MULTIMEDIA RESEARCH
33 BROWNS LANE • BELLPORT, NY 11713 • (631) 286-8925

COMPILATION OF NANOSCALE COMMUNICATION PROJECTS

Part IIA of Front-End Analysis in Support of Nanoscale Informal Science Education Network

Report for
Nanoscale Informal Science Education Network

by
Barbara N. Flagg, Ed.D.
Director, Multimedia Research

Research Report No. 05-020
November 7, 2005

TABLE OF CONTENTS

INTRODUCTION

The Nanoscale Informal Science Education Network (NISE Network) is a national infrastructure that links science museums and other informal science education organizations with nanoscale science and engineering research organizations. The Network's overall goal is to foster public awareness, engagement, and understanding of nanoscale science, engineering, and technology. The Museum of Science in Boston is the lead institution working in partnership with the Exploratorium in San Francisco and the Science Museum of Minnesota in St. Paul to form the core leadership team for the project. An additional 10 organizational partners, 22+ "thinking partners", 12 advisors, and 2 evaluation firms form the initial fabric of the network.

A front-end analysis to support the NISE Network entails three parts:

I. A review of secondary research materials on the adult public's awareness, interest, knowledge and attitudes relating to nanotechnology;
II. A compilation of past and current projects that attempt to communicate nanoscale issues to the general public, including children;
III. A review of secondary research materials on communicating atomic theory and behavior to a general audience.

Part II, presented here, documents work that has been done and is being done to communicate nanoscale science, engineering and technology to the public and the results of those communications. This report compiles past and current nanoscale communication projects, answering the following questions:

- What is the project?
- Who are the target audiences?
- What are the communication goals?
- What are the evaluation findings?
- Who is the contact?
- What are references for this project?

Descriptions of projects are purposely concise. For details, please see the websites and references associated with the projects.

The projects included in this compilation were identified via references supplied by NISE Network affiliates and a review of all NSF award abstracts with "nano" and "outreach" or "education" in their text. Some projects outside the "nano" field are included if they focus on the molecular or atomic level. Projects in formal K-12 education are included if they have some pertinent evaluation information available. Projects focused on undergraduates, graduates or teachers are not included in this report. All images presented with project summaries have been copied from their respective websites.

Projects are compiled in this report by type of deliverable and primary audience.[1] In order to provide project photos in the report and maintain relatively small file sizes, Part II is provided as A and B. Part IIA includes Exhibit projects. Part IIB includes Programming, Media and School-based projects. This document is Part IIA.

Exhibit:

Young children (about 5-8 year olds) and older:
- It's a Nano World - Cornell University

Tweens (about 8-12 years) and older:
- Nanotechnology: The Science of Making Things Smaller – Purdue University
- Nanoworld Discovery Center – University of Wisconsin-Madison, Discovery World Museum
- Nanozone© - Lawrence Hall of Science
- Strange Matter – Materials Research Society, Ontario Science Centre
- Too Small to See - Cornell University

Teens and older:
- Marvelous Molecules: The Secret of Life – New York Hall of Science
- NanoDialogue - European Union
- Nanotechnology: small science, big deal - Science Museum, London
- Nanotechnology; Micromachine - Miraikan, National Museum of Emerging Science and Innovation, Tokyo, Japan
- Northwestern University NSEC museum exhibit with Museum of Science and Industry, Chicago

[1] Some projects should be in this list but not enough information is available by the deadline of this report: Nanooze, an online science magazine for kids sponsored by the National Nanotechnology Infrastructure Network, see www.nanooze.org; Nanopedia, an online information source, see http://nanopedia.cwru.edu; Patterns in Nature Van, a mobile microscope laboratory to visit schools in AZ, see http://www.asu.edu/clas/csss/PINvan/.

EXHIBIT PROJECTS

It's a Nano World

What it is:[2] (see www.itsananoworld.org)

The Nanobiotechnology Center at Cornell University and the Sciencenter in Ithaca, NY, produced in 2003 a traveling 3,000 square-foot interactive museum exhibition on biological wonders of the nano world. Individual exhibits are described below:

- Cell sorters permit visitors to use tools to sort balls based on three "invisible" properties to demonstrate principle of how scientists use machines to separate cells
- Magnification Station presents objects with glasses and microscopes to magnify 2-5 times
- Scope on a rope permits visitors to look at their own skin, hair, clothing, etc. using fixed focus cameras with monitor displays magnifying at 30x and 200x
- Pinball machines present different journeys taken by microscale objects: germs, dust, or pollen; e.g., pollen can land on a flower, bee or nose, the latter produces a sneeze sound
- Giant Magnifying Glass is a lens that enlarges 3-4 times
- Look closer presents photos of familiar objects at decreasing levels of magnification
- Video theater plays two videos: Cells in Motion and Clean Room
- Powers of Ten is a modified Ray and Charles Eames' scaling video, plus a photo flipbook
- Scale Gallery presents microscopic object images that flip to show text description
- How many nanometers tall are you is a nanometer/inches measuring tool

Target Audience:

Museum visitors: Primarily children, ages 5-8. Secondarily older children and adults

Goals:

For children, 5-8 years old (Edu, Inc., 2004, p. 2)

1. "The existence of the microscopic realm: *Amazing things happen that are too small to see with just your eyes.*"
2. "Introduction to basic biological vocabulary needed to understand biotechnology (for example, types of cells in the human body, DNA, Virus, bacteria)."
3. "Size and scale: *Small things are made up of even smaller pieces.*"
4. "Elementary definition of nano: *Nano is really, really small.*"

[2] Image from http://www.itsananoworld.org/exhibits.htm

5. "Introducing nanobiotechnology: *Scientists and kids can use tools to observe small things."*

For adults/older children (www.itsananoworld.org/learninggoals/htm)
1. "Scientists can interact with small things and they are developing tiny things to help my body."
2. "Relative size of different small things."
3. "Relate what scientists do to things I've already experienced."
4. "Inspire curiosity and want to know more about Nanobiotechnology."

Evaluation conclusions:

Front-end, as reported in summative report (Edu, Inc., 2004):
- The smallest thing that K-3 children could think of is something they can see, e.g., a bug or grain of sand
- Cells are often misunderstood
- "Nano" is an unknown concept

Formative (*NISE: Too Small to See*, n.d.):
- Fixed focus camera with monitor display easier to use than standard optical microscope.
- Relative scale model showing, among other items, a strand of DNA as the size of a thread of string and a strand of hair as one meter in width did not convey desired message of size and scale. "Trying to cover the visible to the nano world in one continuous size scale is virtually impossible, and the result is the creation of out-sized objects that confuse museum visitors." (p. 8).
- Over 200 concepts were developed and piloted for It's a Nano World, underlining the difficulty of successfully communicating to this young age group.

Summative (Edu, Inc., 2004):
Pre-post surveys, exit interviews and visitor tracking were implemented with children (n=217), teens and adults at Sciencenter, Ithaca, NY, and Epcot, Lake Buena Vista, FL.[3]
1. The existence of the microscopic realm: Children enjoyed most and used most often cell sorter and magnifier tools. Hands-on activities of sorting and magnifying are preferred over video or still images.
2. Introduction to vocabulary: 15% of children gained rudimentary ability to explain "cell;" e.g., 8 year old girl's pre-definition of "no idea" vs. post-definition of "something so small you can only see it with a microscope."
3. Size and scale: 65% of children drew a smaller thing after playing in the exhibit than they did before playing in the exhibit. Of the smaller things drawn, 72% had been presented in the exhibit; e.g., 6 year old girl's pre-drawing of a flea vs. post-drawing of a virus.
4. Elementary definition of "nano": 25% of children gained ability to explain simple concept of nano; e.g., 8 year old female's pre-definition of "science" vs. post-definition of "something you cannot see because it's so small." "Adults and children could not

[3] No statistical analysis was applied to pre-post results to indicate that any change is beyond chance.

differentiate between micro and nano….Those [adults] that said they learned something about nano from the exhibition were the exception….Adults could not explain the concept of nanotechnology after using the exhibition." (pp. 11-14)

5. Introducing nanobiotechnology: Adults were curious after the exhibit but did not understand that the exhibition was about nanobiotechnology. A majority of visitors used magnification and scope on a rope tools to observe small things.

