Nanotechnology: Small Science, Big Deal!

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General Description

Type of program:

Cart Demo

This cart demonstration reviews the basics of nanoscale science, engineering, and technology (nano) through a number of hands-on activities. Visitors learn that nanometer-sized things are small and often behave differently than larger things do, and that work in this emerging field leads to new knowledge and innovations. Visitors also consider the potential costs, risks and benefits associated with nanotechnologies.

Program Objectives

Learning goals:

As a result of participating in this program, visitors learn that:

1. Nanometer-sized things are very, very small.
2. Nanometer-sized things often behave differently than larger things do.
3. Nanoscientists and engineers study and make tiny things.
4. Nanoscientists and engineers are creating new technologies and materials.
5. Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

NISE Network content map main concepts:

[x] 1. Nanoscale things are very small, and often behave differently than larger things do.

[x] 2. Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.

[x] 3. Nanoscale science, engineering, and technology lead to new knowledge and innovations that weren't possible before.

[x] 4. Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

National Science Education Standards:

1. Science as Inquiry
    - K-4: Understanding about scientific inquiry
    - 5-8: Understanding about scientific inquiry
    - 9-12: Understanding about scientific inquiry

2. Physical Science
    - K-4: Properties of objects and materials
    - 5-8: Properties and changes of properties in matter
    - 9-12: Structure and properties of matter

5. Science and Technology
    - K-4: Abilities to distinguish between natural objects and objects made by humans
    - K-4: Abilities of technological design
    - K-4: Understanding about science and technology
    - 5-8: Abilities of technological design
    - 5-8: Understanding about science and technology
    - 9-12: Abilities of technological design
    - 9-12: Understanding about science and technology

6. Personal and Social Perspectives
    - K-4: Science and technology in local challenges
    - 5-8: Risks and benefits
    - 9-12: Natural and human-induced hazards
    - 9-12: Science and technology in local, national, and global challenges

7. History and Nature of Science
    - K-4: Science as a human endeavor
    - 5-8: Science as a human endeavor

Table of Contents

Time Required

Set-up	Program	Clean Up
		
5 minutes	20 minutes	5 minutes

Background Information

Definition of terms

Nano is the scientific term meaning one-billionth (1/1,000,000,000). It comes from a Greek word meaning “dwarf.”

A nanometer is one one-billionth of a meter. One inch equals 25.4 million nanometers. A sheet of paper is about 100,000 nanometers thick. A human hair measures roughly 50,000 to 100,000 nanometers across. Your fingernails grow one nanometer every second.

(Other units can also be divided by one billion. A single blink of an eye is about one-billionth of a year. An eyeblink is to a year what a nanometer is to a yardstick.)

Nanoscale refers to measurements of 1-100 nanometers. A virus is about 70 nm long. A cell membrane is about 9 nm thick. Ten hydrogen atoms are about 1 nm.

At the nanoscale, many common materials exhibit unusual properties, such as remarkably lower resistance to electricity, or faster chemical reactions.

Nanotechnology is the manipulation of material at the nanoscale to take advantage of these properties. This often means working with individual molecules.

Nanoscience, nanoengineering and other such terms refer to those activities applied to the nanoscale. “Nano,” by itself, is often used as short-hand to refer to any or all of these activities.

Materials

The materials for this program are all included in the NanoDays 2012 kit.

Exploring Materials—Nano Gold (NanoDays 2012)

- Vial of gold flakes
- Vial of red nano gold (20 nm)
- Vial of orange nano gold (80 nm)
- Samples of stained glass made with gold
- Micro-light (very bright white LED)
- Sheet of white paper

Exploring Forces—Static Electricity (NanoDays 2011 and 2012)

- Tube of large balls
- Tube of small balls
- Polar fleece

Recommended: Exploring Properties—Surface Area (NanoDays 2008, 2009, 2010)

- 100 ml graduated cylinders (2)
- Small plastic measuring cups (2)
- Pitcher
- Effervescent antacid tablets
- Food coloring

Exploring Structures—Butterfly (NanoDays 2012)

- Butterflies in protective case
- LED flashlight
- “Blue Morpho Butterfly” image sheet

Exploring Materials—Graphene (NanoDays 2012)

- Flakes of graphite
- Plastic tweezers with a pointed tip
- Scotch tape
- White cards
- Soft drawing pencils
- Pencil sharpener
- Battery and bulb circuit
- “Graphene” image sheet

Exploring Size—Ball Sorter (NanoDays 2012)

- Nesting sieves in three sizes
- Small balls in three sizes
- Container for balls

Set Up

Time

5 minutes

- Set out the materials for each of the activities.
- For optional Exploring Properties—Surface Area demo: Pour 15 mL of green colored water in each of the two small measuring cups. Crush one of the effervescent antacid tablets.
- Review background information for each activity.

