Perspectives on Nano Science and Engineering Education (NSEE)

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(NCLT)

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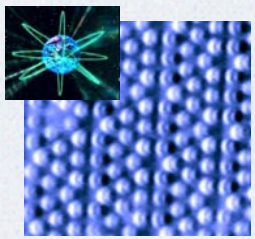
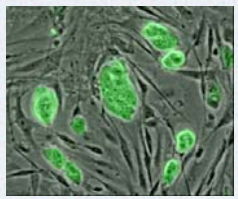
Outline

- **Introduction**
  - What is nano science?
  - Why do we need nano education in the US?
  - Issues and barriers to introducing nano education
- **What is NCLT doing in NanoEd?**
- **NSEE network for rapid NanoEd delivery**
  - Real space interactions
  - Cyberspace collaborations

Science Disciplines at Different Length Scales



atoms

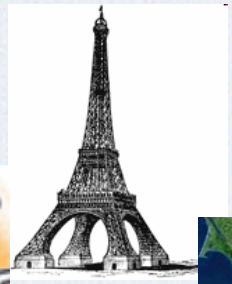


cell

dust mite

human hair

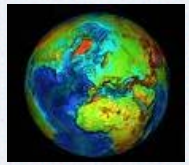
human



Eiffle tower

continent

SF Bay area



earth

planets

10^{-10} m | 10^{-8} m | 10^{-6} m | 10^{-4} m | 10^{-2} m | 1 m | 10^{2} m | 10^{4} m | 10^{6} m | 10^{8} m | 10^{10} m

<-Subatomic sciences

Biological sciences

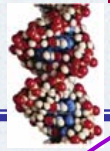
Social sciences

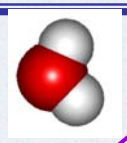
Geological sciences

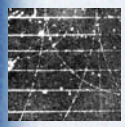
Astronomical sciences

1 - 100 nm
Nano science

Meeting at the Nanoscale







Biology

Chemistry

Physics

Engineering

Tools to Image & Manipulate at the Nanoscale
1982 Scanning Tunneling Microscope
1986 Atomic Force Microscope
1991 NSOM

Macro Scale

Microscopic Scale

100 nm

Nano Scale

1nm

Atomic Scale

Sub-Atomic Scale

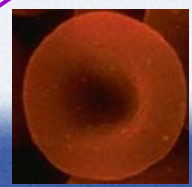
Tools to Fabricate at the Nanoscale
Lithography (optical, e-beam, print)
Focused Ion Beam
Vapor Deposition
Self-Assembly

Engineering

Physics

Chemistry

Biology

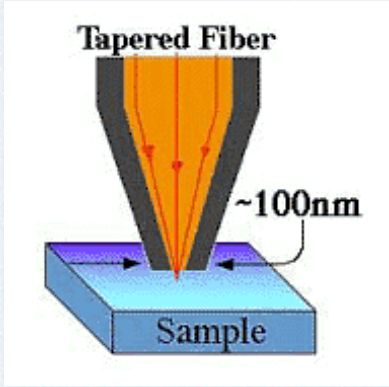


Examples of Physics at Nanoscale - NSOM

Optical microscopy is limited to resolving details at the UV (~200nm).

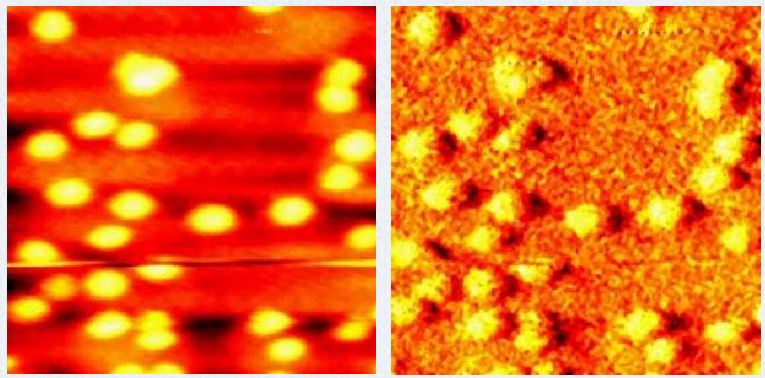
However, optical resolution at the Nanoscale has become possible with the new technique of using the near-field region of light from a nanoscale source that can be accurately positioned within nanometers of a surface (<1/2 the wavelength of light).

By using a **Near-Field Scanning Optical Microscope,** what was known as the *diffraction limit* for conventional optical microscopy can be surpassed.



NSOM can resolve details at <50 nm

AFM NSOM



200 nm 200 nm

Images courtesy of Prof. Cao

Nano Biomimicry

Nature's nanomachines are usually **proteins**.
(**Enzymes** are nanomachines.)

Elastic proteins are in
- muscle (titin—most massive and longest protein)
- gluten (think of kneading dough)
- spider web

The most efficient elastic protein is resilin. (allows fleas to jump 150x their length!)

There is current research to make resilin-based **nanohinges** and **nanosprings**.

nanospring grown at U. of Idaho diameter ~ 60 nm

Application-Sunscreen

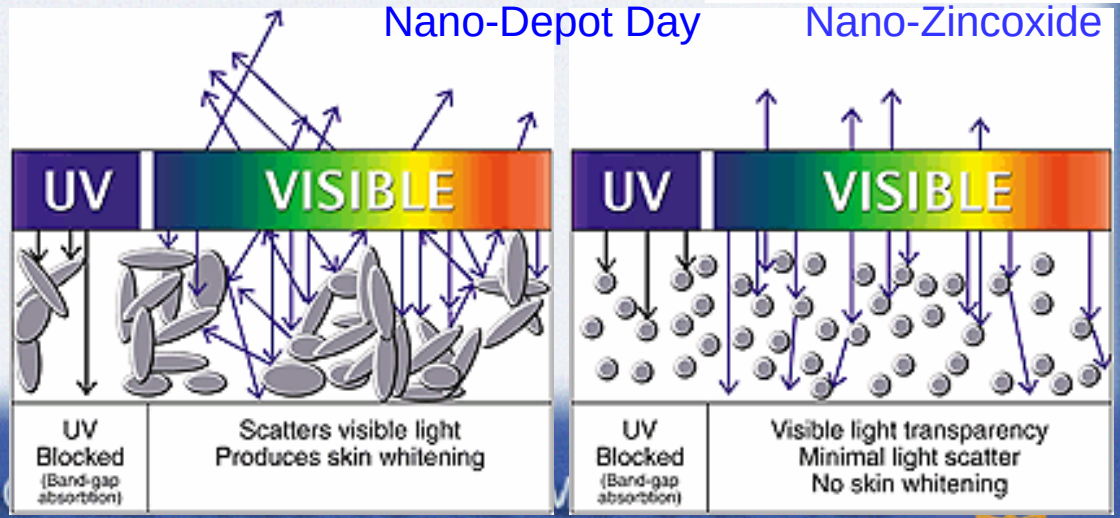
Nano-dispersed zinc oxide (30 nm) provides protection against UVA and UVB rays and is transparent

- cosmetic clarity (no pasty white look)
- higher SPF ratings
- nongreasy, easy application

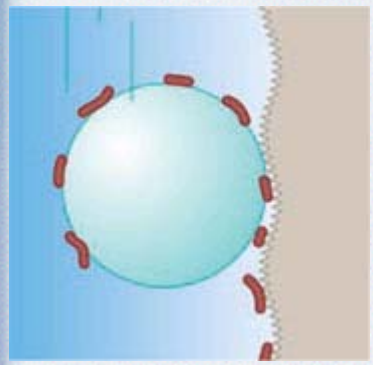
Grandel PR Vitamin Nano-Depot Day

Keys Solar Rx Nano-Zincoxide

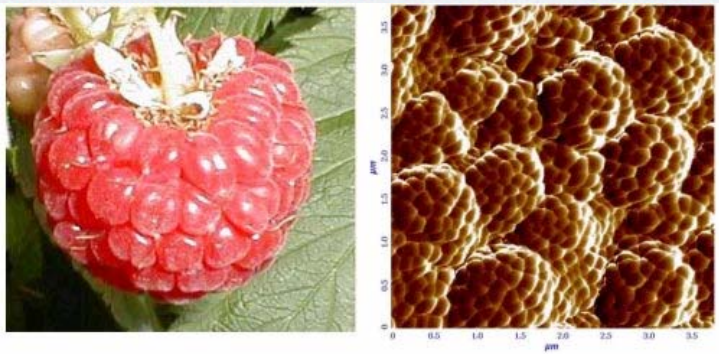
Wet Dreams sunscreen with ZinClear ZnO

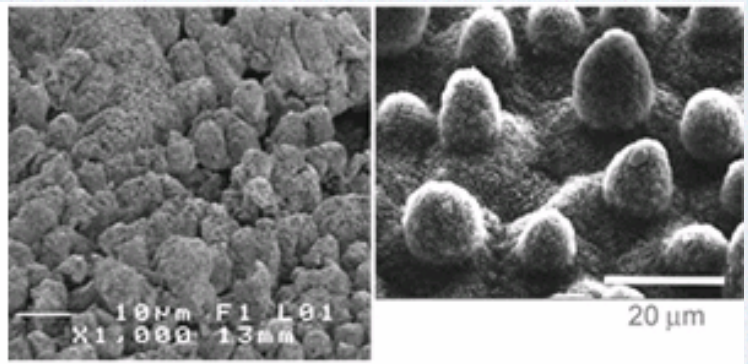


Self-cleaning Surfaces



- water droplets form spherical globules
- rough nanoscale surface picks up dirt
- water and dirt roll off
- biomimicry

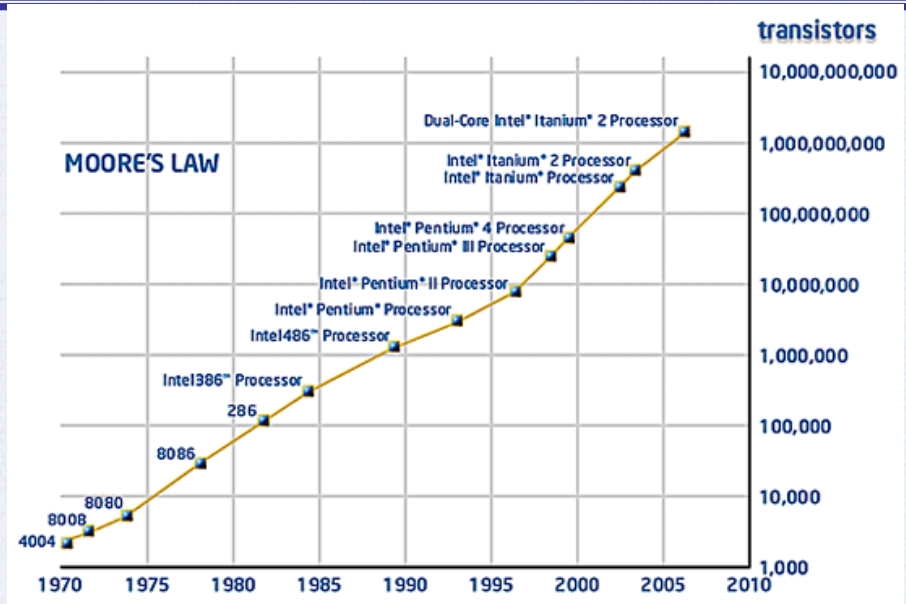




Left: SEM image of surface produced within the project.
Right: SEM image of the surface of a Lotus leaf.
(D. Chakarov, P. Holgerson)

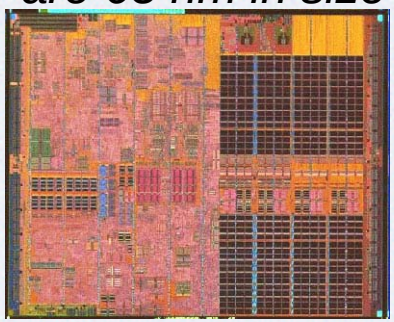
self-cleaning window

Active Nanosystems - Physics

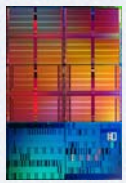


Nanotechnology is already a part of your life, in your computer and cellphone. The latest computer chips from companies like Intel and Texas Instruments have transistors on a scale of 65 nm. 45 nm scale technology is already at the prototype level. What's next to continue Moore's Law? Nanotubes? Single Molecules?