Tracking indicates average time in exhibition is 6 minutes, with almost 1-minute duration average at individual exhibits. Over half of tracked visitors used cell sorters, magnification station, scope on a rope and a pinball machine (dust tippy table). Video theater attracted 26% of visitors tracked; Power of 10 video attracted 23%; scale gallery, 19%. The majority of visitors did not read signs in a gallery intended for young audiences. Epcot staff members requested talking points that they believe encourage visitors to stay in the exhibit longer.

Interviews indicate that children liked most scope on a rope and cell sorter. Staff aided visitors in using the scope on a rope.

Additional pre-visit interventions proved helpful to successful exhibit outcomes:

1. A sub-sample of children who were read a two-minute picture book introducing the ideas and images of the exhibit prior to experiencing the exhibit show "greater understanding of cells and nano" and "more readily gave examples of sub-visible objects that they had seen in the exhibition." (p. 26)
2. A sub-sample of adults to whom interviewers introduced the concept of nano and nanotechnology prior to experiencing the exhibit "were able to refer to examples of nano and nanotechnology in the exhibition and had questions about the technology." (p. 26)

Hands-on activities can present models (e.g, balls representing cells); however, most adults and children are not able to explain what such models are supposed to represent. Models representing familiar items (e.g., pinballs representing pollen) are easier to understand. Models are most effective when museum staff members explain them.

"One of the major understandings that emerged from the development and evaluation of It's a Nano World was that in order to imagine the nanoscale (less than 100 nanometers), visitors need to start with the smallest thing that they can experience and then travel down in size scale." (*NISE: Too Small to See,* n.d., p. 10).

Contact: P.I. Anna Waldron, Amw37@cornell.edu

References:

Edu, Inc. (2004, June). *It's a Nano World: A study of use: Findings from a summative study.* Retrieved August 23, 2005 from http://eduinc.org.

No author. No date. *NISE: Too Small to See* proposal. Made available by Carl Batt, Cornell University, October 7, 2005.

Nanotechnology: The Science of Making Things Smaller

What it is:[4] (see http://news.uns.purdue.edu/html3month/2005/050419.Melloch.museum.html)

Purdue University's Physics, Electrical and Computer Engineering students and faculty developed a traveling exhibit, which includes:

- Scanning probe microscope made out of LEGOs and used to scan LEGO landscapes
- Activities to illustrate some basic principles underlying nanotechnology
- Posters to emphasize how nanostructures are built from ground up
- Kiosk displaying rotating renditions of nanostructures
- Kiosks with cartoon animations on aspects of nanotechnology (see www.nanohub.org)
- SPM images of nano-objects such as buckyballs, carbon nanotubes
- Take home brochures, bookmarks (*Description*, 2005)

In May, 2005, the exhibit appeared at the Children's Museum of Oak Ridge in TN. In Nov., 2005, to Aug., 2006, the exhibit is at the National Inventors' Hall of Fame in Akron, OH.

"Come explore the world of Nanotechnology and how it is used today. See a working LEGO TM replica of a real scanning probe microscope and learn how LEGOsTM can be used to teach nano-science. Learn what nanotechnology is and what the goals of nanotechnology are. Also learn about scanning probe microscopes that can see and manipulate objects millions of times smaller than those observed by an ordinary microscope."
(http://childrensmuseumofoakridge.org/exhibits-index.html)

Target audience:
Middle school level

Goals:
Introduce middle school children to the fascinating and rapidly changing field of nanotechnology

Evaluation conclusions:
Not available

Contact: Education outreach director Michael Melloch, michael.r.melloch.1@purdue.edu

Reference:
Description of NetWork for Computational Nanotechnology. (2005, October 19-20). K-12 & Informal Nanoscale Science and Engineering Education Workshop. Made available by Sherry Hsi, The Exploratorium, October 31, 2005.

[4] Image from http://news.uns.purdue.edu/images/+2005/melloch.museum.jpg

Nanoworld Discovery Center

What it is: [5] (see http://www.mrsec.wisc.edu/Edetc/IPSE_exhibits/about/projects.html)

Through the Internships in Public Science Education (IPSE) program at University of Wisconsin-Madison Materials Research Science and Engineering Center (MRSEC), graduate students produced and tested two prototype exhibits with Discovery World Museum in Milwaukee, WI.

- Scanning Probe Microscopy – "Visitors can read about probe microscopes, see images created by these tools, and participate in interactive features in which their hands perform the role of the tips of the microscope. The interactive features include reach-in boxes for the visitor to feel a shape made of bumps on a surface or to discern a shape created by a stiff material. Another interactive feature involves the visitor using a magnetic wand to discover a magnetic shape behind an opaque panel" (Holladay, 2005, p. 31).
- Liquid Crystals – The "basic properties [of liquid crystals] are explained on one side of the exhibit module. This side also has an interactive feature where users can manipulate the temperature of a sample liquid crystal with a hairdryer and watch the color change, which can been seen on the monitor. The other side of this exhibit module focuses on everyday uses of liquid crystals, such as computer monitors, digital watches, mood rings and nanotechnology applications. This interactive feature involves users guessing which property (heat, chemicals, or electric current) is detected by various liquid crystal sensors. Included on this panel is a temperature-sensitive liquid crystal panel on which visitors can press their hands to see a color change due to body heat" (Holladay, 2005, p. 32).

Target Audience:
Museum visitors, primarily middle school age

Goals:
For the IPSE program: "To produce new and interesting ways to present nanotechnology that Discovery World Museum could adapt into real working exhibits" (Holladay, 2005, p. 2).

For museum visitors: "To teach visitors about an important tool that scientists use to see objects at the nanoscale called probe microscope" and to teach about " a specific nanotechnology material, liquid crystals, and its applications" (Holladay, 2005, p. 30-31).

Evaluation results:
Front-end (Holladay, 2005) Surveys of a total of 495 people, ages 7 to 91 years, were collected in 2004-2005 at a Madison, WI, WalMart; at Discovery World Museum in Milwaukee, WI, and in 2nd – 12th grade classrooms in Watertown, WI.

[5] Image from Holladay (2005).

- Asked for the smallest thing they could think of, most (54%) 2nd-5th graders suggested small visible objects like bugs, raindrop. Microscopic objects (like atoms, cells, bacteria and molecules) were suggested by most (81%) 6th-8th graders, most (58%) 9th-12th graders and 43% of college-educated adults.
- Suggestion of sub-atomic particles as the smallest thing they could think of increases by age/education: 5% for 2nd-5th grade; 1% for 6th – 8th; 21% for 9th – 12th; 43% for college+.
- 7% of respondents correctly ordered in size: cell, bacterium, water molecule, atom; 45% correctly answered that atom was the smallest item in the list of four.
- 45% correctly ordered in size: housefly, eyelash, grain of salt, dust particle.
- 41% reported having heard of nanotechnology. Of these, 42% were able to provide a correct definition. "Correct definitions included mentioning a type of technology and small size. When asked where they had heard of nanotechnology, common sources included television, magazines and newspapers" (p.14).
- 80% reported that they know what an atom is, and 74% of these respondents answered three true/false questions about atoms correctly.
- On a scale of 1 to 4, respondents (n = 135) rated feelings about nanotechnology. On average, the sample found nanotechnology more beneficial than harmful, more important than unimportant, more safe than dangerous, more exciting than boring, and more comfortable than uncomfortable.
- 52% of respondents were neutral about nanotechnology's potential impact on life and society; 20% were "excited" and 13%, "very excited."