Program Delivery

Time

20 minutes

Safety

Exploring Materials—Nano Gold:

- **Do not let visitors ingest the contents of the gold vials.** Keep vials sealed shut.
- **Use caution when handling the stained glass samples.** Do not remove them from their protective case.

Exploring Properties—Surface Area:

- **The antacid tablets contain medication.** Visitors should be supervised when doing this activity, and should not be allowed to consume the tablets or the water they're dissolved in.

Talking points and procedure

Slide 1:

Today we are going to talk about nanoscale science, engineering and technology. Have you ever heard about *nano?* That's OK, you're not alone. It's new. (Or: You have? What have you heard?)

Nano is a prefix, like mega -or micro-. You've probably heard of megabytes or microscopes. Nano basically means small.

Slide 2:
In this program, we'll learn about four concepts related to nano:

1. **Nano is small and different:** Nanoscale things are very small, and often behave differently than larger things do.
2. **Nano is studying and making tiny things:** Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.
3. **Nano is new technologies:** Nanoscale science, engineering, and technology lead to new knowledge and innovations that weren't possible before.
4. **Nano is part of our society and our future:** Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

Slide 3:
Let's get started by talking about what the prefix "nano" means, and some of the ways that nanometer-sized things behave differently or act in surprising ways.

Slide 4:
A nanometer is very small. Can you hold up your hands so they are a meter apart? When I hold out my arm, the distance from my nose to the tips of my fingers is about a meter. A 6-year-old child is about one meter tall.

The picture in the middle is of a red blood cell. A red blood cell is about one-millionth of a meter—a micrometer across.

A nanometer is one thousand times smaller than a red blood cell. A red blood cell is 1 micrometer, or 1000 nanometers, across.

The picture on the right is a DNA molecule. DNA is found in your cells. A DNA molecule is 2 nanometers wide.

Slide 5:
Perform demo: *Exploring Materials—Nano Gold*

> Can you describe the material in this vial? (Show the vial with the bulk gold.) This is the size of gold we are used to seeing. It is gold or yellowish in color.
>
> But in this vial I have nano-sized particles of gold. (Show the vial with the nano-sized gold.) What color is it? Red/ orange.

Nanoscale gold can be red, purple or blue depending on the size of the particles and the distance between them. Nanoscale gold has been used in red stained glass since the Middle Ages!

The photo on the right is of nano-sized gold particles. The different colors are because the gold nanoparticles are different sizes. The middle picture is of a stained glass window. The red glass could be colored by nano-sized gold particles.

Slide 6:
There are other things that change when material is nano-sized. Different forces dominate at the nanoscale, making things behave in unexpected ways.

For example, geckos can climb up walls and across ceilings, but there's no glue on the bottom of their feet! Instead, millions of tiny, nano-sized "hairs" form bonds with the wall. These tiny structures, called *setae*, are only about 200 nanometers wide. Molecules in the setae are attracted to molecules in the wall, and they form a temporary bond. While each bond is weak, there are enough setae that the intermolecular forces overcome the force of gravity. To move, the gecko tilts it foot, breaking the bonds.

Perform demo: *Exploring Forces—Static Beads*

> Do you see a difference in how the balls behave in the two tubes? The small balls seem to float; they are more affected by static electricity than by gravity. The larger balls are more affected by gravity.
>
> When things are very, very small gravity can be a less important force.

Slide 7:
There are other ways that small things act differently from big things.

Recommended Demo: Exploring Properties—Surface Area

> Here we have two tubes and two cups of water. And I have two tablets, one that I'm going to put in the tube, and the other, which I crushed into powder. (Visibly pour the powder into the cylinder.)
>
> I need two volunteers to pour the water. What do you think is going to happen? Ready? Go! (Have them pour.)
>
> The small bits acted differently than the big tablet, because they were smaller.

When a material is nano-sized, chemical reactions often go faster. That's because reactions occur on the surface of objects, and nanoscale objects have a lot of surface area per unit of volume. Aluminum, used everyday in drink cans, can be explosive when the aluminum particles are nano-sized!