Today's Pentium transistors are 65 nm in size

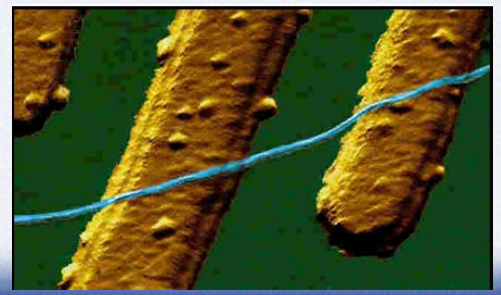


Images courtesy of INTEL



Transistors in:
2007 will be 45 nm
2009 will be 30 nm

Carbon Nanotube Transistors
(Single walled CNTs are 1 nm in diameter)



*Nature **391**, 59 (1998)*

Human resource development

- The NNI predicts that over the next ten years the global nano- technology market will be one trillion dollars in size.
- The world will need about two million nano-literate workers by then. US will need about 1/3 of this.
- Where will they be coming from? Import or US training?
- **How do we do it??**

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

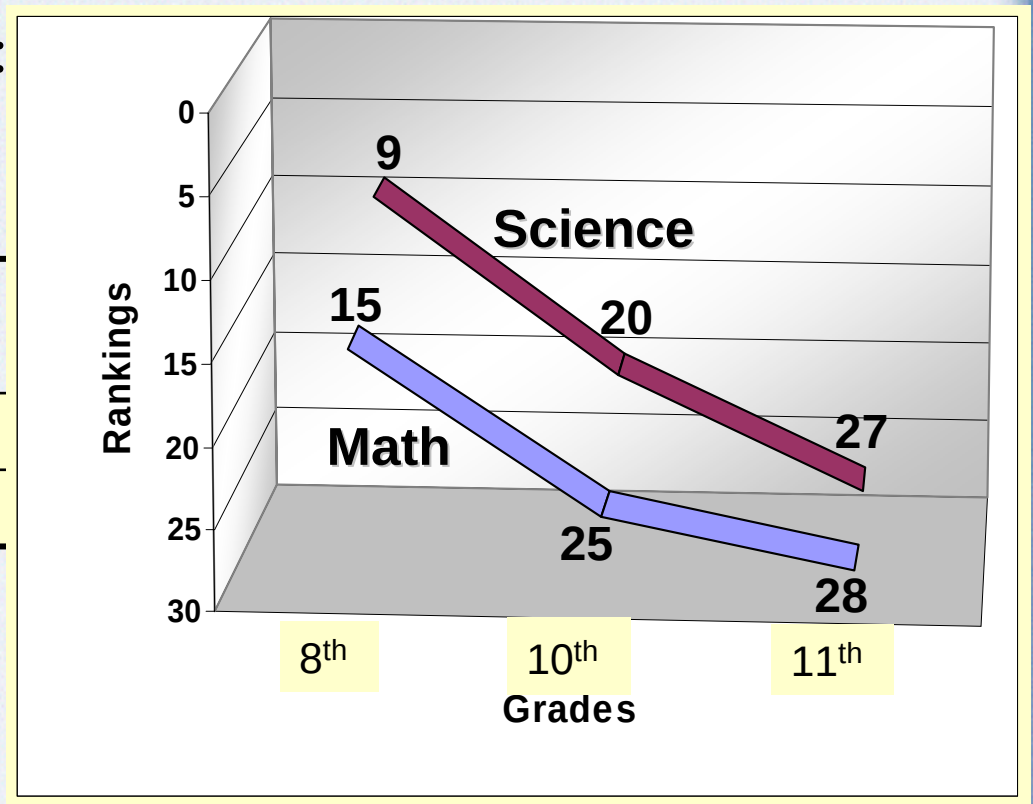
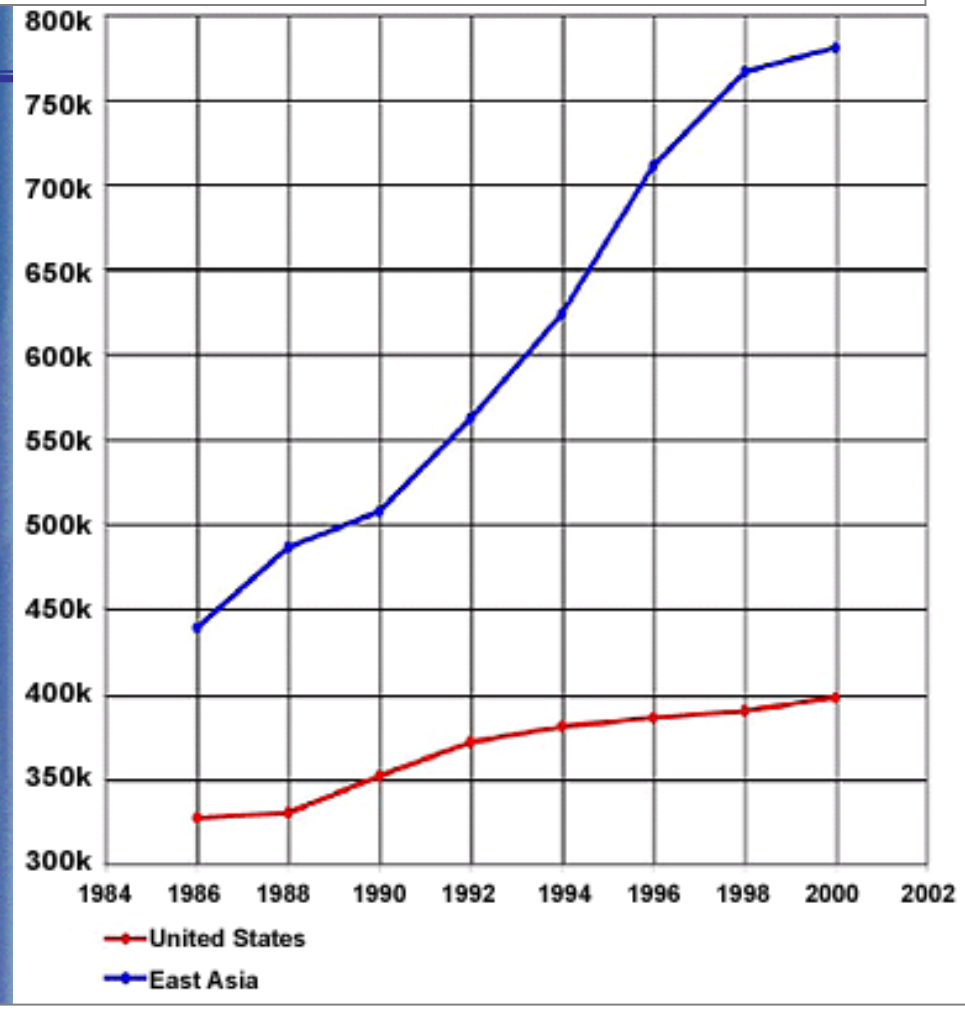
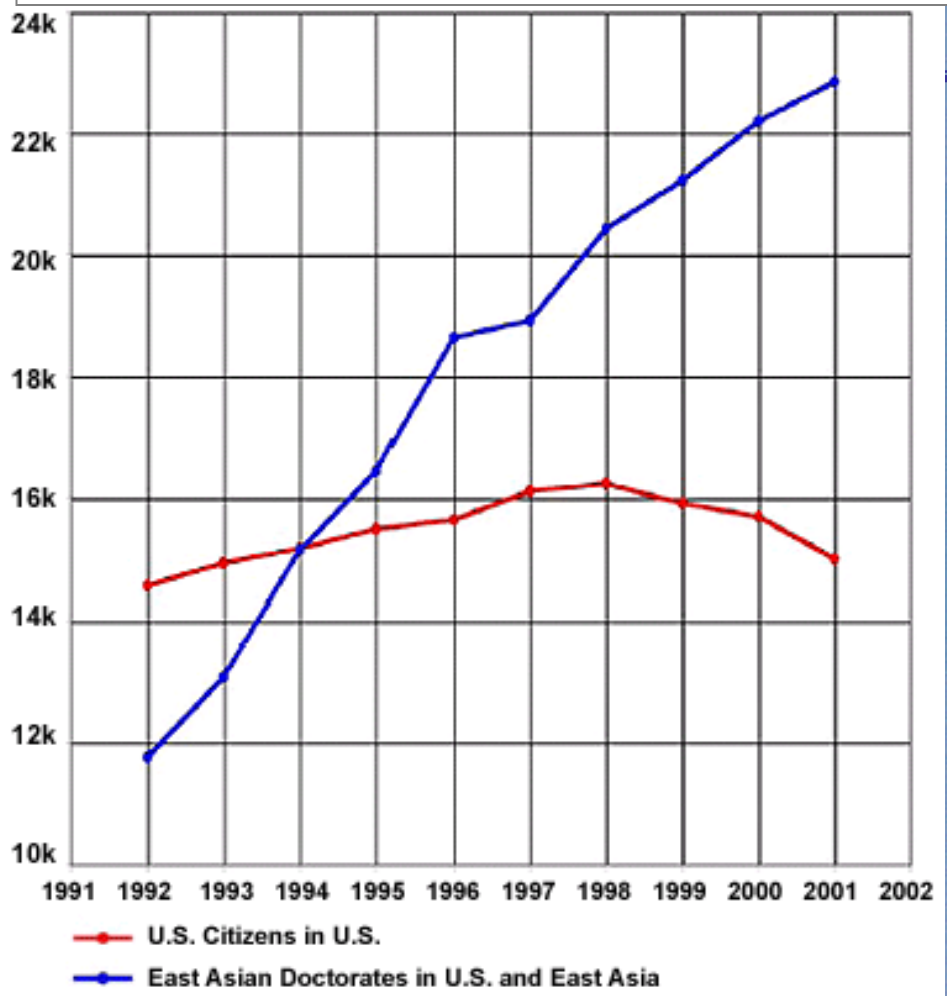


Figure 1: Science and Engineering First University Degrees in the U.S. and East Asia



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]

Time for training

- Student Training
  - Middle School (20 years)
  - High School (15 years)
  - College Degree (10 years)
  - Graduate or Doctoral Degrees (5 years)
- Teacher Training
  - In-service
  - Pre-service

Urgent need in teacher training

- Inadequate pool of qualified math and science teachers
- High attrition rates for qualified teachers
  - 33% (during first 3 yrs)
  - 46% (during first 5 yrs)

- High percentage of out-of-field teachers (uncertified in that subject)
  - For Middle School: 69%
  - For MS Physical Science: 93%
  - For High School: 31%
  - For HS Physical Science: 63%

Barriers to rapid introduction of new science concepts

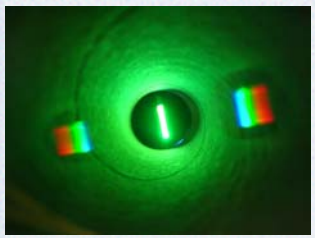
1. Need many more well trained teachers
2. No uniform and standardized curriculum across the country
3. Lack student interest in math and science
4. Slow to revise and up-date course content
5. Lack vertical integration
6. No more space for new courses in the curriculum

NCLT is designed to lower these barriers!

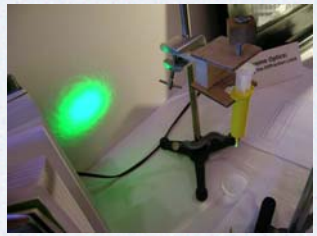
Center Vision & Mission

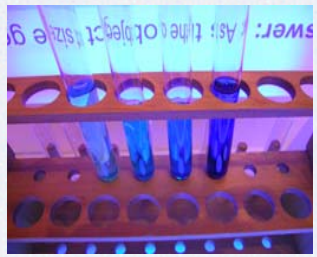
Our vision is to build a ***globally competitive*** Nanoscale Science & Engineering (NSE) ***workforce*** and a well-rounded NSE education leaders.