Formative (Holladay, 2005):
The prototype exhibits were assessed at campus outreach events using observation and in-depth interviews:

- "Children and teen visitors were more likely to use the interactive features, while adults were more likely to simply attend to the text….the interactive features of our museum exhibits especially interest younger visitors." (p. 35).
- "In the liquid crystal module, many people expressed favorable feelings about the interactive features, especially the liquid crystal panel on which they could press their hands and see a color change. Some people requested that more interactive features be added, particularly a liquid crystal mood ring to try on. According to post-use interviews, people understood that this module was about how heat or other stimuli can change the reflective qualities of liquid crystals" (p. 35).
- "Many people felt favorable towards the probe microscopy module interactive features as well. They enjoyed discovering the shapes in the boxes and commented that they would like to have additional shapes to discern. Similar to the liquid crystal module, many people understood the principle of this probe microscopy module, namely, that probe microscopes feel objects rather than see them. In summary, people enjoyed the interactive portions of our exhibit and understood the basic concepts behind them" (p. 35).

Contact: P.I. Wendy Crone, crone@engr.wis.edu

References:
Holladay, C. (2005). *A year in review: Internship in nanotechnology museum exhibit design.* Master's Description Paper, University of Wisconsin, Madison, WI. Retrieved November 1, 2005, from www.mrsec.wisc.edu/Edetc/IPSE_exhibits/about/share.html

MRSEC Interdisciplinary Education Group & Discovery World Museum. (no date). *IPSE Exhibit Prototypes 2005-2005 Liquid Crystals & Scanning Probe Microscopy.* Made available by Wendy Crone, University of Wisconsin-Madison, September 23, 2005.

Other projects from Wisconsin's MRSEC:
Payne, A. C., deProphetis, W. A., Ellis, A. B., Derenne, T. G., Zenner, G. M., Crone, W. (2005, May). Communication science to the public through a university-museum partnership. *Journal of Chemical Education, 82* (5), 743- 750. Retrieved September 23, 2005, from http://www.jce.divched.org/Journal/Issues/2005/May/abs743.html
(This article describes the history of the IPSE program and describes 45-minute activities that previous years' interns had developed in the areas of ferrofluids, giant magnetoresistance, nanolithography, societal implications. Nanoscale activities are available at http://mrsec.wisc.edu/Edetc/IPSE/educators/index.html)

Bentley, A.K., Farhoud, M., Ellis, A. B., Lisensky, G. C., Nicketl, A. L., & Crone, W. (2005, May). Template synthesis and magnetic manipulation of nickel nanowires. *Journal of Chemical Education, 82* (5), 765-768. Retrieved September 23, 2005, from http://www.jce.divched.org/Journal/Issues/2005/May/abs765.html
(This article describes a college chemistry experiment but could be used at high school level.)

Nanoworld Kits: http://mrsec.wisc.edu/Edetc/supplies/index.html This site has explanations for table top demonstrations, including amorphous metals, carbon nanotubes, ferrofluids, LEDs, memory metal, refrigerator magnets. The latter, which illustrates scanning probe microscopes, is reported in detail in
Ellis, A.G. Kuech, T. F., Lisensky, G. C., Campbell, D. J., Condren, S. M., & Nordell, K. J. (1999). Making the nanoworld comprehensible: Instructional materials for schools and outreach. *Journal of Nanoparticle Research, 1,* 147-150.

Exploring the Nanoworld kit: http://mrsec.wisc.edu/Edetc/supplies/kit/index.html The kit includes a 32 page book of a dozen experiments, a light emitting diode circuit, a fiber optic, a memory metal wire, a refrigerator magnet, a diffraction slide, and a 9-V battery.

Cineplex of Movies: http://mrsec.wisc.edu/Edetc/cineplex/ This site has short QuickTime movies and text explanations for 6th – 12th grade teachers to use as demonstrations in the classroom. Some basic topics include ferrofluids, amorphous metals, atomic imaging, self assembly.

Video Lab Manual: http://mrsec.wisc.edu/Edetc/nanolab/index.html This site has movies and text explanations for experiments from basic (e.g., disassembly of a liquid crystal watch) to advanced (e.g., organic light emitting diodes).

Nanozone©

What it is: [6] (see www.nanozone.org)

This exhibit opened in 2004 at the Lawrence Hall of Science, Berkeley, CA, and includes:

- How Small is That?: Facilitated activity with images of macro, micro and nano scales
- Live Demonstrations: Demonstrators use larger-than-life models and power point slides to explain nano tools and research
- Measure Yourself in Nanometers: Hands-on exhibit to measure height, feet, hands in nanometers
- Look Familiar?: Hands-on exhibit of photos of magnified objects with clues and answers on the underside of a flip block
- Zoom In: Hands-on exhibit to examine common objects at various magnifications
- How Small is Small?: Make and take activity in which visitor constructs a size wheel for macro, micro and nano scales
- The Case of the Green Milk: Computer game invites players to design and test a microcantilever tool to detect the tiniest signs of disease in cows
- Save Ratty: Computer game invites players to design a tiny biocapsule to protect new cells implanted in the body
- Chester McZoom: Computer game invites players to design viruses to make nanowires
- What the Heck is Nanotech?: Video in which young actors answer core questions about nanotechnology
- Nano Fab Lab: Multiplayer computer interactive that incorporates video interviews of nanotech scientists to present their interests and inspirations
- Fishing for Fun: Cooperative computer game to build a bridge by answering multiple choice questions about scientists and research
- What is Nanotechnology?: Computerized Q&A kiosk uses a touchscreen with full words to ask questions and hear a possible 500 answers from a computer-generated human
- Seeing Small: Video in which expert presents Scanning Electron Microscope
- Shop the Nanomall: Animated ads introducing potential products with information cards explaining the science
- Talk to the Scientist: Audio recordings of scientists answering questions
- Scientists' Life Stories: Animations of scientists' youth to their current work as researchers
- Scientist Stats Cards: Laminated cards with background information about nanotech scientists
- Pull Up a Seat: Stool seats with photos of tiny things magnified
- Website showcasing exhibit materials and evaluation documentation

[6] Image is from nanozonecatalog.pdf from http://www.nanozone.org/museum.htm

Target Audience:
Museum visitors, primarily 8-14 year olds, at the Lawrence Hall of Science, Berkeley, CA

Goals:
For nano size and scale (Stafford, Molinaro, & *nanozone* Leader Team, 2005, p. B)

1. "A nanometer is a unit of measurement for small matter."
2. "There are things smaller than you can see."
3. "There is tremendous variety in the size of things smaller than you can see."

For nanotechnology research and applications (Stafford et al., 2005, pp. G, H, I)

1. "What are nano applications? Applications can be described in terms of how they work and their unique properties at the nanoscale."
2. "Who's doing the research? Researchers are understandable, motivated and interesting people."
3. "Why are nano applications important? Nanotechnology applications are useful to individuals and society."

Evaluation conclusions:

Front-end (Edu, Inc., n.d.):

- One in ten respondents (N = 60) had heard of nanotechnology and said they learned about it from work, school, parents or self-study.
- Five in ten respondents could rank atom, DNA, and cell in ascending order by size. Atom was the most difficult concept to articulate.
- Six in ten respondents were "very interested" or "interested" in how scientists move individual atoms, although respondents reportedly had difficulty articulating the concept of an atom.

Formative (Stafford et al., 2005):
General design recommendations are presented based on numerous evaluations.[7]
For nano size and scale (p. B)

1. "Everyday objects and common words are important. Based on testing, we propose the following list of macro, micro and nano-size objects to introduce visitors to the nano scale. a. Macro – pollen, ant, dust mite, hair, plant cell, pencil tip, rice, threads such as silk and cotton. b. Micro – red blood cell, bacteria. c. Nano – carbon nanotube, buckyball, DNA, virus, quantum dot, protein….The distinction among macro, micro and nano was tangible to most visitors."
2. "Magnified images of common objects are highly appealing. A good introduction to matter that is smaller than one can see is to show the detail of macro-size objects such as bugs and hair follicles at increasingly smaller scales."
3. "10^{-9} is not a useful definition of a nanometer to the general public. Our most common reference to a nanometer is, "There are one billion nanometers in a meter."