Slide 8:
Let's talk about how scientists and engineers study and make nano-sized things.

Slide 9:
Everything on Earth is made of tiny building blocks called *atoms*. Atoms are tiny particles smaller than a nanometer. The way that these tiny building blocks are arranged helps determine the properties, or behavior, of a material.

These three pictures all have something in common. These things are all made of carbon atoms. Carbon atoms can form diamond, the hardest natural material known on Earth. But they can also form a much softer material, graphite (pencil lead). Both diamonds and graphite are made entirely from carbon atoms.

They have different properties because the carbon atoms are arranged differently. Diamonds are hard and shiny because they have a sturdy molecular structure. Graphite is soft and slippery because its carbon atoms are stacked in sheets.

Carbon can form nanometer-sized structures, including carbon nanotubes and buckyballs. Like larger forms of carbon, these tiny objects have special properties due to the way their carbon atoms are arranged. Researchers are studying how to grow these nanoscale forms of carbon, and use them to build nanotechnologies.

Slide 10:
Computer chips are a good example of nanotechnology we use every day.

Intel currently makes computer chips with tiny features that are only around 30 nm across. 60 million transistors this small can fit on the head of a pin! This is about as small as we can go with current manufacturing techniques. To make even smaller, faster chips, we'll need new technologies.

Slide 11:
To make tiny new nano-sized devices, researchers are studying *self-assembly.* Self-assembly is a process where things grow themselves. This happens all the time in nature. For example, water molecules self-assemble into ice crystals and fall to the ground as snowflakes. Researchers are learning how to make different objects self-assemble in the lab.

Video of snowflake growing:

> This is a video loop of a snowflake self-assembling in a laboratory. Some researchers are working on finding ways to get other kinds of structures to self-assemble. There are already computer chips on the market that are created (in part) through self-assembly of silicon crystals.

Slide 12:
Nanoscientists are inspired by other things in nature, too. One example is the Blue Morpho butterfly.

Perform demo: *Exploring Structures—Butterfly*

(Shine the light through the yellow butterfly). When I turned on the light, the yellow butterfly stays yellow. That's because the yellow color comes from pigment. This is like the color in paint.

Let's look at what happens when I shine the light through the blue butterfly. (Shine the light through the Blue Morpho butterfly from the back.) Where the light shines through, the blue color disappears. That is because Blue Morpho butterflies have colorless scales with nano-sized ribs.

The blue color you see is created by the reflection of light off these tiny nanostructures. Scientists are using similar colorless nanostructures in low energy displays.

Slide 13:
Scientists and engineers are developing new nanotechnologies.

Slide 14:
Nanotechnologies could transform the ways we create, transmit, store, and use energy. Some scientists think nanotechnology will allow us to build ultra-efficient transmission lines for electricity, produce more effective and inexpensive solar cells, make cheap, efficient biofuels, and improve the safety of nuclear reactors. But more research and investment is needed before nano energy solutions can be developed or widely distributed.

Perform Demo: *Exploring Materials—Graphene*

This demonstration is with graphite, which is made of many layers of graphene.

To get a light bulb to light up, you need to complete the circuit. Wires need to connect the light bulb and the battery. If I touch the wires to this area where I drew with a pencil, the graphite is a conductor, just like a wire, completing the circuit and lighting the bulb.

The 2010 Nobel Prize in Physics was awarded to two scientists for producing and studying graphene. Graphene is a sheet of carbon, like the graphite in pencils, but it is only one atom thick. Why is this interesting? Graphene can be used in very small computer chips because it can be made into a tiny semiconductor.

Slide 15:
Nanotechnology might lead to improvements in healthcare. Remember the red-colored nano gold? That might one day be used to treat cancer! Therapies using nano gold are currently in clinical trials with humans. In the therapy, nano gold is injected in the blood and used with near-infrared light to heat and kill tumors with very little harm to nearby tissue.

Slide 16:
Another new use for nanotechnologies is in water filters.

Perform Demo: *Exploring Size—Ball Sorter*

> In this container, I have different sizes of balls. To separate the balls by size I can use this stacked set of sieves.
>
> Just as I was able to use sieves to separate the different sizes of balls, a nanofilter could remove very small things like viruses or salt from our drinking water!