Our primary mission is to ***build national capacity*** in Nanoscale Science and Engineering Education (NSEE)



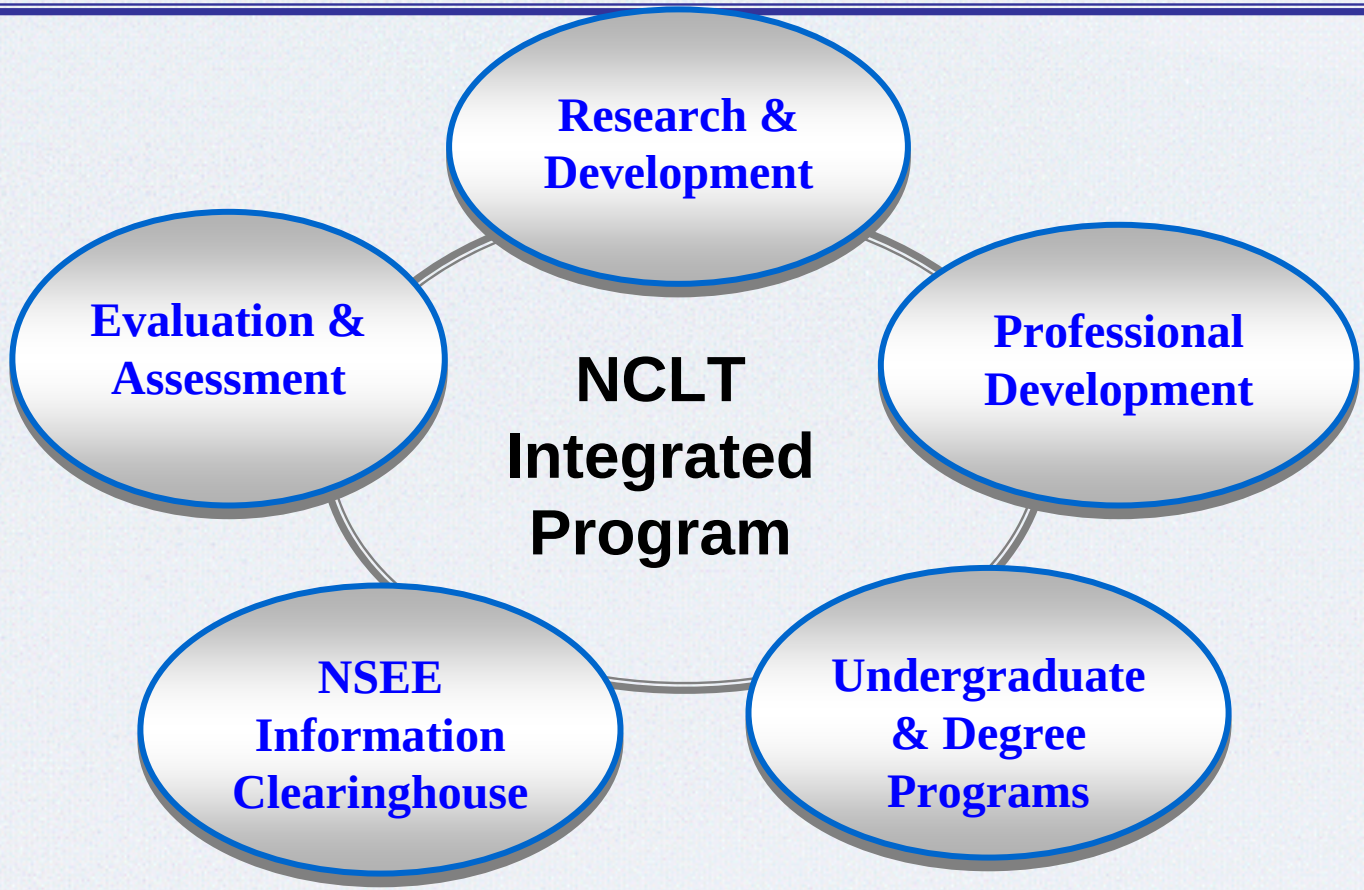
Learning and teaching through inquiry and design of nanoscale materials and systems for applications

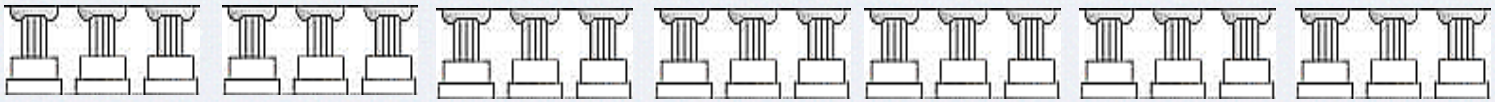




Developing Curricula • **New Learning Standards** • **NSEE Knowledge Base**

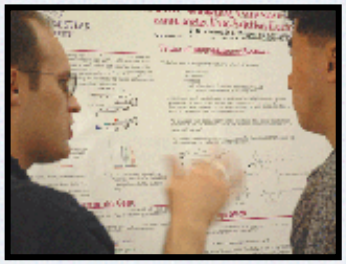
NCLT Center Strategy





Supported by NCLT Cyber Infrastructure

NCLT Community



Education & cognitive science researchers

Nano researchers

Students & Postdocs

Teachers, faculty members & administrators

Government officials

Experts in learning tools, visualization, simulation & modeling

Editors, designers, programmers, etc.

Some "Big" nano concepts, learning goals, and linkage to national standards

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.

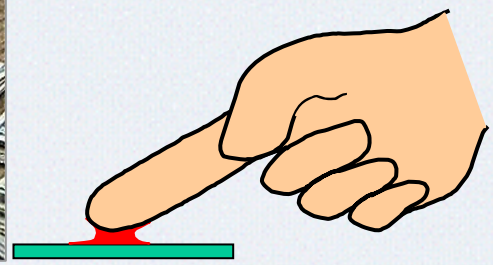
F. Geometry can have an impact on nano materials design and applications.

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, **Science 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, **Science and technology in society**; NSES/9-12/G/1/a, **Science as a human endeavor**. **(F)** 2061/9-12/9C/2, **Shapes.**

Size Scale & Material Properties

Water at macro scale—a lubricant

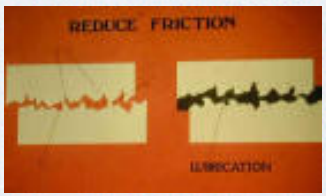
Water at nano-micro scale—an adhesive



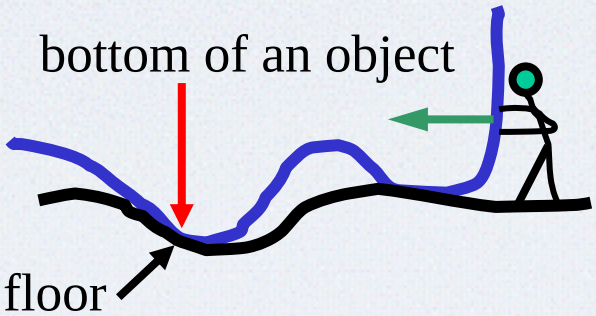
Concept: The size and dimension of objects/materials affect material properties and how we can use them.

Standards: NSES/5-8/B/1/a, Properties and changes of properties in matter; NSES/5-8/B/3/a, Transfer of energy; 2061/6-8/4D/1, The structure of matter; 2061/6-8/4E/4, Energy transformation; 2061/6-8/11D/1, Scale; 2061/6-8/12B/9, Computation and estimation

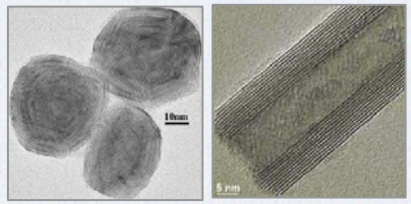
Surface Smoothness & Friction



Close-up view of friction between surfces:



Nanolubricants



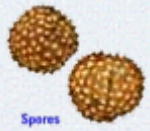
Nanosphere **Nanotube**

Concept: **Surface smoothness reduces friction.**

Standards: **NSES/5-8/B/2/c,** **Motions and forces;** **2061/6-8/4F/3,** **Motion ;** **2061/6-8/11D/1,** **Scale;** **2061/6-8/12B/9,** **Computation and estimation**

Size Scale & Dominant Force

What happens when we drop…?



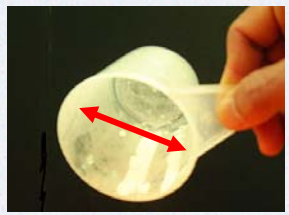
Spores

Flour

• • •

Nano-particles

Van der Waals Forces

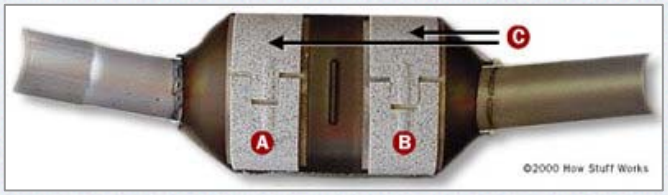


Submicron-sized flour sticks to the sides of the measuring cup

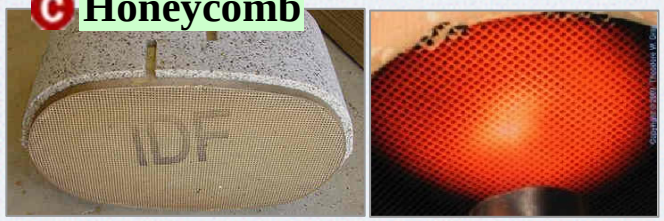
Concept: Electrostatic forces dominate in the nanoworld.

Standards: NSES/5-8/B/2/c, Motions and Forces; 2061/6-8/4E/4, Energy transformation; 2061/6-8/4G/1, Forces of Nature; 2061/6-8/11D/1, Scale; 2061/6-8/12B/9, Computation and estimation

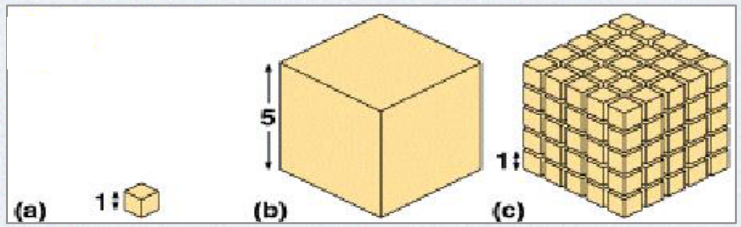
Surface Area & Chemical Reaction



C Honeycomb



Surface area increases while total volume remains constant



Total surface area (height × width × number of sides × number of boxes)	6	150	750
Total volume (height × width × length × number of boxes)	1	125	125
Surface-area-to-volume ratio (area ÷ volume)	6	1.2	6

Concept: Surface area affects the rate of chemical reaction.

Standards: NSES/5-8/B/1/a, Properties and changes of properties in matter; NSES/5-8/B/3/e, Transfer of energy; 2061/6-8/4D/1, The structure of matter; 2061/6-8/4E/4, Energy transformation; 2061/6-8/11D/1, Scale; 2061/6-8/12B/9, Computation and estimation

Unique Properties at the Nanoscale

Nano-properties enable new nanotechonology:

• A twist of a molecule can change its electrical conductivity from a metal to a semiconductor.

•A nano-material may melt at lower temperature, or become harder.