[7] More detail about specific challenges and educational strategies is provided in this report. It is recommended that exhibit designers and formative evaluators read this report in full.

4. “Measuring macro objects in nanometers (such as oneself or common objects like pencils and rice) is an engaging activity and a good introduction to a nanometer as a unit of measurement.”
5. A facilitated activity with an expert was required to communicate that “there is tremendous variety in the size of things smaller than you can see.”

For nanotechnology research and applications (p. F)

1. “When talking about future possible technologies, it is valuable to limit the hype factor by not portraying them as deceptively real. Animations and humor are useful.”
2. “Providing information about a scientist’s family, childhood, and hobbies is particularly appealing.”
3. “Supporting visitors in learning about all the various aspects of an application requires a facilitator.”
4. “Selective choice of scientists who have accessible research is critical. Two examples from our work include Tejal Desai’s work on a diabetes treatment and Bob Full’s work on mimicking the super-stickiness of a gecko’s toes.”

Communicating nano size and scale seems more successful with comparisons of macro, micro and nano-size objects; magnified images of everyday objects; measurement of macro objects in nanometers; a definition of “one billion nanometers in a meter,” and activities facilitated with an expert. Communicating about nanotechnology research and applications seems more successful with restrictions on hype; portrayal of scientists as real people; selection of accessible research; and activities facilitated by an expert.

Summative (available in 2006 on website)

Contact: P.I. Marco Molinaro, mmolinaro@ucdavis.edu

References:

Edu, Inc. (undated). *Windows on research: Front-end research: Evaluating museum visitors’ readiness for and interest in learning new science.* Retrieved August 15, 2005 from http://www.nanozone.org/museum.htm

Stafford, C. L., Molinaro, M., & *nanozone* Leader Team. (2005, August). *Lessons learned from Nanozone*. Retrieved August 15, 2005, from http://nanozone.org/museum.htm

Strange Matter

What it is: (see www.strangematterexhibit.com)
A traveling exhibition developed by the Ontario Science Centre and the Materials Research Society, in two versions (6,000 sq. ft. and 1,700 sq. ft.), encourages investigation of the structure of materials to discover what gives them their properties. Each of the exhibition areas includes interactive exhibits, a micrograph of a close-up look at materials' structures and information on where to find the materials in everyday life. The areas explore properties of metals, semiconductors, ceramics, polymers, composites, biomaterials and exotic materials. Exhibit areas are briefly described below:

- Introduction area: Intro panel, Overview video, website
- Touch table: Younger visitors can discover materials through hands-on experimentation
- Smash the Glass: Drop a bowling ball on heat-tempered glass, over and over
- Materials Evolution: Trace the development of materials throughout history
- Amazing Magnetic Liquids: Use magnets to manipulate a pool of ferrofluid. Swish gloved hands in a vat of magneto-rheological fluid that morphs from fluid to solid with a magnetic force[8]
- Crystals: Watch real-time growth of crystals.
- Zoom: Look at materials from macro to nano scale.
- Foam: Explore which materials contain elements of foam from beer, bread and spittlebugs to space applications from NASA. Check out aerogel
- Amorphous Metals: Drop ball bearings to see which metal plate gives the ball the most bounce and why
- Structures and Defects: Play with a sheet of ball bearings to discover the role 'grain boundaries' play in creating stronger metals
- Memory Metals: Stomp on Nitinol flowers and return them to shape by heating them.
- Sand to Supercomputers: Discover why silicon is the cornerstone of materials science

A demonstration theater presents experiences with polymers. An example script is available at www.princeton.edu/~pccm/outreach/LSCPCCMPolymerShow.pdf. The website has interactives to zoom inside stuff, transform stuff, crush stuff or improve stuff; video clips of researchers; text information about materials science and the exhibit; as well as pdfs for a family guide and a 5th – 8th grade teacher guide (www.strangematterexhibit.com).

Target Audience:
Museum visitors, 9 years and older

Goals:

1. "The exhibition and web site should create a sense of awe and motivation, and must strive

[8] Image from http://www.strangematterexhibit.com/photographs.html

to be as “cool” to kids as following the antics of rock bands
2. The show should increase public understanding of basic scientific principles, issues and trends in materials research
3. The exhibition must show viewers that materials research is pivotal in helping make advancements in other areas of science and technology
4. Students, especially those as young as 5^{th} – 8th graders, should come away with an interest in materials science as a rewarding career path.
5. Through active community outreach, MRS scientists will work to improve public science literacy.”
(http://www.strangematterexhibit.com/releases_strangematteratlsc_community.html)

Evaluation conclusions:

Front-end (Randi Korn & Associates, 1999):
A total of 30 visitors to the Maryland Science Center, including children (10-14 years old) and adults, were interviewed about atomic models and images depicting scale changes and about a group of materials. Randi Korn (1999) summarizes that “…most potential visitors know very little about materials science and were not confident about what they did know. Nevertheless, most interviewees found the subject matter compelling, and when sufficiently probed, many saw the connection between atomic structure and how materials behave” (p. iii).

With respect to models and illustrations of atomic structure, visitors recognized that they “represent atoms, molecules, elements or chemicals, [but] they often used this terminology interchangeably. Furthermore, they were unable to talk about the models more specifically or to differentiate among them when asked to” (p. iii). Visitors were shown two 3-D models (ball and stick polymer, space-filling sodium chloride) and one illustration of a polymer chain. Adults attempted to identify the models whereas children began with simple physical description. Most of the adults and a few children could identify the models as representing atomic or molecular structure but lacked confidence in their responses and could not elaborate. “And some interviewees, particularly children, talked about atoms and molecules interchangeably with terminology associated with biology, such as genes and cells, when describing models” (p.iii). When asked to match four illustrations of atomic structure with numerous provided labels, all interviewees had difficulty and said they were guessing. The images represented a crystal structure, a polymer, a molecule and impurities. Visitors were unfamiliar with images and many of the labels. The image of the molecule was most familiar, but the majority labeled it as an atom or nucleus; only 3 adults (20%) and 2 children (13%) labeled the molecule correctly.

With respect to interpreting size and scale, “overall, interviewees know that the scale of the atomic world is small and understand what it means to change scale in terms of “zooming” in and out. Yet when confronted with comprehending the micro-scale world of atoms, their own perceptions of ‘small’ no longer work” (p. iv). Most interviewees guess that hundreds or thousands of atoms, instead of a million atoms, would fit the width of a human hair. To choose a more magnified image in sets of paired images, adults relied on labels and children relied on the look of the image; but equal numbers of adults and children chose correctly despite their different methods. Zoom lines and scale bars were most often misinterpreted. “The ‘flea in the foreground,’ a visual label, followed by the x1000 notation were interpreted correctly most frequently by adults and children….[but] many adults seemed at first stymied by the flea, it being an unconventional form of labeling" (p. iv).

"Interviewees were not initially accustomed to talking about materials in terms of materials science. However, once they were taken through the process of looking at and describing a variety of materials and prodded through continuous questioning, most visitors indicated that atomic structure was responsible for the differences among materials" (p. v). "Most adults and children talked most easily about the behavioral properties of materials that were either familiar to them or those with properties that could be observed through simple manipulation" (p. v).

Formative evaluation (Randi Korn & Associates, 2002, August and November):
These evaluations looked at visitor response, operational functionality and conveyance of content of prototypes. Results are not summarized here because the summative evaluation below explains visitor responses to the full exhibition.

