A Decade of Nanotechnology Education: Lessons Learned and Looking Ahead
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1959
Feynman gives after-dinner talk describing molecular machines building with atomic precision

1974
Taniguchi uses term "nano-technology" in paper on ion-sputter machining

1981
STM invented

1985
Buckyball discovered

1986
AFM invented

1989
IBM logo spelled in individual atoms

1997
First company founded: Zyvex
## Dakota County Technical College

### Nanoscience Technology Program Course Outline and Credit Allocation

**rev. 2011**

<table>
<thead>
<tr>
<th>Semester 1 at DCTC</th>
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<th>Semester 4 At Univ. of MN</th>
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Nano-Link: Center for Nanotechnology Education (formed in 2006)

Funded by:
National Science Foundation
Advanced Technology Education Program

Home Institution:
Dakota County Technical College/Inver Hills Community College
Minnesota US

Nano-Link is an Alliance of 12 Educational Institutions
High Schools (2), Colleges (10) and Universities (2) throughout the US
Offering Certificates, 2 year degrees and 2+2 programs leading to a BS degree
Multi-disciplinary Nanotechnology (Electronics, Biotech, Materials,)

D. Newberry: Director/PI
Nano-Link is an alliance of educational institutions (high school through graduate school) that provides nanoscience educational content, guidance and direction to anyone who wants, needs or desires that information.

www.nano-link.org

Nano-Link provides nanotechnology content in 3 forms:
- Entire, 16 week courses (30 available)
- College level labs (45+ available)
- Modularized topic specific, 1 hour, activity based content
  - Used by over 580 educators in 4 countries, (46 US states) reaching over 70,000 students
- Outreach and Professional Development
  - We visit schools (classrooms) – students rotate through stations - 5 activities/class period
  - Educator Workshops – 6 to 8 hours, 10 activities, technical background
Agenda

- **Introductions and Logistics**
- Nanotechnology Overview
- A Glance at Forces and Interactions
- Cross Link Polymer Activity - Part I
- Discussion - what’s going on with those polymers and water
- Cross Link Polymers Activity - Part II - different liquids, variations and considerations
- Major concepts and correlation to traditional science concepts
- DCTC Nano Programs and Courses -- Nano-Link Modular Approach
- Critical Thinking
- Back to Polymers - the ring structure and interaction with liquids
- Models and Simulations - Overt and Covert Assumptions
- Why does salt dissolve in water?
- Cohesive and Adhesive Forces - Superhydrophobicity - Examples from Nature
- Superhydrophobic Activity
- Aspirin Calculation - practice with numbers, conversions - hyper vs reality
- SA to vol ratio - discussion
- Applications of Nanotechnology
- Crystal Structure - Discussion and Activity
- Quantum Physics and Quantum Dots
- Biologicals nano particles
- Scientific method activity
- Fluids - Discussion and activity
Why is understanding the molecular or atomic level structure of a material important?

Atomic (electronic) structure → Molecular structure → Physical characteristics → Electrical characteristics → Biological characteristics
A Classic Example

Wikipedia
NanoScience Nanotechnology
On a typical day...
Lessons Learned

• One size does not fit all  
  • Students often do not want to move  
  • Need to tailor program to local industry

• Depth of nanoscale content/understanding will vary

• Most educators lack experience interacting with industry

• Some educators hesitant to jump in to “new” content

• Target students are afraid of “science” and “math” – self doubt

• Technical college/2 year stigma
Nanotechnology Careers

Is a Career in Nanotechnology in your Future?

- Think about choosing a field that is new and exciting and which is predicted to influence every facet of our lives.
- The National Science Foundation’s estimated job projection for the U.S. is nearly one million workers by 2015.
- The U.S. market value of products using nanotechnology is estimated to be $1 trillion or 5% of the GDP by 2020.

How many researchers are working in nanotechnology today?
A 2008 survey estimated there were about 400,000 workers worldwide in the field of nanotechnology, with an estimated 150,000 of those in the United States. (Roco, Mirkin, and Hersam, 2010)

What are future workforce needs?
A study funded by the National Science Foundation projects that 6 million nanotechnology workers will be needed worldwide by 2020, with 2 million of those jobs in the United States (Roco, Mirkin, and Hersam, 2010). To find out about nanotechnology programs at college and graduate levels, see College and Graduate Programs. If you are interested in 2-year degrees or training programs, see Associate Degrees. Certificates, & Job Info.

Ref: nano.gov
Where are the career areas?