•The same material may change color, magnetic properties, or react faster

Factors influencing nanoscale properties:

•Quantum Mechanics,

•Random Fluctuations (Brownian Motion),

•Electromagnetic Forces,

•The dramatic increase of the surface area to the volume ratio

Questions about Nanomaterials, Related Nanoconcepts Research & Linkages to Curricula

	What makes them unique?	How can they be used?	How can they be made and characterized?
Nano Concepts introduced / Linkage to Science Curricula	**Manipulation of Light in the Nanoworld** •Work circle and research activities carried out Year 1	**Information Storage and Processing** • Research Activities start Year 2	**Tools for Probing the Nanoworld** • Scanning Probe work circle and research activities carried out Yr. 1
Nano Concepts introduced / Linkage to Science Curricula	**Mechanical Properties of Nanomaterials** • Research Activities start Year 2	**Nanomaterials for Energy, Environment, and Pharmaceuticals** •Work circle and research activities carried out Year 1	**Design and Fabrication of Nanomaterials** • Self-assembly/ Nanopatterning work circle launched Year 2

Learning Research in NSEE

Education Research into the best practices to understand nanoscience at grades 7-12

Two Research Projects:

- "An Investigation of Secondary Student' Interests and Understanding of Nanoscience"

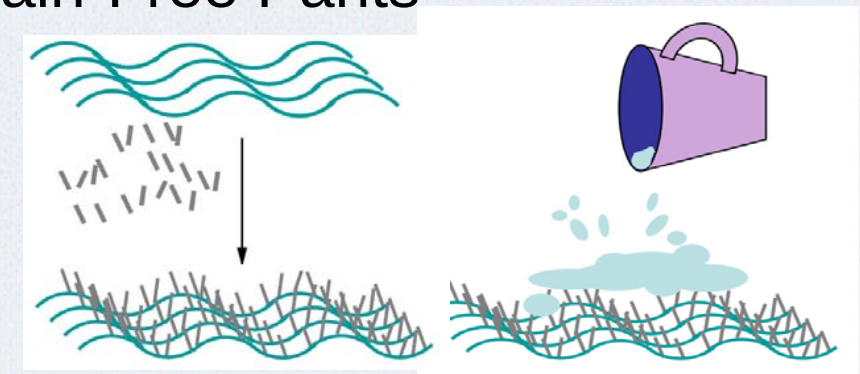
- "Size and Scale: An investigation of Student Conceptions of Size"
  - developing literature reviews, classroom nanoscience activities and outreach programs
  - collected 415 student surveys & 58 individual student interviews

Experiments/Activities

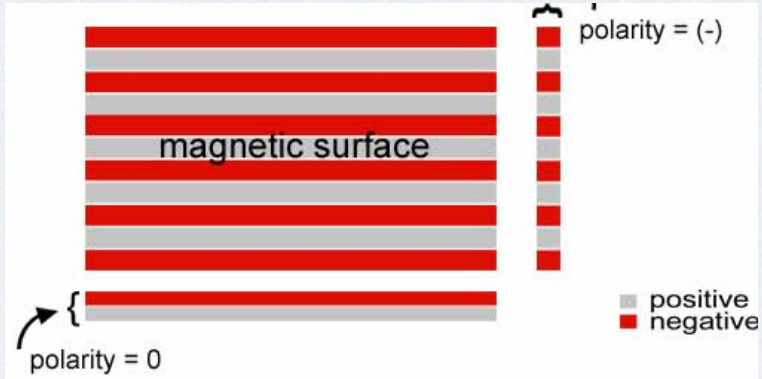
Introduce nanoscience phenomena to students in the classroom allowing students to interact with the materials.

Presented by: Kelly Hutchinson, Purdue University

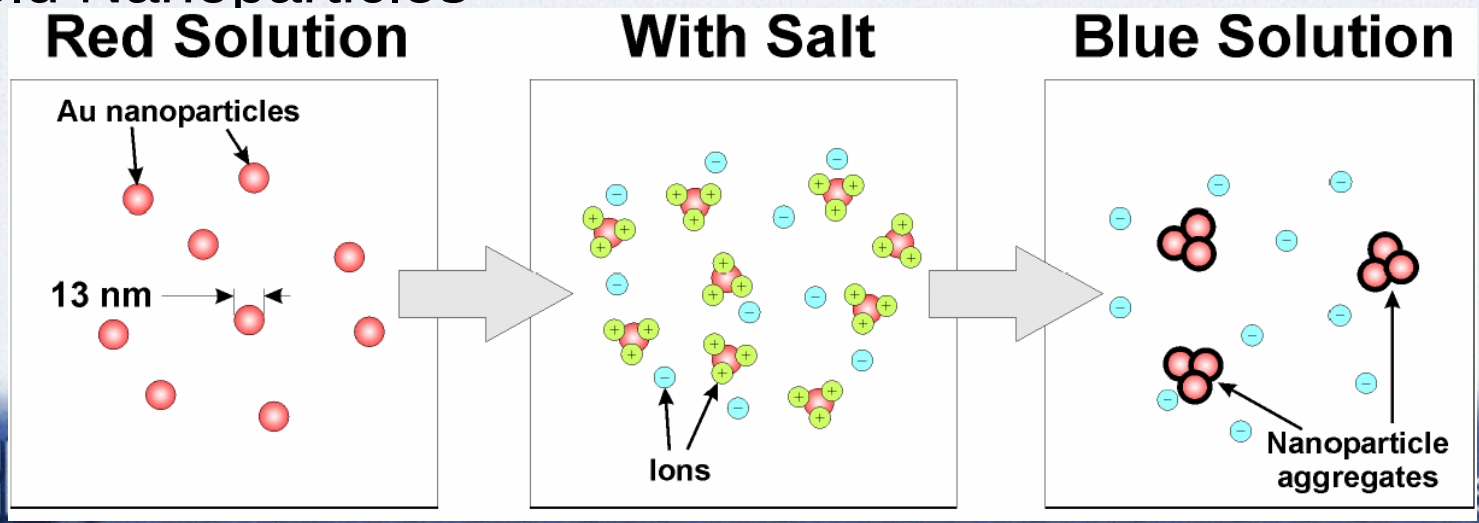
- Stain-Free Pants



- Hopping Magnet



- Gold Nanoparticles



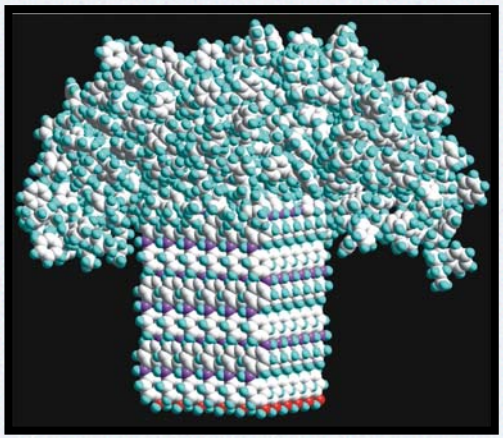
Learning Research: Self-Assembly

Current Activities focus on:

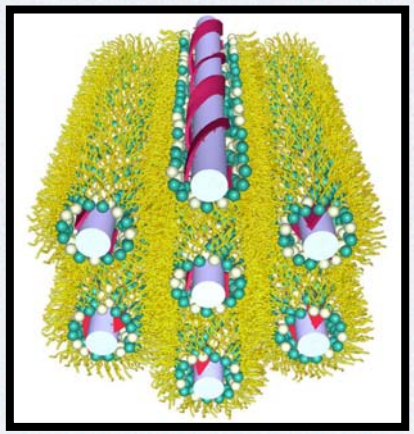
- the folding of DNA strands into specific geometric patterns and
- the capture and alignment of nanotubes in fluid through the application of electric field gradients (dielectrophoresis)

Bottom-Up: Molecular Self-Assembly

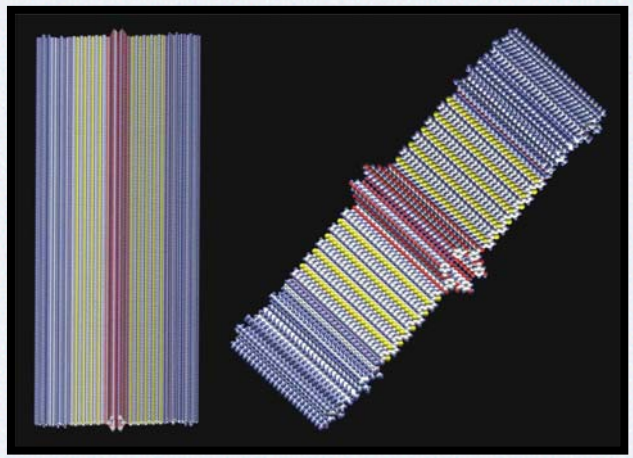
- Spontaneous organization of molecules into stable, structurally well-defined aggregates (nanometer length scale).
- Molecules can be transported to surfaces through liquids to form self-assembled monolayers (SAMs).



Supramolecular rodcoil "mushrooms"

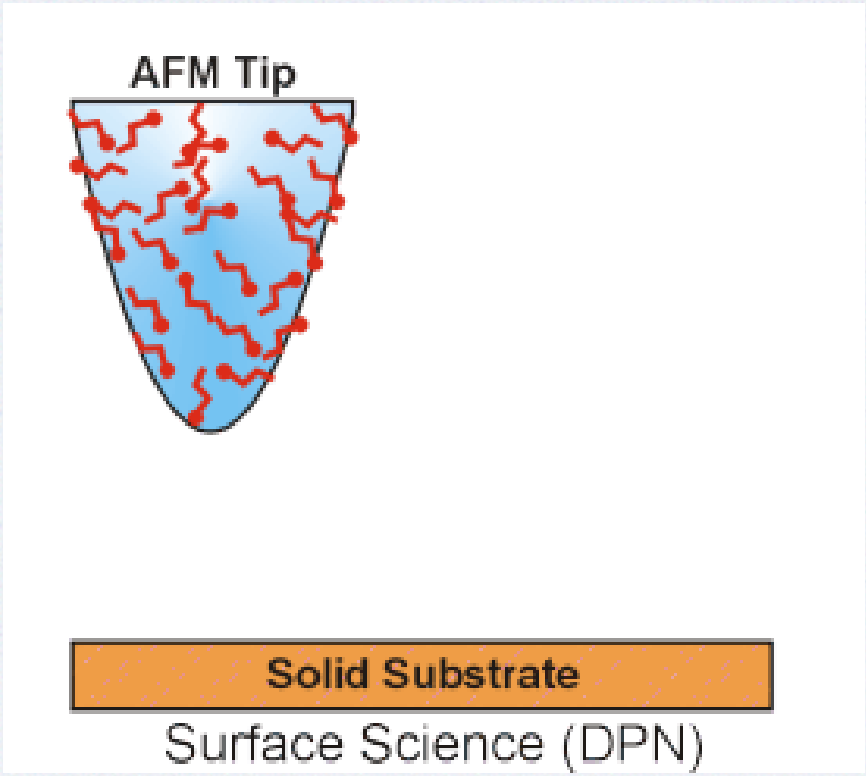


Polythiophene wires



Supramolecular rodcoil nanoribbons

Dip Pen Nanolithography



Learning Research & Evaluation

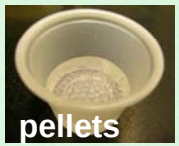
Nanoconcept Inventories- developing three to pilot:

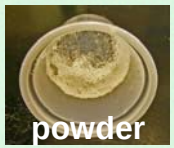
- 8-item inventory assessing understanding of size and scale
- 27-item inventory assessing conceptual understanding of size and scale, surface area to volume ratio and the mathematical skills required to understand these concepts
- 20-item inventory that tests knowledge and conceptual understanding in a variety of areas (i.e. size/scale, surface area to volume ratio, color, data storage, electricity, etc.)

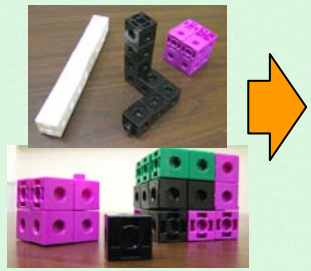
Nano concept research: Nanomaterials

Investigating: Changes in Surface area to Volume Ratio

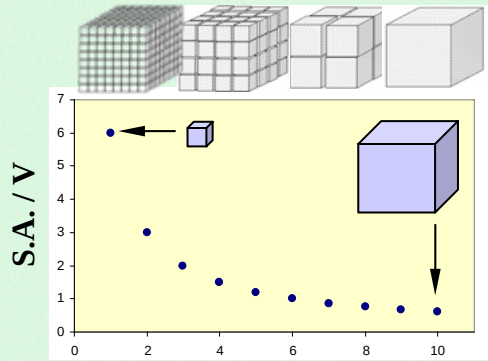
Which form of polymer absorbs water faster?