Summative evaluation (Randi Korn & Associates, 2004):
The summative evaluation at Liberty Science Center in the spring of 2004 used timing and tracking observations (n = 115, 9+ yrs.), uncued exit interviews (n = 50, 9+ yrs.), and telephone interviews with website users (n = 25 adults) and non-users (n = 25 adults) after their museum visit. (A peer review critique with five museum professionals was also utilized but is not reported in this summary.)
"Overall, visitors said they enjoyed the experiences offered by the *Strange Matter* exhibition. Interviewees talked excitedly about interacting with old materials in new ways (e.g., Smash the Glass) or learning about new materials (e.g., ferrofluids)….A few noted that particular exhibits were broken, not interesting or confusing" (p. iv).

In terms of outcomes:
- "Most interviewees said they enjoyed the exhibition. Some mentioned enjoying learning about new materials.
- Most interviewees learned how a specific material such as tempered glass, silicon, etc., behaved or was made. Many interviewees discussed learning about materials, such as ferrofluids, that they had never heard of before visiting the exhibition.
- Most interviewees described materials science as the study of the properties and/or applications of materials. None discussed processing or scale.
- Many interviewees talked about the positive aspect of materials such as clothing, shelter, tools, etc. About two-thirds of interviewees cited potential negative aspects to materials; however, most gave examples not featured in the exhibition.
- Most adults and all children could not draw connections between how a material looks and behaves and what is its structure and how it is processed. The few who discussed structure used the same general terms that visitors in the front-end evaluation had used.
- Most who used the web site said it enhanced their experience of the exhibition" (p. vii).

Visitors spent a median time of 13 minutes in the exhibition, ranging from 44 secs. to 1.5 hours. Visitors spent the most time at staffed exhibits and interactives. Children spent significantly more time in the Touch Table and Smash the Glass areas than adults. Nearly half of visitors stopped at six or more of the 12 exhibit areas.

“The interactives successfully engaged visitors and introduced them to the materials’ properties. Interactives tended to attract the most visitors and hold their attention for the longest times. For example, 87 percent of visitors stopped at one or more interactives. Additionally, interactives fostered adult-child interactions, as 55 percent of families used interactives together” (p.iv).

“In terms of the Introduction section, few visitors stopped at any of its exhibits: the Introduction element (What’s This Exhibition About? panel), Overview Video, or Web site station” (p.v).”

“The videos and Demonstration did not hold most visitors’ attention and, as such, key exhibition messages, including who materials scientists are and how they work, were lost on most visitors. One-third of visitors watched one or more videos in their entirety. Only one visitor watched the Overview video.…In fact, none of the interviewees talked about material scientists.” (p. vi-v).

In terms of the Demonstration, of the 18 visitors who attended it, three stayed to its conclusion. Visitors who participated in the Demonstration praised it, so its inability to hold visitors for the program’s duration may be related to external issues rather than poor content,” e.g., time constraints, competitive exhibits, noise (pp. vi – v).

“…panels were used the least often and held visitors’ attention for the shortest times. In fact, several panels were completely ignored by all visitors observed” (p. v).

“Zoom was used by less than one-third of visitors…. no visitors understood scale. In fact, most interviewees who used Zoom said they thought it was simply about looking at magnified materials and did not discuss the different levels of magnification” (p. v).

“Web site users found the Strange Matter companion site enjoyable and easy to use. They praised the content for being informative and interesting as well as accessible and appropriate for a range of audiences. Some also appreciated that the content related to their daily lives. Most Web site users also praised the Web site’s design, favoring its colorful, child-friendly appearance. However, over one-half of Web site users encountered technical difficulties that negatively impacted their experience: having to download software to view some of the features and download time. Zoom, Transformer, and Materials Smack Down were the most popular features. Web site users liked these activities because of their humorous presentation and compelling content. Fewer visitors used the Change the World Challenge, as they thought it as for older children or found it text heavy. Few visitors used any of the resources or outside links either because they thought that information was more appropriate for teachers or because of time constraints. Most Web site users felt the Web site had enhanced their experiences of the exhibition as it provided a self-paced way to learn more about things they saw in the exhibition. In fact, Web site users recalled more about the exhibition than did non-users. Furthermore, Web site users were four times more likely to say they learned something from the exhibition than non-users. Non-users tended to dislike using the Internet, so their reasons for not visiting the Strange Matter Web site were personal rather than related to its content or execution” (p. viii).

Scientist/Science Center collaboration: (Steinberg, 2005)

When the Strange Matter exhibit appeared at the Liberty Science Center (LSC) in New Jersey, the Princeton Center for Complex Materials (PCCM) provided a team of scientists each week for 12 weeks. Daniel Steinberg explains the lessons learned from this collaboration (Steinberg, 2005):

- The scientists must be willing and eager to participate. “Within PCCM, we had a commitment from our faculty that at least one group or individual would be going each week” (p. PP2.2.3).
- The science center must be eager to collaborate with the scientists. LSC “was very understanding of the nature of PCCM’s and the university culture” (p. PP2.2.4).
- Plan on lots of planning time: a dozen phone conversations, preliminary events in which LSC explained the program to PCCM scientists.
- LSC provided travel packets for scientists – info about LSC, museum and exhibit brochures, driving directions, parking pass, business card.
- Presentations by scientists should enhance exhibition experience. “The scientists did not have experience in working with the family audiences that attend science centers. To help frame the discussions and keep presentations consistent in tone and educational level, the demonstrations educator Erich Goldstein at LSC developed a humorous 30 minute script, “The Chain Gang,” which PCCM, in turn, tweaked for the faculty. This script was designed to help scientists introduce the world of polymers to general audiences while allowing plenty of opportunity for kids to participate. We then modified it and added a couple of activities to suit the scientists’ needs….the script was essential in allowing the scientists to understand the level at which they would be communicating to these young audiences. Some of the scientists stuck closely to the script while others deviated from it substantially” (p. PP2.2.4). The script is available at www.princeton.edu/~pccm/outreach/LSCPCCMPolymerShow.pdf.
- Scientists could not use PowerPoint slides or viewgraphs or equations. “This presented quite a challenge for many of the faculty” (p. PP2.2.5).
- Important aspects for the script: a complete list of materials; instructions for how to run each demo; language of the script as appropriate for the level of visitor even though faculty chose adapt.
- Materials: fairly easily acquired and safe; materials kits kept at both PCCM and LSC.
- Training sessions for scientists: “Having a full set of supplies enabled us to conduct practice and training sessions at any time at PCCM….A few days before each individual or group was scheduled to present the outreach director would go over the script with the scientists to be sure they were comfortable with it, making adjustments as needed for different areas of expertise” (p. PP2.2.5).

“The demonstrations were apparently successful. Each week Liberty Science called or sent an e-mail praising the efforts of the scientists. This praise was based on the audience reaction to these wonderful shows. Also each and every week a scientist or group of scientists came back and expressed how happy they were to have been a part of this program and truly enjoyed the experience….It is near perfect synergy in which research centers provide the science expertise and science centers and museums provide their expertise in serving family audiences” (p. PP2.2.6).

Contact: P.I. Richard Souza, souza@mrs.org

References:

Randi Korn & Associates. (1999, October). *A front-end evaluation of Materials MicroWorld*. Prepared for the Materials Research Society. Made available by Richard Souza, Materials Research Society, October 11, 2005.

Randi Korn & Associates. (2002, August). *The Materials Research Society Select "Materials MicroWorld" Exhibits Formative Evaluation Phase I.* Made available by Richard Souza, Materials Research Society, October 11, 2005.

Randi Korn & Associates. (2002, November). *The Materials Research Society Select "Materials MicroWorld" Exhibits Formative Evaluation Phase II.* Made available by Richard Souza, Materials Research Society, October 11, 2005.

Randi Korn & Associates. (2004, August). "*Strange Matter" Summative Evaluation.* Prepared for the Materials Research Society. Made available by Richard Souza, Materials Research Society, October 11, 2005.

Romanaux, E. (2005, January/February). Polymer power: Partnering to enrich an exhibition. *Dimensions*, 6-7.