Current applications of nanoscale science and technology, and thus career opportunities, exist in areas such as

- Electronics/semiconductor industry
- Materials science including textiles, polymers, packaging, among others
- Auto and aerospace industries
- Sporting goods
- Biotechnology
- Medical fields and pharmaceuticals
- Environmental monitoring, control, and remediation
- Food science including quality control and packaging
- Forensics
- University and federal lab research
- Military and national security
- Energy capture and storage
- And many more areas
Looking Ahead

Multi-disciplinary nature of nanotechnology = applies to everything

Integrate nano concepts into “all” traditional classes – Callister comment
Students need to learn fundamental concepts somewhere

Challenge – understanding the nanoscale requires knowledge in multiple subjects

Emphasis on 21st Century skills

Customized curriculum

STEM to STEAM
Quantum Dot Rainbow
Source: Andrey Rogach

References:

Description:
Semiconductor nanocrystals, also called colloidal quantum dots, typically have a size between ~1 and 10 nm and lie in the transition regime between bulk solids and molecules. They are fascinating objects for studying basic novel properties of matter, generally described by the term "size quantization effect". A famous demonstration of the size-dependent properties of semiconductor nanocrystals is the continuous change of their emission color. Shown is an example of the range of CdSe nanocrystal emission spectra.

Most nanocrystals are highly luminescent, and the emission is tunable through the whole visible and the near-IR spectral range by controlling the composition and size of quantum dots. Highly luminescent semiconductor nanocrystals are interesting for different applications, ranging from thin film optoelectronic devices to fluorescent labels. The incorporation of luminescent semiconductor nanocrystals into photonic crystals and microcavities has attracted considerable attention as a promising pathway to novel light sources with controllable spontaneous emission.
Nano => understanding at the atomic level

Understanding properties

Products

Markets

Industries
America Desperately Needs More STEM Students. Here’s How to Get Them

This article is by Rodney C. Adkins, senior vice president of IBM’s Systems & Technology Group. He is a National Academy of Engineering inductee and serves on the national board of the Smithsonian Institution.

There is no doubt that to advance our economy and our society we need to create the next great technology innovations, not just consume them. That’s why there is such urgency for the U.S. to develop a stronger workforce of experts in science, technology, engineering, and math (STEM). After all, according to the U.S. Department of Labor, only 5% of U.S. workers are employed in fields related to science and engineering, yet they are responsible for more than 50% of our sustained economic expansion.

Employment Outlook for STEM Professionals Is Robust -- and Moving

STEM occupations generate the technological changes that shape all other occupations, and the outlook for such jobs is encouragingly positive. Here’s a birds-eye view of the growing demand for STEM careers.
What employers are saying:

- Employers are highly focused on innovation as critical to the success of their companies, and they report that the challenges their employees face today are more complex and require a broader skill set than in the past. Notably, employers indicate that they prioritize critical thinking, communication, and complex problem-solving skills over a job candidate’s major field of study when making hiring decisions.

- Ref: IT TAKES MORE THAN A MAJOR: Employer Priorities for College Learning and Student Success (April 2013)
Nanoscale properties of concrete define the physical properties, lifetime, environmental impact and more….

Ref: MRS Journal Dec 2015
Innovations in Cement Based Materials
Figure 3. Flexible plastic electrophoretic displays. Images courtesy of Plastic Logic.

Ref: MRS Journal Dec 2015
From Academic Discovery to Industrial Applications

A piece of Corning's Gorilla Glass undergoing a flexibility test in the laboratory. Image courtesy of Corning Incorporated.
Ref: MRS Bulletin Nov 2015
Progress in Mesoscale Science

Figure 4. A graphical representation of the blossoming scientific opportunity spanned by the grand challenges (red) and transformative opportunities described in Reference 9.
**Pȟahíŋ – porcupine quills**

- *Pȟahíŋ* (porcupine quills) are used to decorate clothing and ceremonial items.
- They are often dyed with various plants to create vivid colors. However, some plants and plant parts work more effectively than others.
- **Question**: Can we show why certain plants work better than others? Can we predict which plants will make a better dye for pȟahíŋ? Pore size? Can we show the barbs that make them so dangerous?
Pȟaŋkéska: Abalone shell

- These pȟaŋkéska are used as a vessel for burning sage and other herbs.
- We have observed that, over time, the bottom of the pȟaŋkéska becomes brittle and flakes apart. This is different than the way íŋyaŋpi break apart after a sweatlodge ceremony.
- **Question:** Why does the pȟaŋkéska become brittle? Why does it flake apart?
Thank you!!!!