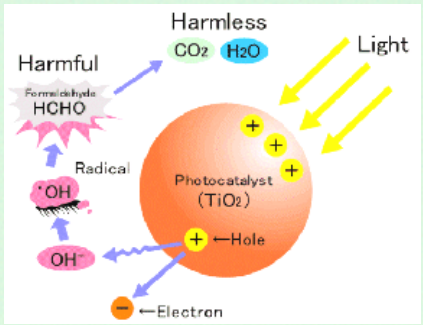


Modeling with snap cubes

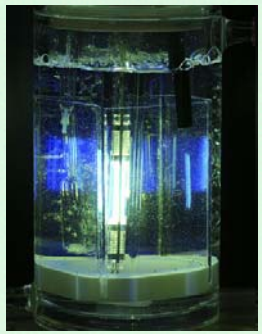


Length

Application: Using TiO_2 nano particles to Regenerate Clean H_2O



TiO_2 photocatalyst



Industrial waste water

International space station

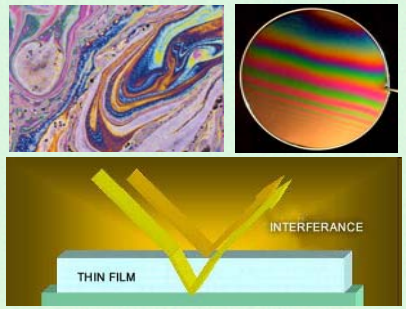
TiO_2 -based, water treatment system

Manipulation of Light in the Nanoworld

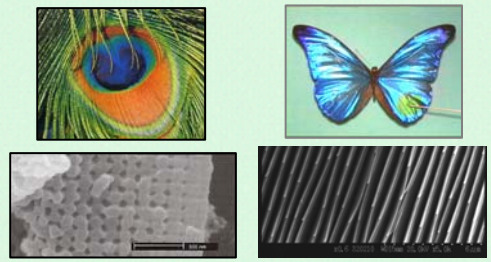
Investigating: Light and Its Interaction with Nano Structures

Homemade CD-ROM spectroscope

Diffraction



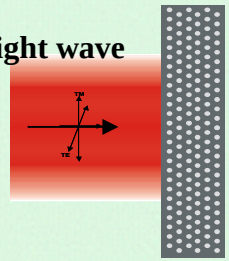
Interference



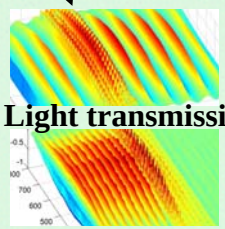
Reflection due to structure

Application: Creating Opal-like, Photonic Structures

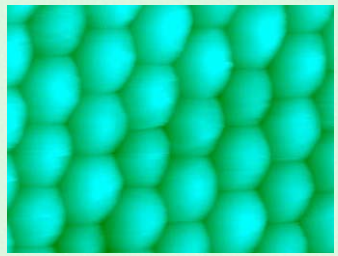
Light wave



Simulated opal structure

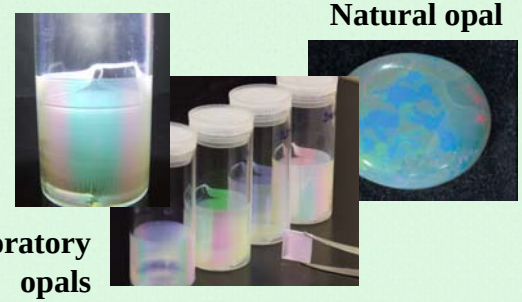


Predict structure via simulation



Self-assembly of polystyrene nanoparticles

Natural opal



Laboratory opals

Artificial opal by design

Macroscopic Models of Nano SPM Instruments

Nathan Unterman*, Emma Tevaarwerk+, Marcel Gridnic*, Venkat Chandrasekhar+

*Glenbrook North High School, +Northwestern University

Key Nano-Concepts:

- **Nanostructured materials can be measured with a nanosized tip.**
- **Dominant Forces in the nanoworld are different from those in the macroworld.**

National Science Education Standards (9-12)

- A: Science as Inquiry (models)
- B: Physical Science (structure of matter)
- E: Science & Technology

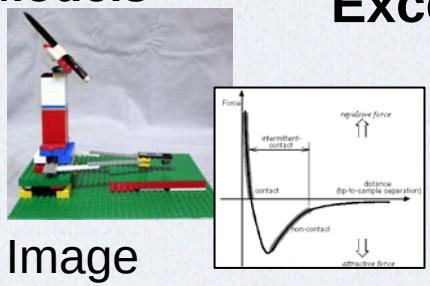
Benchmarks for Science Literacy (9-12)

- 4D, Physical Setting,
  "all matter is made up of atoms"

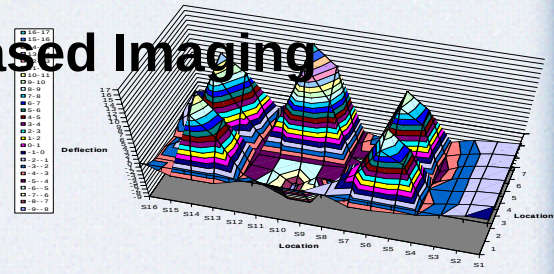
Activity Progression

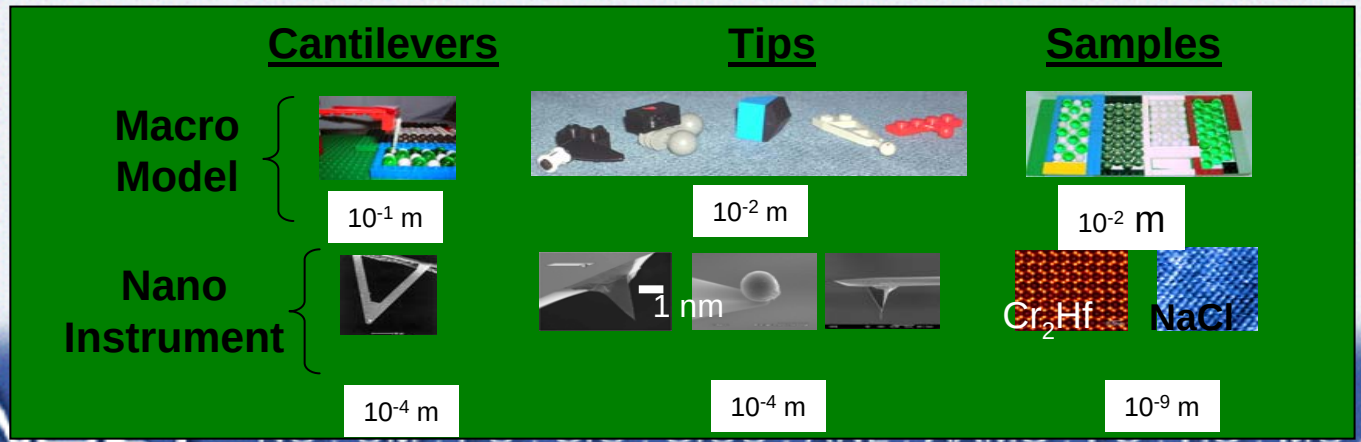
- Build Model AFM
- Build Sample
- Collect & Graph Data in Excel
- Analyze Data & Discussion
- Observe & Analyze Real C-AFM Image