Steinberg, D. (2005). A new type of partnership for science outreach: Princeton Center for Complex Materials, Strange Matter and the Liberty Science Center. Materials Research Society Symposium Proceedings, 861E. Retrieved August 19, 2005, from www.mrs.org/publications/ epubs/proceedings/fall2004/pp/PP2_2.pdf.

Too Small to See

<u>What it is:</u>
NSF Award Abstract - #0426378 "Cornell University, through Main Street Science (the education program of its Nanobiotechnology Center), proposes to create a 3,500 sq. ft. traveling exhibition on nanoscale science and engineering in partnership with Sciencenter of Ithaca, New York. Intellectual Merit: The exhibition will address two questions: How do we see things too small to see, and how do we make things too small to see? In sections titled Small, Smaller, Nano; Seeing Nano Structures; Making Nano Stuff; and Nano and Me, hands-on activities and experiences will present the tools, processes and applications of nanoscale science and engineering for children ages 8 to 13 and adults. Broader Impact: This traveling exhibition is projected to reach some three million visitors in at least six sites as part of its national tour. It will then become a permanent exhibition at Sciencenter. Dissemination will be supported by a web site, take-home materials, a children's book and activities to carry out at home, along with links to formal education." Retrieved from www.nsf.gov.

<u>Target Audience:</u>
Museum visitors, primarily 8-13 year olds and adults

<u>Goals:</u>
1. "Learn how things that are too small to see are made visible and analyzed"
2. "Experience and remember features of the nanoscale 'landscape'"
3. "Acquire hands on experience and be able to name some technologies used to manufacture things at micro and nanoscale"
4. "Gain an understanding of nanoscale science and engineering as a field of research and as a career option" (*NISE: Too Small to See*, n.d., p. 6)

<u>Evaluation conclusions:</u>

Front-end (Waldron, Spencer & Batt, n.d.):
A survey of a stratified sample of 1500 people aged 6 to 74 reveals that most do not think on the level of nanoscale when asked for the smallest thing they can think of; that most have never heard of "nano" or "nanotechnology," and that most cannot correctly order in size the terms: milli, micro, nano, or the terms: atom, molecule, germ. College age respondents expressed the most familiarity with "nano" and "nanotechnology; " 71% say they have heard of the words.

Formative and summative not available yet.

<u>Contact:</u> P.I. Anna Waldron, Amw37@cornell.edu

<u>References</u>:
No author. No date. *NISE: Too Small to See*. Made available by Carl Batt, Cornell University, October 7, 2005.
Waldron, A. M., Spencer, D., & Batt, C. A. (undated). *Too small to see: The current state of public understanding of nanotechnology.* Made available by Carl Batt, Cornell University, October 7, 2005.

Marvelous Molecules – The Secret of Life

What it is: (see http://www.nyscience.org/marvelousmolecules/ae-abouttheexhibit.html)
Opening in 1999 at the New York Hall of Science, this 3500 sq. ft. exhibition features molecules for living, energy, moving, sensing, defending and reproducing. Exhibits include:

- Shared Chemistry of Living Things: Video about molecules interacting to make life happen
- Zoom to the Molecule: Computer simulations to peek inside the molecular structure of living things, like pheromones locking into a moth's sense organs
- Fluorescense Microscope: Daily demonstration of special microscope
- How Many Molecules are You?: Guess how many and what kind of molecules make life
- Build a Molecule Model: Hands-on building with snap-together plastic models
- How Many Molecules?: 3-D molecule display
- Food Energy from Molecules: Hands-on display of how eating provides us with energy
- Body Heat: Hands-on use of infrared camera
- EcoSphere: A System in Balance: View sealed aquarium
- How Muscles Work: Model showing how molecules work to create movement
- More Strength, More Molecules Moving: Test muscle strength
- Sensing Molecules: Solve 3-D smell puzzle[9]
- Molecules in Plants Kill Beetles
- Make a Medicine: Program to create a new medicine
- Engineering a Tomato: Program to create a tomato immune to frost damage
- DNA Molecule Model: DNA model and real DNA
- Fruit Fly Mutations: Witness how changes in small molecules result in major differences
- Your DNA and Your Traits: Test yourself for 8 different characteristics
- Giant Cellulose Molecule – 80 foot high icon[10]

Target Audience:
Museum visitors, primarily 12 years old and up

Goals:
"The big idea of the exhibition is: *Inside what appear to be very different living things, molecules interact in similar ways to make things happen*." (Serrell & Associates, 2001, p. 1)

Evaluation conclusions:
Summative (Serrell & Associates, 2001):
Photos, observations (n=30) and interviews (n=28 dyads) were used with casual adult and family visitors to assess a subset of the exhibit elements, ordered below by visitor counts.

---

9 Image from http://www.nyscience.org/marvelousmolecules/ae-abouttheexhibit.html#moleculesforsensing

10 In addition, The New York Hall of Science has a Scanning Electron Microscope and an online game that is a simulation of the microscope (see http://www.nyscience.org/nyhs-interact-online/io-microscope.html). Also at the Hall is Realm of the Atom described online as: "Discover what makes all matter matter. Realm of the Atom shows visitors an innovative approach to the quantum theory of how individual atoms behave. Examine the world's first 3-D dynamic model of an atom magnified one billion times." (http://www.nyscience.org/nyhs-exhibits/exhibits.html)

- Build a Molecule Model[11] was the most popular exhibit element, holding visitors from 19 secs. to 27 mins., with an average of 5 mins. Half of visitors duplicated models on display; the other half made up their own, and several did both. Some visitors and very young children did not know what the structures represented, but many understood the idea of atoms connected to each other to make molecules.
- Sensing Molecules was also popular and involves two parts: 1) "Visitors could sniff four different odors and compare two kinds of molecules, two visible ones and one that was concealed in a box but could be felt, before they lifted the top to see inside" (p. 18). Most visitors smelled, felt in the box and flipped the lid to look inside. 2) "Visitors could fit a small molecule puzzle piece into another large molecule graphic puzzle piece, and if it was the correct fit, a photograph lighted up (a human, a dog, a moth, an amoeba) and a sound was played (sniffing, fluttering, oozing)" (p. 20). Almost half of visitors used all four puzzles and repeated some. Children successfully used this exhibit alone.
- DNA Molecule Model and Fruit Fly Mutations let visitors "look at and read about a large model of a DNA molecule, see live mutated fruit flies…and see a test tube containing real DNA" (p. 21). Most visitors used the magnifying glass to look at fruit flies and DNA.
- Zoom to the Molecule involved computer simulations in which "visitors could choose a material and select various magnifications to zoom in on the molecular structure" (p. 21). The simulations had high holding times, and most users were solitary males.
- Food Energy from Molecules showed visitors "models of animals and their food and three molecular models. For each animal's food, the question was asked, What energy-rich molecules does __ contain? Each answer, under the flip label, was the same: fat, carbohydrates, and protein" (p. 17). One-third of the visitors looked at all three flip labels, with a high degree of recall.

Generally, observed visitors read labels, with most reading at the elements: Build a Molecule Model, DNA, Food Energy, and Sensing Molecules. Half of the elements in the exhibition were used by adults while their children were elsewhere.

The evaluators conclude that *"Marvelous Molecules* elicits lots of social interaction-with visitors calling each other over to "Look!" at the exhibits, reading labels and reading out loud and evidence of recalling the big idea, as well as remembering many specifics about the individual elements. Almost every element showed some strengths, either in terms of popularity, time spent or learning behaviors. The not-so-good news is that the concepts may not be comprehended by a majority of children under 12 and some of the adults" (p. 26).

<u>Contact</u>: Martin Weiss, VP Science, mweiss@nyscience.org

<u>References:</u>

Serrell & Associates. (2001, July). *Marvelous Molecules: The Secret of Life* Summative Evaluation. Retrieved October 25, 2005 from www.informalscience.org/tools/summative.html.

[11] For clarity, the element titles of the 2001 evaluation have been changed to match the element titles in the current online exhibit description. Two elements in the evaluation could not be matched to the current exhibit elements online and so are not discussed in this summary.