Slide 17:
Nanotechnology will affect our economy, environment and personal lives.

Slide 18:
Many technologies can be viewed as either good or risky, depending on the circumstances. Can you think of a time when fire is a good or useful thing? (Heating, cooking) What do we do to protect ourselves when fire is not a good thing—when it's dangerous? (Fire extinguisher, fire department)

Nanotechnology has potential for new and improved technologies, but we may also have to think about potential risks and how to protect ourselves.

Slide 19:
The discussion of how nanotechnology is to be part of our society and our future is the responsibility of everyone, not just scientists and engineers. You are already making decisions about whether or not to use nanotechnologies, though you may not always know it.

Slide 20:
How many of you use sunblock? Many sunblocks contain nano-sized particles of zinc oxide or titanium dioxide.

Perform Demo: *Exploring Products—Sunblock*

> The sunblock rubs in better than the ointment because it contains tiny, nano-sized particles of zinc oxide. The nanoparticles of zinc oxide are so small that they don't reflect visible light, making the sunblock transparent on skin.

The ointment also contains zinc oxide, but the particles are much bigger. Both products are equally effective at absorbing UV radiation and keeping it from reaching your skin. Many people prefer sunblock that rubs in clear, but some are concerned about having nanoparticles in the products they use.

Slide 21:
Let's review what we've learned. What do you remember about nano?

Slide 22:
Nano is:

- Small and different
- Studying and making tiny things
- New technologies
- Part of our society and our future

Do you have any questions?

Thanks for stopping by today!

Tips and troubleshooting

This presentation can be very long, especially if you field a lot of questions or add additional information to the various parts. Try to adjust your pacing based on your audience's response. Feel free to go more quickly through some parts or to add in additional information for an interested audience. You can also replace some of these demonstrations and activities with different ones.

Common visitor questions

Is sunblock with nanoparticles safe?

Research shows that sunblock containing nanoparticles of zinc oxide or titanium dioxide is safe to use. The zinc and titanium minerals in the sunblock don't go through the outer layer of healthy, adult skin. Still, some people have concerns about the use of nanoparticles in sunblock and other products.

How are gold nanoparticles used to treat cancer?

Gold nanoparticles can be made so that they absorb near-infrared light and heat up. Infrared is the color that comes out of a remote control. This light is invisible and passes right through our bodies without doing any harm.

The therapy is in clinical trials with humans. Nano gold is injected into the blood. It collects at the cancer tumor. Near-infrared light is shined on the tumor site. The light passes through the body, except where the gold nanoparticles have collected in the tumor. The gold heats up, burns the tumor and destroys it, with very little harm to nearby tissue.

Going further…
Here are some resources you can share with your visitors:

NISE Net has a website with information and activities for the public:
whatisnano.org

Intel has a video on the building of a fabrication plant, how chips are made and uses for microprocessors. The video is a little over 2 minutes long, and can be found at:
http://www.youtube.com/watch?v=duzO0YX4WnA

Clean Up

Time
5 minutes

Store all materials.

Exploring Properties—Surface Area: Clean and dry the graduated cylinders and other containers.

Universal Design

This program has been designed to be inclusive of visitors, including visitors of different ages, backgrounds, and different physical and cognitive abilities.

The following features of the program's design make it accessible:

[x] 1. Repeat and reinforce main ideas and concepts
- The presentation is organized into discrete chunks.
- A content overview is provided at the beginning of the program (program outline), and the content is summarized at the end of the program.

[x] 2. Provide multiple entry points and multiple ways of engagement
- Concise key phrases are used to support main ideas.
- Main ideas are presented through multiple senses (sight, hearing, smell and touch).

[x] 3. Provide physical and sensory access to all aspects of the program
- Main ideas are presented through multiple senses (sight, hearing, smell and touch).
- Slides are made accessible by using large, high-contrast text and images and by using large, clear fonts.

To give an inclusive presentation of this program:
- Make sure your face is visible at all times.
- Make sure you don't stand in the way of the slides.
- Keep props and models visible when they are relevant.
- Pace the program so that visitors can follow the content easily.
- Pace the program so that the images, text, speaking and objects don't compete with each other.
- Ask the audience questions, and check in with them along the way to make sure they're engaged and with you.
- Use descriptive language when presenting objects and images.
- Make a handout of the presentation available to visitors, either to use during the presentation or to take home.
- Make sure your audience knows about any special accommodations you offer.

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