LEGO Models



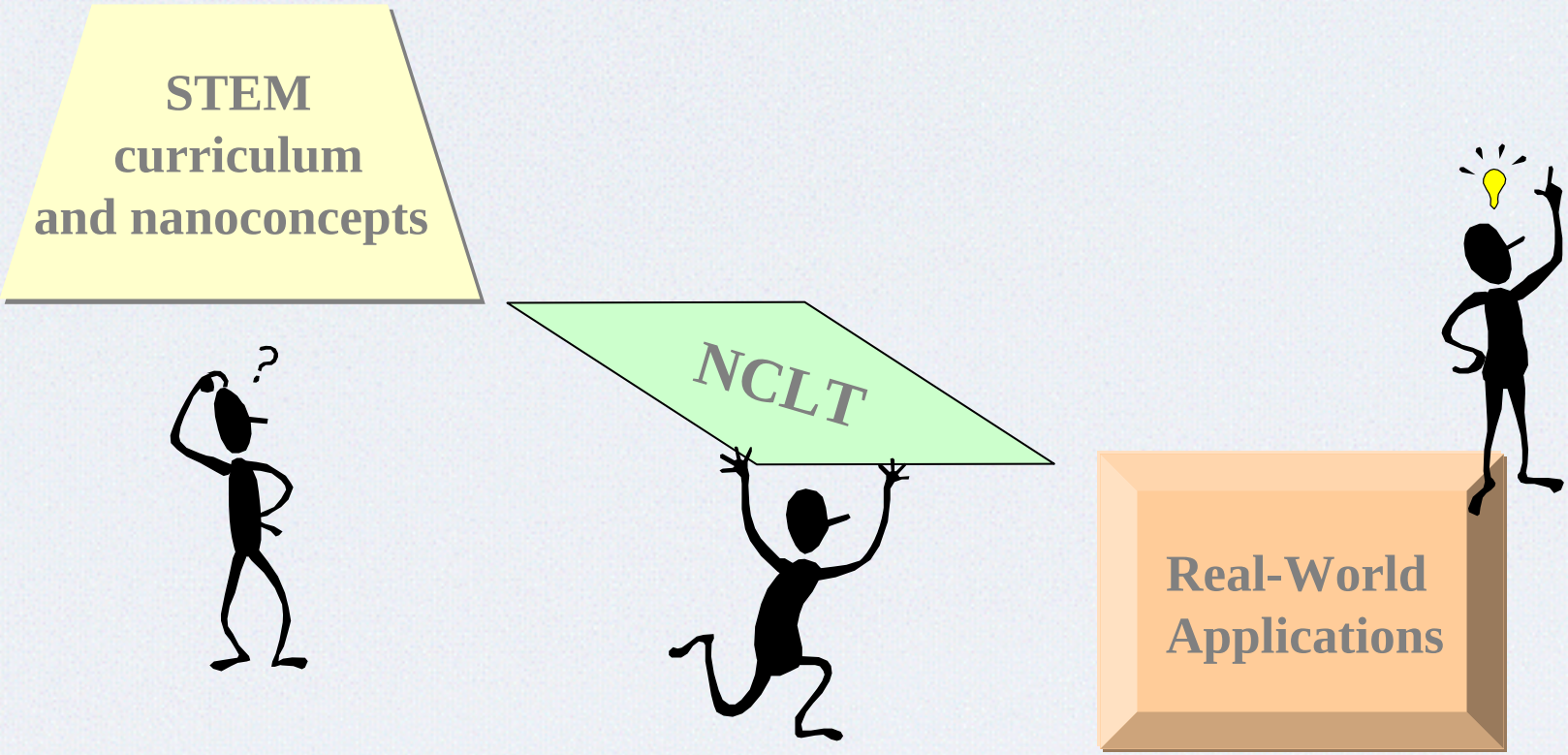
Excel-based Imaging



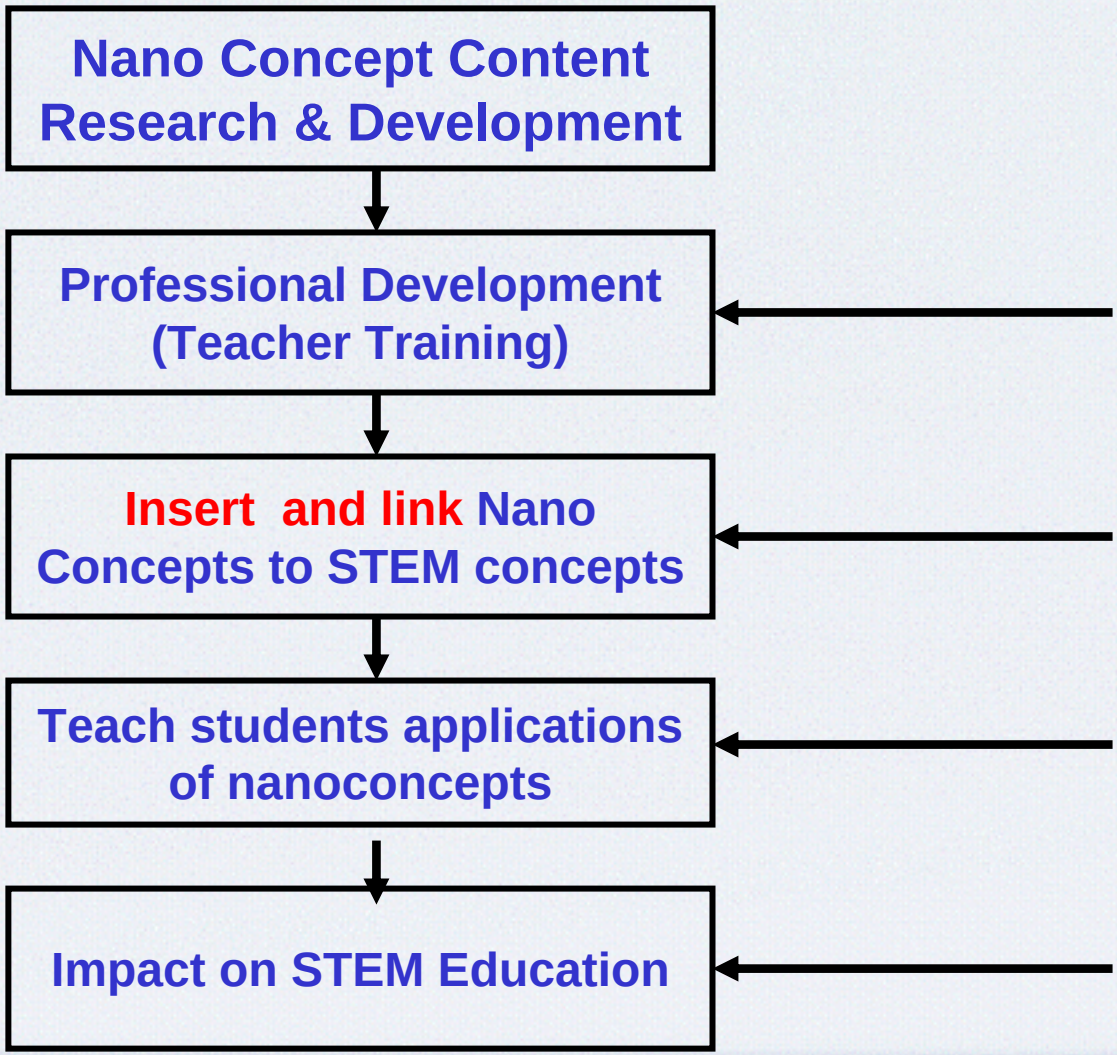


Nano-Day at Northwestern

Connections to the Real World promotes students' interest in science



Pre-College Integration of NSE Concepts



Professional Development

Goal:

Recruit, train and develop multiple cohorts of HS teachers who will lead nanoscience curriculum adoption in their schools and promote the inclusion of NSE at professional, regional and national meetings

Current Efforts:

- 2006 PD workshops (2-weeks) at Purdue & UTEP (23 teachers)
- Nanoscience Workshops (1-or 2-weeks) at Fisk University & Argonne (30 teacherss)
- Joint sponsorship of the RET teachers with the Northwestern MRSEC (10 teachers) plus weekly NSE seminars culminating with a curriculum development project for credit
- 2007 Future expansion: Alabama A&M University and Hampton University

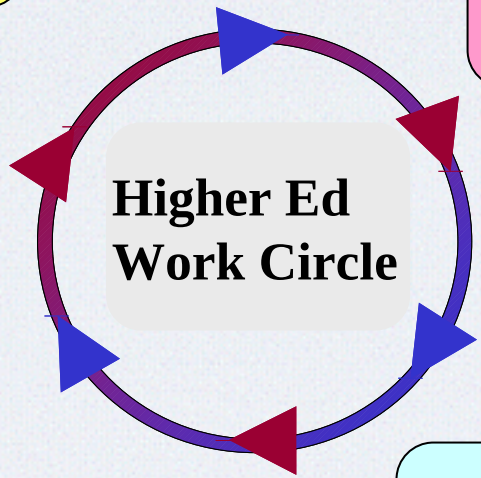
Higher Education Initiatives

- Nanomaterials Unit – research on effectiveness of NSE curriculum in non-major course
- Faculty workshop (10 colleges/universities represented)
  - Provided plans for incorporation into curriculum
  - Partnerships forming for Degree programs & Certification
- Development of courses on NCLT Cyberinfrastructure

Higher Education Initiatives

Degree Programs

Learning & Teaching Research & Evaluation

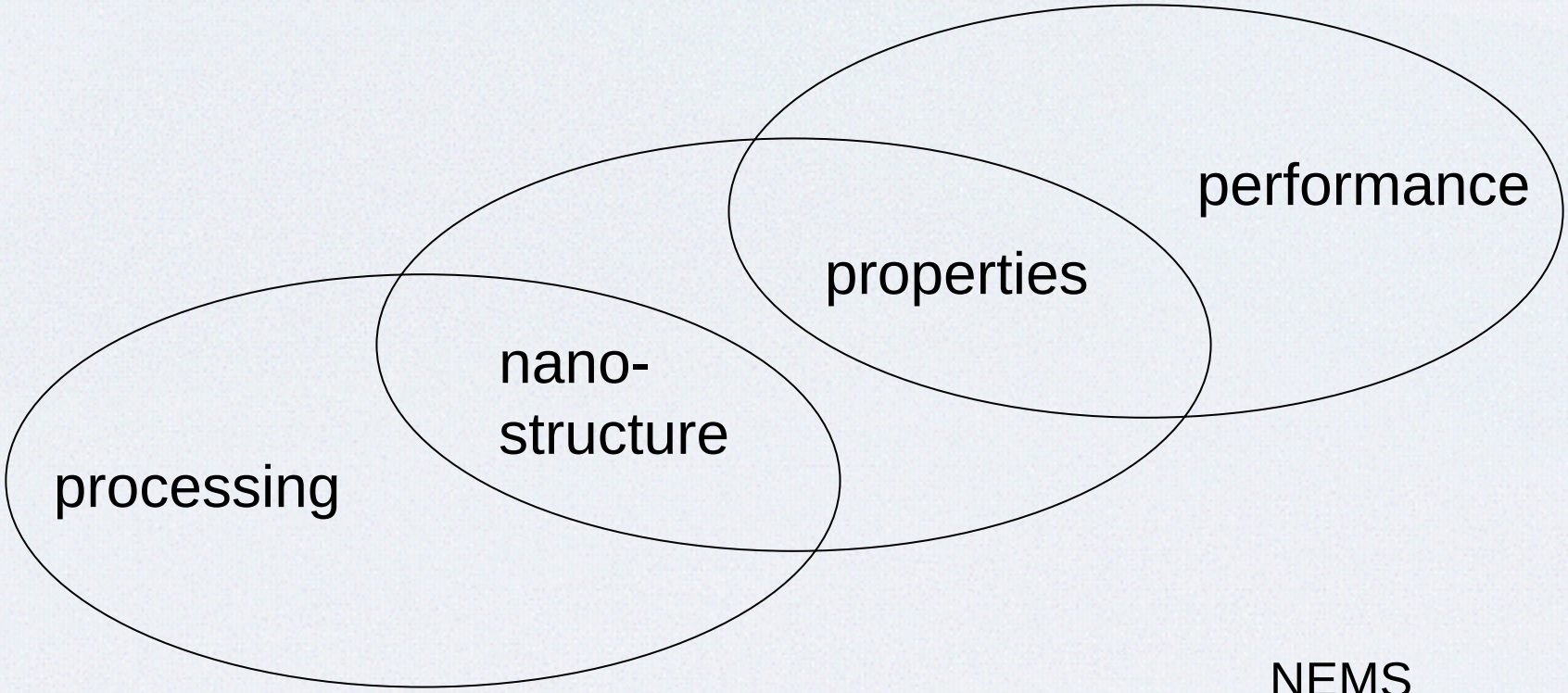


Instructional Resources

Big Ideas/ Nanoconcept Inventories

Faculty Enhancement

Degree Program Recommendations:



Self-assembly
Nanofabrication

Scanning probes
Spectroscopy

Size-dependent
properties
Quantum effects

NEMS
Nanoelectronics
Nanophotonics,
etc.

NanoEd Resource Portal

A repository for the collection and dissemination of information for the NSEE community

- Nano Courses
- Nanoconcepts and Applications
- Nano Learning Research
- Global Research Gallery
- Degree Programs
- Seminars
- Nano Resources
- News
- Events
- Glossary & Categories
- How to Participate

Degree Programs

The NanoEd Resource Portal will post existing and emerging degree programs in Nanoscale Science and Engineering (NSE) and Nanoscale Science and Engineering (NSEE) education. The program listings will accumulate over time, including 2-year Associate Degrees in NSE(E), Bachelor Degrees with a concentration or minor in NSE(E), 4-year Bachelor Degrees in NSE(E), Master Degrees in NSE(E), PhD programs in NSE(E), and certificate programs at all levels. Please notify us if you are interested in posting your degree program.

Send Your Comments / Feedback

Contribute to NanoEd

PROGRAM:	**2-year A.A.S. Degree in Nanoscience Technology**
STATUS:	Active
INSTITUTION:	Dakota County Technical College, MN
DESCRIPTION:	This major prepares students for employment in nanobiotechology, nanomaterials and nanoelectronics careers. The program is offered through a partnership with the University of Minnesota. The program offers an A.A.S. 72 credit degree of which 39 credits are nano-specific courses. Students learn equipment usage in hands-on labs as well as concepts and applications of working at the molecular and atomic scale. Transferable General Education courses round out the curriculum. **Sampling of Courses:** • Fundamentals of Nanoscience • Computer Simulation • Nanobiotech/Agriculture • Nanomaterials • Nanoelectronics • Introduction to Materials Characterization • Elements of Micro- & Nanoelectronics Manufacturing
STUDENT QUALIFICATIONS:	High-school graduates or above. Computerized Placement Test (CPT) and a score above the minimum standards in math and reading are required for acceptance into several first semester courses.
CONTACT:	**Coordinator:** Deb Newberry **Phone:** 1-651-423-8328 **E-mail:** deb.newberry@dctc.edu **Program Website:** http://www.dctc.edu/prospStudents/programs/nanoTech.cfm

DAKOTA COUNTY TECHNICAL COLLEGE

2006 NCLT Faculty NSEE Workshop

- August 6-9, 2006, Cal Poly San Luis Obispo
- 32 faculty participants from 17 colleges/universities
  - 8 from community colleges
  - 24 from 4-year institutions
- Emphasis on partnering with the NCLT for learning & teaching research in nanoscale science & engineering

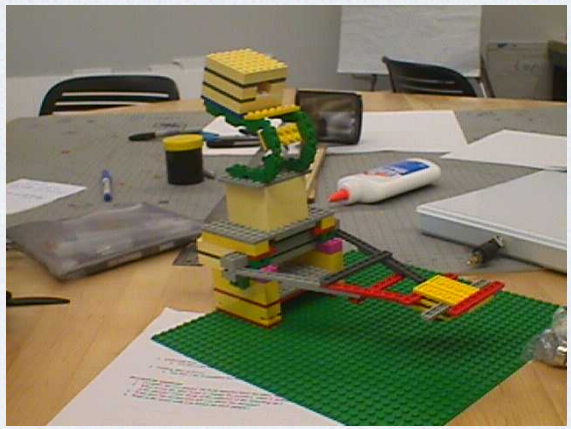
Participants:

Scanning Probe for Middle School

Challenge: Make "sample" invisible

Edible AFM

Magnetic Message

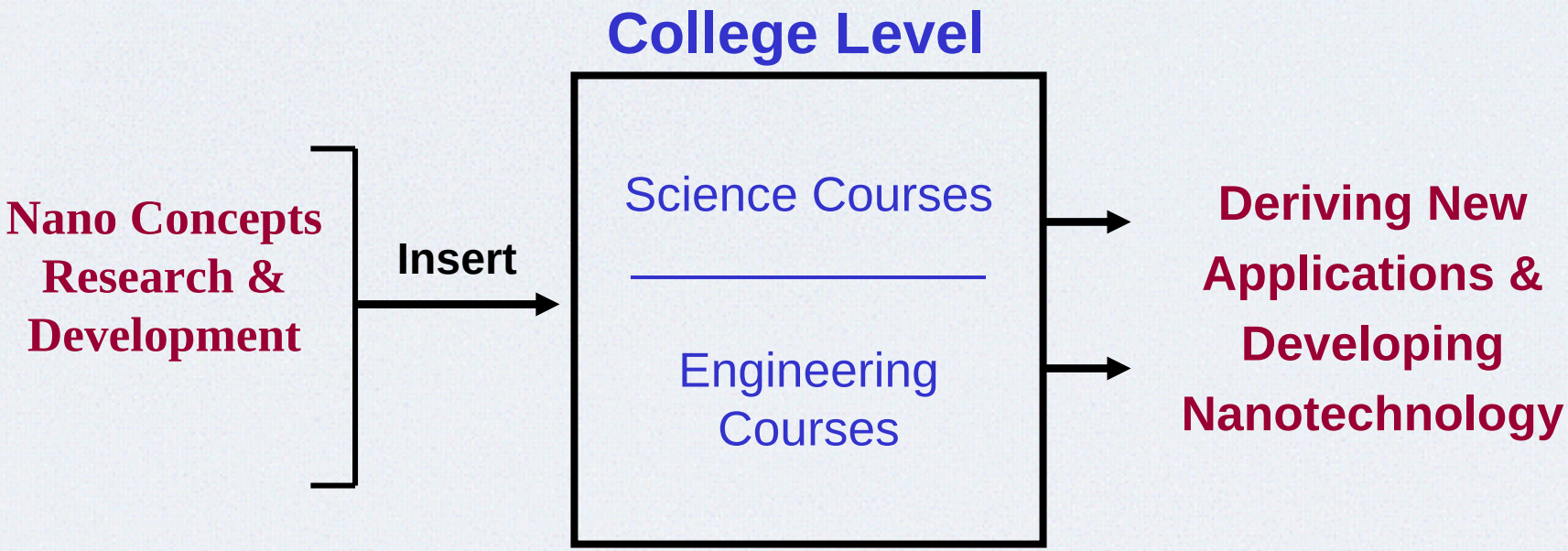


Touching Atoms

Nanoscale Engineering Design & Communication

Freshmen Engineering Students + **Middle School Teachers** + **Challenge**

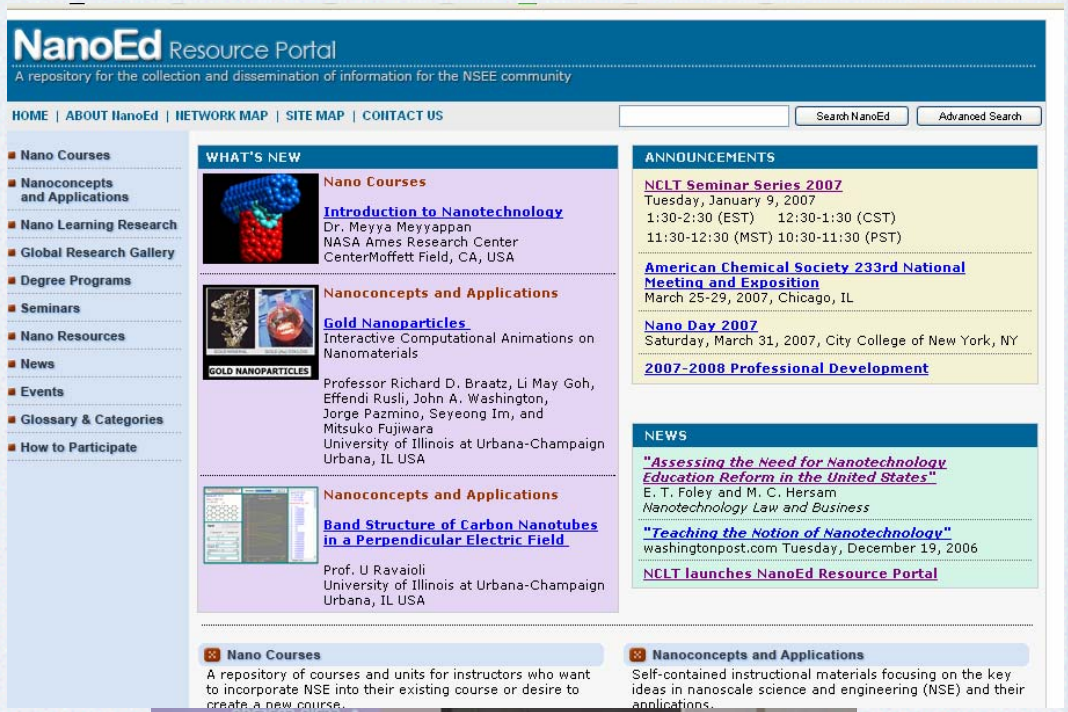
College Level Insertion of NSE Concepts



Developing A Global NSEE Network

Through…

- NanoEd Resource Portal
- Faculty Workshops
- Professional Development
- Nanoscience Days & Joint Ventures
- Big Nano Ideas Workshop



Networking w/ Institutions across the U.S. and around the globe

- Morehouse College
- Network for Computational Nanotechnology
- Northwestern University
- NSF Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (NSEC at UIUC)
- Purdue University
- University of Illinois/Chicago
- University of Illinois/Urbana Champaign
- University of Michigan
- University of Texas at El Paso
- The Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (NSEC @ UIUC)
- Cornell University
- Massachusetts Institute of Technology (MIT)
- Alabama A&M University
- Fisk University
- Hampton University
- Nanoscale Informal Science Education Network (NISE)
- NASA/Ames Research Ctr
- Rensselaer Polytechnic Institute
- SRI International
- Carleton College
- Dakota County Technical College
- Ferris State University
- Florida Atlantic University
- Vanderbilt University
- National Center for Design of Biomimetic Nanoconductors
- North Seattle Community College
- Puerto Rico EPSCoR
- Georgia TECH (NNIN)
- Johns Hopkins University
- Stanford Research Institute (NIMD)
- Foothill College
- Lansing Community College
- Michigan Tech
- San Jose State University
- University of California Los Angeles
- University of Central Florida
- University of Texas at Arlington
- University of Wisconsin/Milwaukee
- Ventura Community College
- Winona State University
- Argonne National Laboratory
- Asia Nano Forum (ANF)
- Cal Poly/San Luis Obispo
- College of Lake County
- European Materials Research Society (E-MRS)
- University of Washington
- Mid-Continent Research for Learning and Education (McReal-NIMD)

Faculty Workshop

Community of Learners

Summer Science Institute

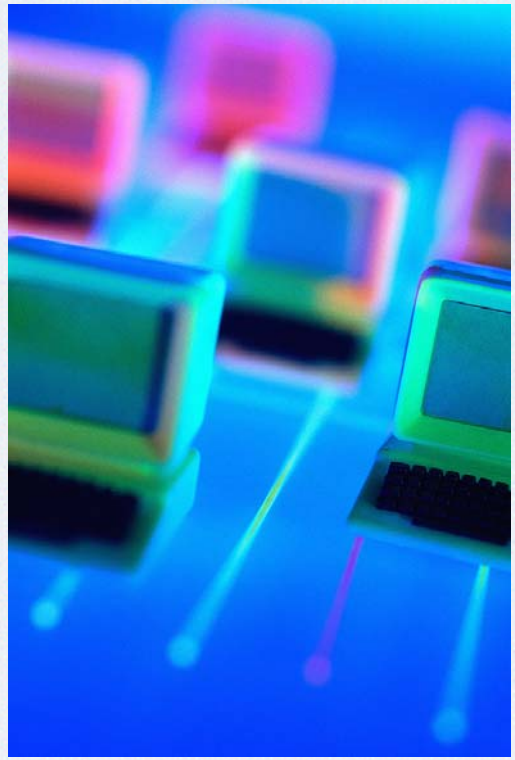
Nanoscience Days

Professional Development

NanoEd Resource Portal

- Networking with the NSEE community - people and institutions - in a centralized web environment

- Maintaining a repository of nanoscale science and engineering education (NSEE) resources for collaborations and dissemination

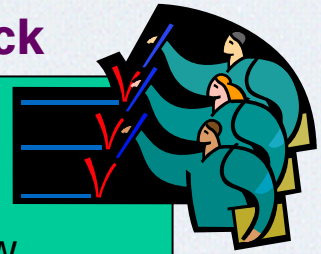


Proposed Strategy: Contributions & Usage

Contributions from…

- College students
- Faculty
- Teachers
- Students (7-12)
- Community Colleges
- Industry
- Govt. Agencies

Quality Check



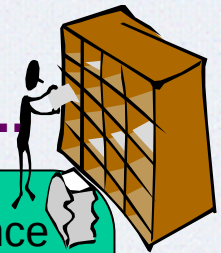
- peer review
- advisors
- NCLT review
- comments & ratings
- user feedback

Uploading & Downloading…

- Courses & Units
- NanoConcepts
- Learning Research
- Simulations
- Seminars
- Instructional Materials

…and more!

Categorization by…



- Level or audience
- Author
- Subject area
- Keywords
- NSE topic area
- Resource

and Usage…

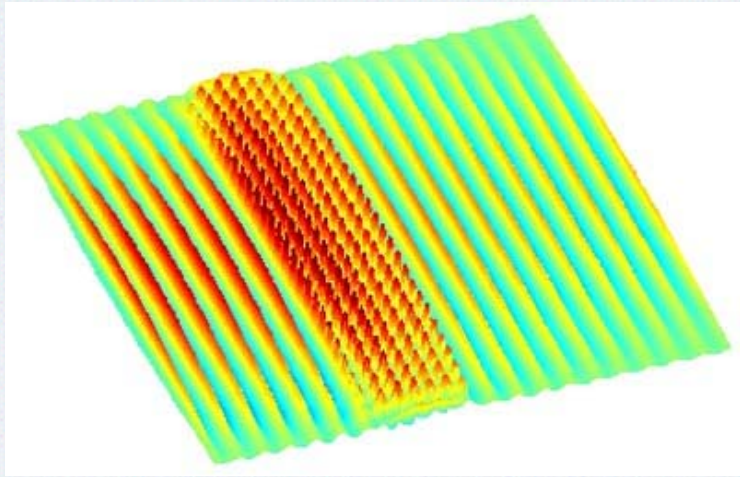
Content Search…

- by Categorization
- Ultra Search powered by Oracle Database
- Quick Links

NSEE Simulations

Simulations bring cutting-edge research to the classroom

Nanoconcept simulations are being developed for middle and high school, college and graduate school levels. Suggestions for how to integrate these simulations with existing courses are included.



Photonic Bandgap Crystal Simulation

- Here showing incident light at 560 nm being blocked by the crystal.
- Created by Boyang Liu & Prof. Ho, Northwestern University

NSEE Courses

Complete NSE courses taught by university professors.

Courses include:

- videos of the lectures
- lecture notes
- assignments
- syllabi

Such lectures are to be integrated into other courses or used directly at other universities and colleges. They are also open to the public as a clear source of information about nanoscience and nanotechnology.

Prof. Hersam teaches a nanomaterials course encouraging student involvement.

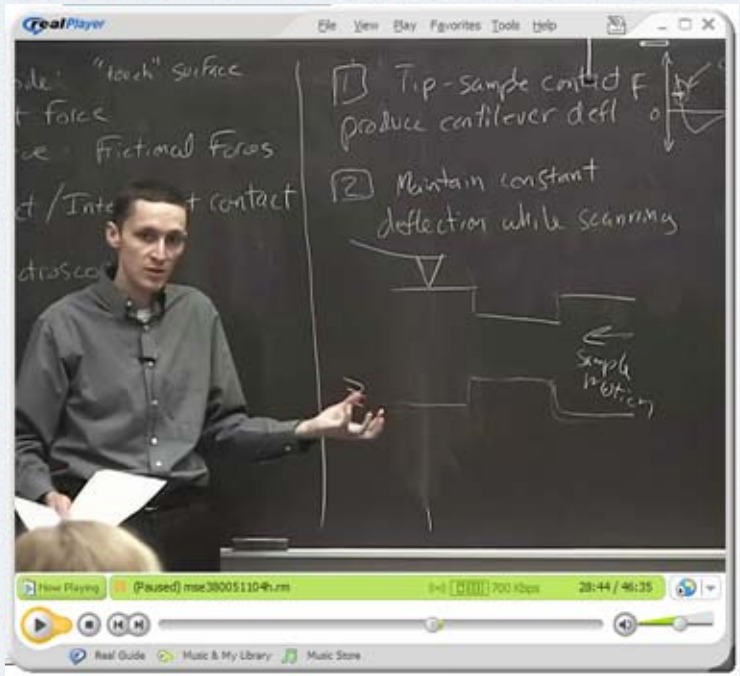
NSEE Nano Units

Focused, smaller lecture series on one particular topic in NSEE.