NanoDialogue project

What it is: (see http://icadc.cordis.lu/fep-cgi/srchidadb?CALLER=EN_NEWS&ACTION=D&SESSION=&RCN=24075)

The European Union's NanoDialogue project "began with a workshop, held in June 2005, based on the 'exhibition game' methodology, to design the content of the project's communication instruments. These include: seven interactive exhibition modules including hands-on exhibits; multimedia and educational products on N&N; and a website for disseminating information and for collecting feedback…. The exhibition modules will be shown in the eight participating countries over the course of at least six months, starting in February 2006. Simultaneously, a series of locally organized events, science demonstrations and debates will be organized to further engage citizens. Once the project is completed, at the end of February 2007, the exhibition modules will be shown elsewhere in the participating countries (Belgium, Estonia, France, Germany, Portugal, Spain and Sweden)."

The project partners include eight science centres around Europe, as well as ECSITE, the European Network of Science Centres and Museums. In order to include issues of social participation, the project consortium also includes the Centre for Studies on Democracy at the University of Westminster in the UK.

Target audience:
EU museum visitors - adults

Goals:
1. To communicate to the general public the latest research developments in nanotechnology
2. To engage researchers, civil society and citizens in a social dialogue on nanotechnologies and their related sciences

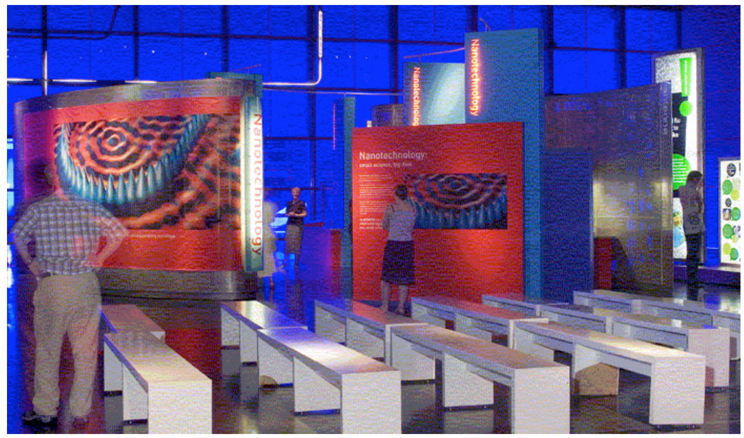
Evaluation conclusions:
"The project will collect and analyze feedback from the workshop participants, in the exhibitions and via the website. The feedback will be used to formulate a series of recommendations to the European Commission on the 'governance' agenda in the European Research Area (ERA). The recommendations will be discussed in a final European conference gathering relevant experts, decision makers and stakeholders."

Contact: Project coordinator Luigi Amodio, Director, Fondazione IDIS - Città della Scienza ONLUS (Italy) amodio@cittadellascienze.it

References:
Press Release. (2005, June 30). *NanoDialogue project to engage the public in a debate on nanotechnologies and nanosciences.* Retrieved October 1, 2005, from http://icadc.cordis.lu/fep-cgi/srchidadb?CALLER=EN_NEWS&ACTION=D&SESSION=&RCN=24075

Nanotechnology: small science, big deal

What it is:[12] (see http://www.sciencemuseum.org.uk/antenna/nano/)



At the Science Museum, London, is a new space referred to as Antenna, which presents science and technology news. The traveling exhibit "Nanotechnology: small science, big deal" was on view for 6 months in the Antenna space and is currently touring the UK.

Five sections of the exhibit examine applications in

1) Healthcare: Products on the market now; areas of research that could detect disease early or target drugs towards specific areas of the body.
2) Environment: Energy generation such as cheaper, more efficient solar cells; pollution prevention and clean-up; carbon nanotubes to filter water; issue of manufactured nanoparticles getting into environment;
3) Home: Examples of clothing, sports gear, scratch-resistant paint, self-cleaning windows;
4) Security: Items for crime fighting, surveillance, military;
5) Communications: Decreased display size; increased memory power

The sixth section looks at the science, communicating about scale and how scientists see and manipulate matter on the nanolevel. This area shows an atomic force microscope, a scanning tunneling microscope and buckyballs (Quinton-Tulloch, 2005).

A feedback touch-screen interface addresses more complex social and ethical issues: the software asks a question, provides three videos of people giving alternative opinions, provides an option for more text information, and permits keyboard submission of the visitor's opinion. The comments will be sent to the Government Dept. of Trade and Industry (Quinton-Tulloch, 2005).

Target Audience:
Museum families with children 11 years and older. Independent adults.

Goal:
Main message: "Nanotechnologies are the ability to see, model and manipulate matter on an atomic scale and apply it to making products. They will have a big impact in your life but there are many technical and ethical questions we still need to answer" (Quinton-Tulloch, 2005, p. 3).

Level 2 messages:

- "Nanotechnologies depend on nanoscience – research at the nanoscale where things work differently.

[12] Exhibit image provided by Jo Quinton-Tulloch, Science Museum, London

- Nanotechnologies are used in many areas of research and industry but are in the very early stages of development and will have a wide variety of applications.
- The UK is one of the leaders in nanoscience.
- The UK is the world leader in the social and ethical implications of nanotechnology.
- People are concerned about the risks of nanotechnologies. There is a lot of hype surrounding nanotechnologies – and we aren't as far along as images in the media portray.
- The future of nanotechnology applications is not determined. There are many ideas around at the moment and not all of them will happen, and not all of them will be important or revolutionary" (Quinton-Tulloch, 2005, p. 8).

Evaluation conclusions:

Front-end (Quinton-Tulloch, 2005):
Museum visitors most frequently conceive of nanotechnology as tiny robots going into people's bodies. The most interesting topics included how nanotechnology is done; benefits; and medical applications. The least interesting topics were risks and computer applications. "We also noted that primary school children have trouble reading and understanding words like 'nanotechnology,' 'benefits,' and 'applications' and haven't heard of atoms and molecules" (p.3).

Summative (Quinton-Tulloch, 2005):
Exit questionnaires of 24 family groups and 24 independent adults; observation of stations; and accompanied visits with 4 families and 4 independent adults using meaning maps conclude:

- Limited understanding of, a positive attitude toward, and an interest in learning about nanotechnology prior to visiting the exhibit
- Broader and deeper understanding of nanotechnology and reinforcement of positive attitude after visiting the exhibit
- All visitors increased their knowledge of nanotechnology; almost all visitors identified one or more of the top-line messages of the exhibit
- Almost half of visitors increased awareness of debates surrounding nanotechnology
- "Particularly families consider nanotechnology specifically in relation to their every-day lives; whereas independent adults also consider the implications of nanotechnology for society, policy and the government" (p. 6).

Contact: Head of Exhibitions and Galleries Jo Quinton-Tulloch, Science Museum, London, Jo.Quinton-Tulloch@nmsi.ac.uk

References:

Quinton-Tulloch, J. (2005, October 17). *Nanotechnology: What is it and what are we doing about it?* Presentation at annual meeting of Association for Science-Technology Centers, Richmond, VA. Made available by Jo Quinton-Tulloch, Science Museum, London, October 25, 2005.

