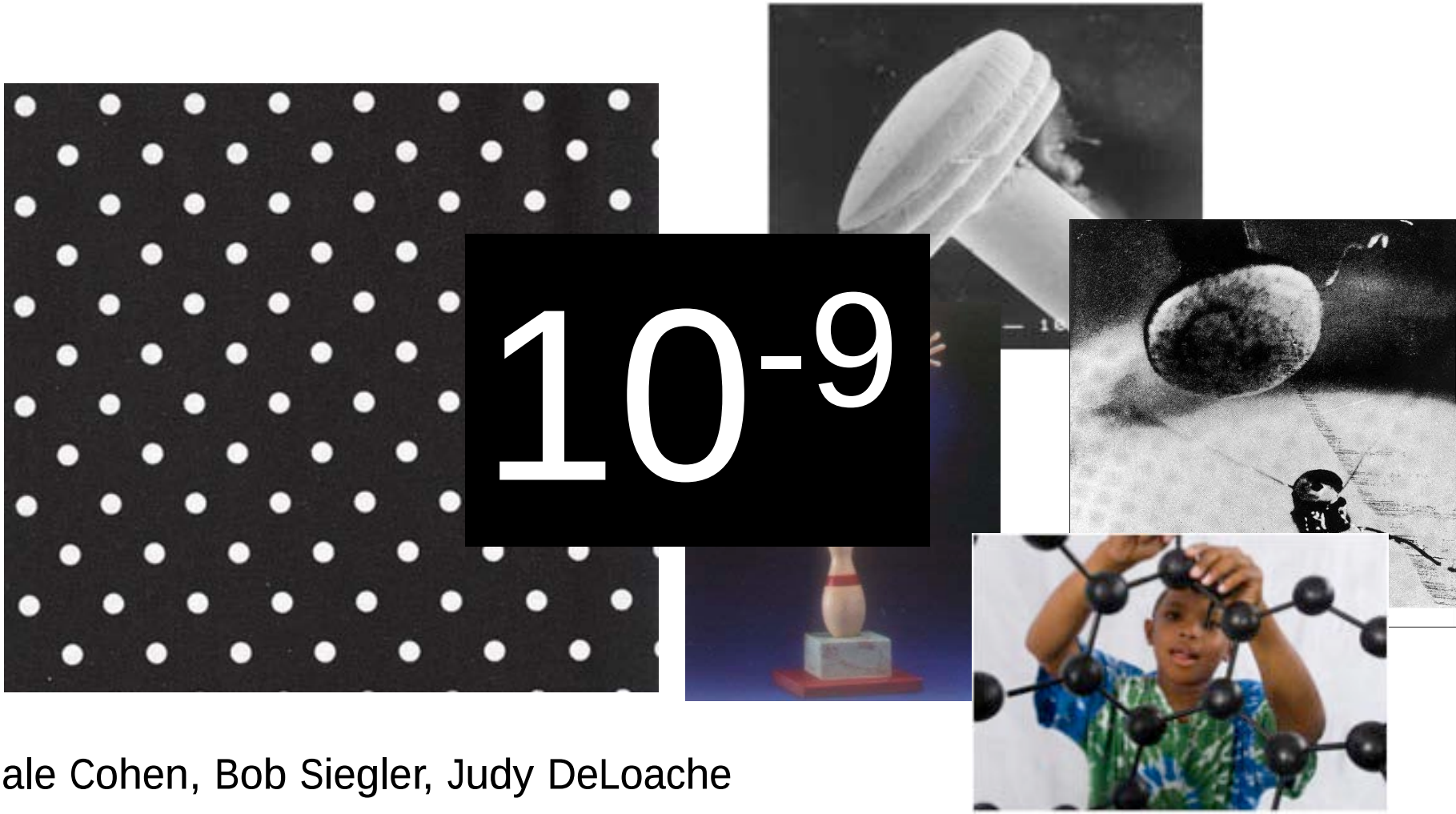
- **Investments by federal, state and local agencies to foster innovation in education**
- **Governments (federal, state, local) should provide the funds and allow education community to develop varied programs**
- **Require alliances for collaboration among different stakeholders – government, non-government, universities and schools, business and venture communities**
- **Fund programs for student internships in industry**
- **Ensure that programs provide access to under-represented sections of the population**

It's a Nano World	1,000,000	NSF	
TOO SMALL TO SEE — ZOOM INTO NANOTECHNOLOGY	1,000,000	NSF	
NANOOZE	200,000+	NNIN Nanoscale Science, Engineering & Technology	
Chronicles	200,000+	NSF	EarthSky A CLEAR VOICE FOR SCIENCE
Radio	75,000,000	USDA	EarthSky A CLEAR VOICE FOR SCIENCE
NANOOZE The Exhibit	100,000+?	NNIN Nanoscale Science, Engineering & Technology	
	2,000,000+?	NSF	

Informal

What’s a nano?





Dale Cohen, Bob Siegler, Judy DeLoache

Retail