Nano units include:

- videos of the lectures
- lecture notes
- and other explanations

Being focused, Nano Units are good discussions of nanoscience and technology and may for example serve graduate students who are looking to learn principles and techniques of advanced scanning probe microscopy.



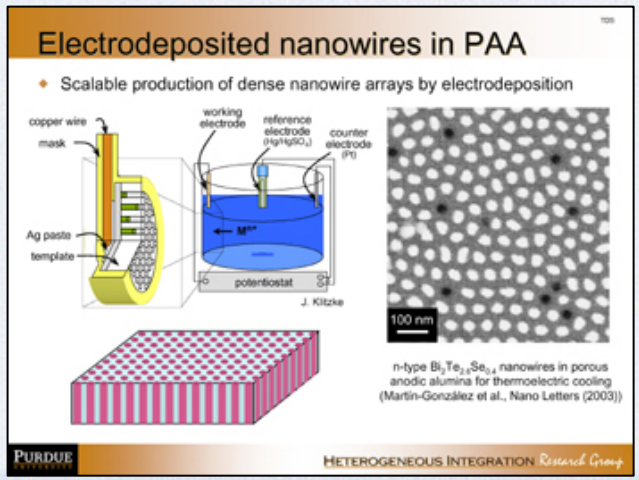
Prof. Lauhon teaches a unit on principles of Atomic Force Microscopy.

NSEE Seminar

Seminar videos from experts from around the globe focusing on both the laboratory results and educational methods of nanoscale science and engineering

Recent results, and innovative teaching methods are presented as real-time web broadcasts, allowing a question and answer format for the audience. Videos are then permanently displayed along with powerpoint slides.

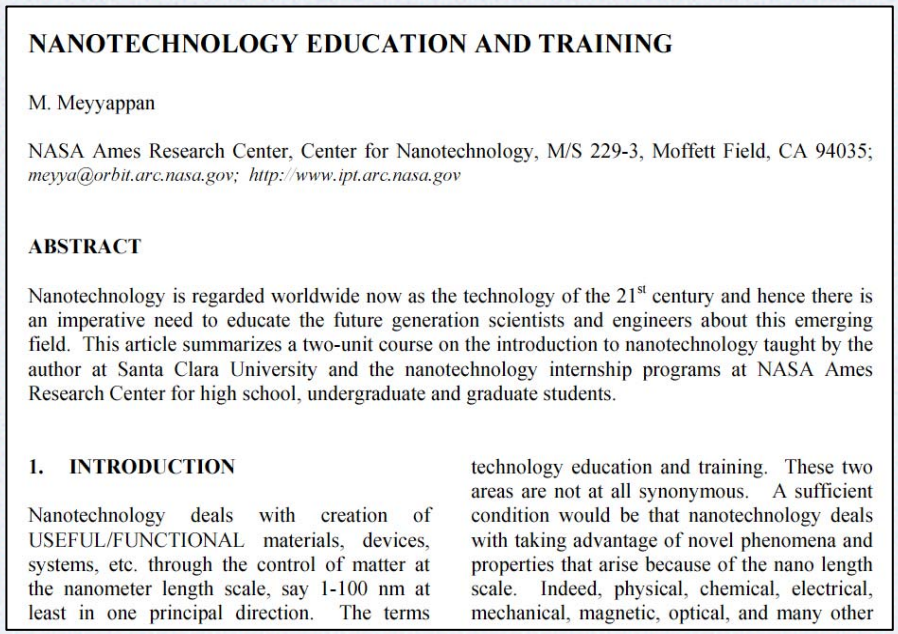
Dr. Sands discusses nanowires and their impact on thermopower technology.



Other Resources

Educational implementation strategies and pedagogies for effectively teaching nanoscale science and engineering concepts.

Interactive educational games for middle school or non-scientists stressing important concepts such as size and scale and properties of nanostructured materials.



NANOTECHNOLOGY EDUCATION AND TRAINING

M. Meyyappan

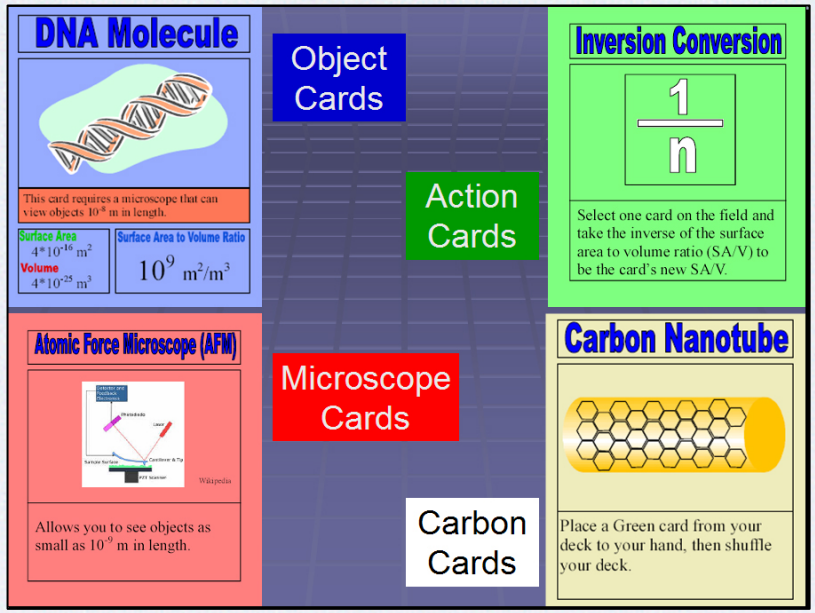
NASA Ames Research Center, Center for Nanotechnology, M/S 229-3, Moffett Field, CA 94035; *meyya@orbit.arc.nasa.gov; http://www.ipt.arc.nasa.gov*

ABSTRACT

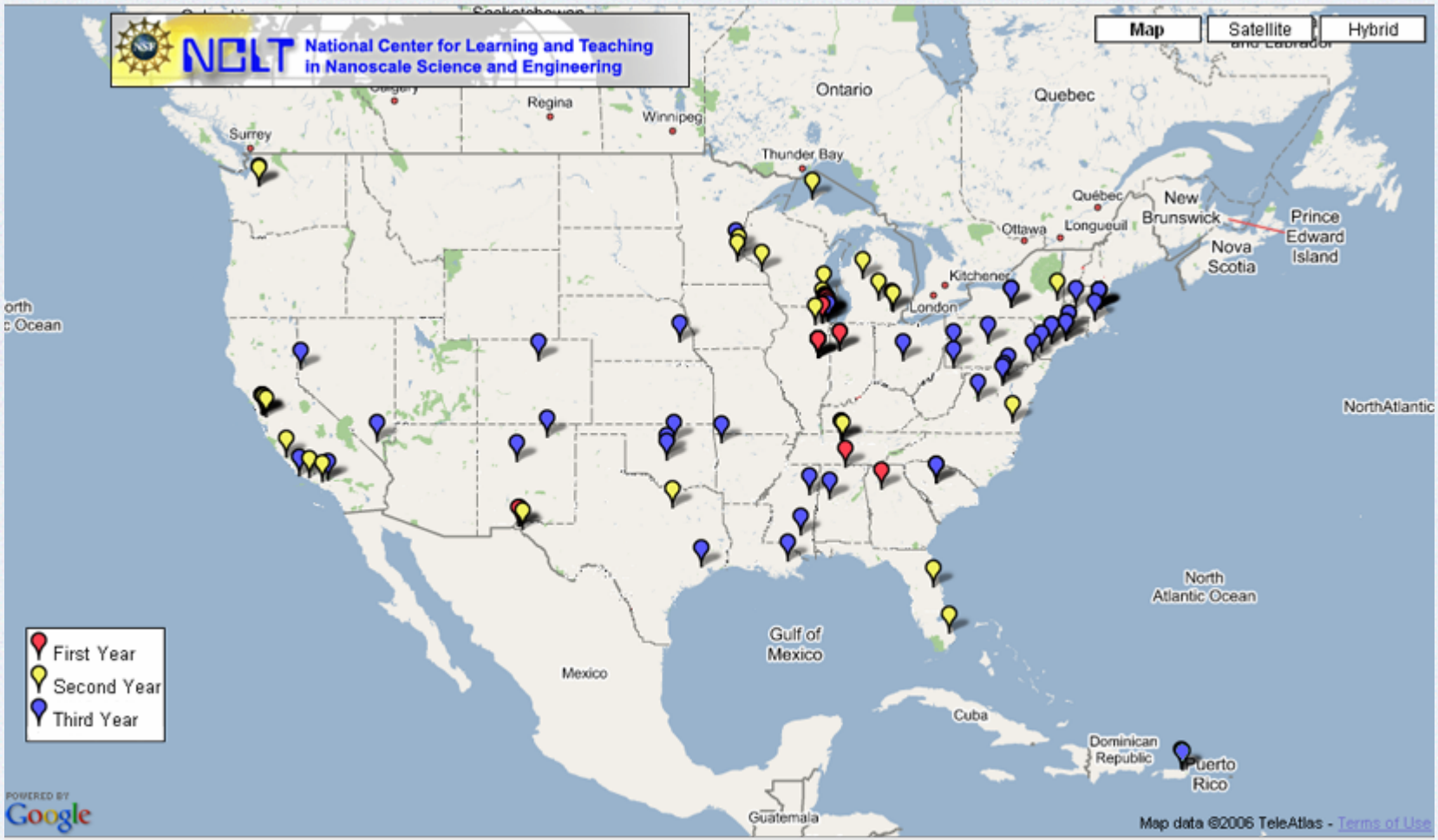
Nanotechnology is regarded worldwide now as the technology of the 21st century and hence there is an imperative need to educate the future generation scientists and engineers about this emerging field. This article summarizes a two-unit course on the introduction to nanotechnology taught by the author at Santa Clara University and the nanotechnology internship programs at NASA Ames Research Center for high school, undergraduate and graduate students.

1. INTRODUCTION

Nanotechnology deals with creation of USEFUL/FUNCTIONAL materials, devices, systems, etc. through the control of matter at the nanometer length scale, say 1-100 nm at least in one principal direction. The terms technology education and training. These two areas are not at all synonymous. A sufficient condition would be that nanotechnology deals with taking advantage of novel phenomena and properties that arise because of the nano length scale. Indeed, physical, chemical, electrical, mechanical, magnetic, optical, and many other



Networking Strategy



Potential Future Resources

- Develop series of Nanoconcepts & Applications for the classroom (7-16)
- Develop thematic NSE courses for colleges
- Upload Learning Research & Progressions for NSEE
- Provide customizable instructional materials for teachers – aligned with national standards
- Develop Online NSEE Journal - Recruit students, post docs and professors for submissions

Goal: Reach one million people within the next 5 years!

Summary of NCLT activities

1. Need many more well trained teachers **Developing nation-wide nanoscience Professional Development**
2. No uniform and standardized curriculum across the country; no more room for new courses **Insert and link nanoconcepts to STEM courses**
3. Lack student interest in math and science **Link to applications (via inquiry and design)**
4. Slow to revise and up-date course content **Use cyber-infrastructure to take the latest research ideas and applications directly into the classrooms**
5. Lack vertical integration **Engaging researchers in all aspects of our integrated NanoEd program**
6. How to rapidly introduce NanoEd into the classrooms? **Establishing a national NSEE Network**

How to join the Network?

- **Visit our website:** http://www.nclt.us/nclt.html
- **Call 847-467-0994**
- **E-mail:** nclt@northwestern.edu

Thank you for your participation!