Nanotechnology
Micromachine

What it is: (see http://www.miraikan.jst.go.jp/e/exhibition/index_fla.html)
Tokyo's National Museum of Emerging Science & Innovation (nicknamed Miraikan) includes four themes, one of which is Innovation and the Future. Within this theme are four major exhibition areas: Robot World, Superconductivity, Nanotechnology, and Micromachine. The latter two areas are described briefly below.
The nanotechnology area ranges from the basics to applications, using models, computer graphics and actual devices. Exhibits include:

- Wonders of the nanoworld: 3-D model to visualize electrons as waves
- A world built by nanotechnology: Videos and models describe large-scale integration semiconductor elements
- Electronics and nanotechnology: History and future of miniaturization
- Optoelectronics and nanotechnology: Information and communication systems using lasers utilizing nanotechnology
- Quantum effects and nanotechnology:[13] Models and computer graphics introduce the nature of electron waves and their usage
- Scope of the nanoworld: Videos and images presenting the range and forms of the nanoworld
- Interviews with researchers: Videos of researchers at the forefront
- Nano Encyclopedia

The micromachine area explains how micromachines are made, what products they are used in, how they work and how they will evolve. Exhibits include:

- What are micromachines? Visitors can move micromachines through a microscope and compare with normal machines
- Production of micromachines: Models and videos present methods for creating machines that are 1/100th of a millimeter
- Micromachines in daily life: Microsensors; micro functional parts
- Understanding micromachines in further depth and scope: Create your own micromachine
- Interviews with researchers: Videos of researchers on the forefront

More generally, the museum director, describes nanotechnology activity at the museum:
"At the nanotechnology exhibit, the interpreters and volunteers combine to offer visitors an excellent opportunity in understanding real atomic force microscopy and scanning electron microscope technology. The staff shows visitors several images of materials in micro- and nanometer size, and helps visitors understand how the equipment works. Visitors observe the surface image of a CD, in real time, and this has proven invaluable in their understanding of the nanoscale phenomena. We also have classroom laboratories where guest scientists, who are very much active in their particular field, come to teach and work with children of all ages. These scientists include Nobel Laureates like Dr. Shirakawa who was awarded the Nobel Prize in 2000

[13] Image from http://www.miraikan.jst.go.jp/e/exhibition/d_nano_quant.html

for chemistry. In addition to the special guest lab classes, we have on-going science workshop classes that teach students of all ages about superconductivity, DNA, and building and operation robots. In addition, we also have 6 world-class laboratories that are involved with on-going research. Each Saturday, there is a tour provided by volunteers, so, let's look at what we call the 'Lab Tour'. This is a unique way to introduce people to real, cutting-edge science. Of the six running labs we have at Miraikan, one is a laboratory where project teams of researchers carry out the latest research and development on nanoscience and nanotechnology. The 'Nanospace Project' is funded by the government, and is conducting creative, high level research. Visitors have the chance to interact with researchers through a lecture directly in front of the glass wall of the lab, a tour of the lab, and then a sit down session over coffee with the scientists. Volunteers coordinate and run the entire tour" (Mohri, 2004, p. 3).

Target audience:
Museum visitors

Goals:

1. "Present concepts and guidance from leading scientists.
2. Focus on the interconnection between science and technology and society, with science and technology being perceived as a human activity.
3. Explore various aspects of science and technology also including background themes and the impact on nature.
4. Develop methods that make science and technology easy to understand.
5. Strive to maintain our viewpoint of considering the relationship between our future society and science and technology." (http://www.miraikan.jst.go.jp/e/miraikan/aboutus.html)

Evaluation conclusions:
The museum director, Mamoru Mohri (2004) reports in a recent presentation:
"…we conduct surveys of our visitors and they have told us that their interest in science grew, they understood more than they ever had before and that they were more comfortable with science and therefore were more willing to ask questions. We also have a high return rate of visitors, many being students who visited on a school trip and wanted to return on their own. The only negative comments were requests for more of a particular display or exhibit. A typical response to our Lab Tour is this example. We surveyed participants, and according to the results, the tour works! 95% of those surveyed were interested in Nanotechnology after the tour, and 78% of those surveyed could understand the concept of, 'nanotechnology'" (p. 4).

Contact: Deputy Director Noyuri Mima, n-mima@miraikan.jst.go.jp

References:
Mohri, M. (2004, December 4). *The human face of science.* Presentation to Asian-Pacific Economi Cooperation Science Centre Impact Project Forum. Retrieved October 24, 2005 from http://www.aspacnet.org/apec/conferences/scoping_meeting.html

Northwestern NSEC museum exhibit with Museum of Science and Industry, Chicago

What it is: (see http://www.nsec.northwestern.edu/museum.htm)
Northwestern University's Nanoscale Science and Engineering Center (NSEC) "has entered into a partnership with the Museum of Science and Industry, Chicago (MSI) on the development of a conceptual design plan for a unique exhibit on nanoscale science. Center research will inform the content and concept of the exhibit, and the development team (including Dr. Barry Aprison, Director of Science and Technology, and exhibit developer, Dr. Patricia Ward, from the museum, plus center researchers, a design firm, a multimedia group, and an evaluator) are taking the project from early stages of brainstorming to compelling conceptual design plans, through front-end evaluation, creative interpretive design activities, formative evaluation, and exhibit modeling. The exhibit will reflect areas of cutting-edge research of the center and the museum's commitment to presenting captivating, interactive experiences that are memorable and thought provoking. Once completed the exhibit will increase knowledge about nanoscale science and its powerful applications in the 21st century to more than two million museum visitors annually."

Target Audience:
Middle school level museum visitors, parents and teachers

Goal:
"To develop effective interactive experiences that promote interest, understanding, and learning about nano-scale science and nanotechnology." (B. Aprison, personal communication, October 30, 2005)

Evaluation conclusions:

Front-end: (Gilmartin, 2002)
Open-ended interviews of 41 visitor groups were conducted at the Museum of Science and Industry in Chicago in the summer of 2002. Awareness and knowledge of nanotechnology was relatively low:

- 44% of visitor groups had heard of the term "nanotechnology."
- 10% of visitor groups could correctly explain the term, typically referring to applications.
- Some related nanotechnology to time, as in nanoseconds.
- Visitors were most familiar with applications of high-speed computer chips, nanobots and biosensors, although some were uncertain whether the application they noted was actually a nanotech application.

The researcher notes that words like "molecules, atoms and matter, while familiar, provoked discomfort" among interviewees, particularly those without science background. The phrase "the building blocks of all physical things" was less discomforting.

Most groups saw only positive benefits to nanotechnology but some expressed general fears associated with any emerging technology. Issues raised concerned medical side effects, privacy and regulatory control.

Visitors were given the following definition of nanotechnology:

> "Nanotechnology is an emerging field of technology that is developing out of the science of the very small (one billionth of a meter) – the world of atoms and molecules, the building blocks of all physical things. Note: A nanometer is one billionth of a meter; a molecule is about 1 nanometer in size. Tools that can be used to see, pick up, and move atoms allow us to build nano-sized structures and devices with unprecedented capacities for information processing and storage, electrical conductance, and bio- and chemical- sensing."

Once introduced to the definition of nanotechnology, visitors were most interested in:

- The small scale of the science
- Personal benefits of technology applications
- Cutting-edge and contemporary nature of the topic

More knowledgeable visitors were interested in applications, current developments and learning about how devices are made. Less knowledgeable visitors were interested in medical applications. Most everyone was intrigued by the small scale of nanoscale science. Comparing nano size to human hair was successful in helping visitors understand the small scale, but visitors had difficulty grasping the physical structure of a nano object.

From listening to visitors' reactions to exhibit ideas, the study concludes that visitors want to

- Learn about new technologies – applications; personal relevance; breaking news; risks;
- Try out some things that scientists are doing – manipulate atoms and materials
- See what's behind technologies – see devices and how they work
- See specific examples – e.g., see biosensor used

Strategies for exhibits in nanotechnology suggested by the researcher include:

- "Starting small" – creatively communicate the nano size
- "Emphasize the new" – present cutting-edge information
- "Capitalize on visitor excitement on breakthrough technology to demonstrate their role and involvement" – present information about publics role in science
- "Address fears and concerns" like self-replicating robots and bioimplants going awry
- "Present easily digestible information"

Contact: P.I. Barry Aprison, barry.aprison@msichicago.edu

References:

Gilmartin, J. (2002). *Nanotechnology: Front-end evaluation report.* Museum of Science and Industry: Chicago, IL. Made available by Barry Aprison, Museum of Science and Industry, August 18, 2005.