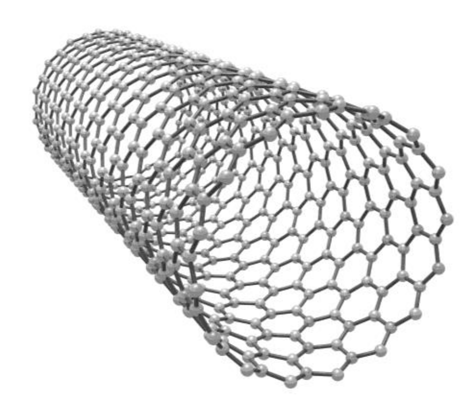
Exploring at the Nanoscale

Lesson Focus

Lesson focuses on how nanotechnology has impacted our society and how engineers have learned to explore the world at the nanoscale. Students participate in hands-on activities to understand exactly how small the nanoscale is, explore how surface area changes at the nano scale, and work in teams to develop futuristic applications of nanotechnology.



Lesson Synopsis

The "Exploring at the Nanoscale" lesson explores how nanotechnology has impacted the world, and how engineers have to consider the ramifications of working at a very small scale. Students work in teams and explore the increased surface area exposed as items are made smaller and smaller. Students examine and measure large blocks of tofu or gelatin, determining the surface area. Then they slice the block into smaller and smaller pieces, exposing more surfaces, and impacting the surface area. Students also explore the size of small, comparing various items to understand how large a nano is. They work as an engineering team to determine a new application of nanotechnology for a product or process of their choice. Teams present concepts and proposals to a group of potential research funders (the rest of the class) and each then vote for the proposal with the most potential. Student teams complete reflection documents.

Age Levels

8-14.

Objectives

- Learn about nanotechnology.
- Learn about scale.
- Learn about surface area.
- Learn about engineering design.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- nanotechnology
- problem solving
- teamwork

Lesson Activities

Students learn how engineers working at the nanoscale have a greater surface area to work with. Students work in teams to explore increasing surface area as large blocks are cut to multiple, smaller parts. They then explore a challenge of determining how nanotechnology might help engineers improve a product or a process, and present their proposal to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- TryNano (www.trynano.org)
- National Nanotechnology Initiative (www.nano.gov)
- Dartmouth Electron Microscope Facility Images (www.dartmouth.edu/~emlab/gallery)

Supplemental Reading

- Nanotechnology For Dummies (ISBN: 978-0470891919)
- Nanotechnology: Understanding Small Systems (ISBN: 978-1138072688)

Optional Writing Activity

- Write an essay or a paragraph about how nanotechnology might impact space exploration.

For Teachers:
Teacher Resource

Lesson Goal

The "Exploring at the Nanoscale" lesson explores how nanotechnology has impacted the world, and how engineers have to consider the ramifications of working at a very small scale. Students work in teams and explore the increased surface area exposed as items are made smaller and smaller. Students examine and measure large blocks of tofu or gelatin, determining the surface area. Then they slice the block into smaller and smaller pieces, exposing more surfaces, and impacting the surface area. Students also explore the size of small, comparing various items to understand how large a nano is. They work as an engineering team to determine a new application of nanotechnology for a product or process of their choice. Teams present concepts and proposals to a group of potential research funders (the rest of the class) and each then vote for the proposal with the most potential. Student teams complete reflection documents.

Lesson Objectives

- Learn about nanotechnology.
- Learn about scale.
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Materials

- Student Resource Sheet
- Student Worksheets
- One set of materials for each group of students:
  - Block of extra firm tofu or gelatin, cutting surface (plastic plate or cutting board), dull knife, ruler or measuring tape

Procedure

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
2. Surface Area Activity
   a. Divide students into groups of 2-3 students, providing a set of materials per group.
   b. Explain that students must work as a team to determine the surface area of a block of tofu at various points (whole, sliced in half, quartered, etc.). Students will first measure the full block and determine the surface area, then cut the block in half and refigure surface area, then half again, etc. -- until there are many tofu blocks of about ½ inch in width.
3. Nanoscale Applications Activity
   a. The same group of 2-3 students work to develop a proposal for a new application of nanotechnology.
   b. Presentations are made to potential research funders (the rest of the class) who vote for the proposal with the most potential.
4. Evaluation - Students complete evaluation/reflection sheets

For Teachers:
Teacher Resource

◆ Time Needed
Two to three 45 minute sessions

◆ Tips
- For younger students, a spice or sugar coating on the tofu or gelatin can help students visualize how the surface area has increased. Use a small amount of sugar or spice to coat a large tofu block, and then show students how much more sugar or spice is required to coat all the tiny cubes cut from the large block of tofu.
- For older students, incorporate a research period at www.trynano.org to learn more about applications and nanomaterials.

For Students:
What is Nanotechnology?

Imagine being able to observe the motion of a red blood cell as it moves through your vein. What would it be like to observe the sodium and chlorine atoms as they get close enough to actually transfer electrons and form a salt crystal or observe the vibration of molecules as the temperature rises in a pan of water? Because of tools or 'scopes' that have been developed and improved over the last few decades we can observe situations like many of the examples at the start of this paragraph. This ability to observe, measure and even manipulate materials at the molecular or atomic scale is called nanotechnology or nanoscience. If we have a nano "something" we have one billionth of that something. Scientists and engineers apply the nano prefix to many "somethings" including meters (length), seconds (time), liters (volume) and grams (mass) to represent what is understandably a very small quantity. Most often nano is applied to the length scale and we measure and talk about nanometers (nm). Individual atoms are smaller than 1 nm in diameter, with it taking about 10 hydrogen atoms in a row to create a line 1 nm in length. Other atoms are larger than hydrogen but still have diameters less than a nanometer. A typical virus is about 100 nm in diameter and a bacterium is about 1000 nm head to tail. The tools that have allowed us to observe the previously invisible world of the nanoscale are the Atomic Force Microscope and the Scanning Electron Microscope.

◆ How Big is Small?

It can be hard to visualize how small things are at the nanoscale. The following exercise can help you visualize how big small can be! Consider a bowling ball, a billiard ball, a tennis ball, a golf ball, a marble, and a pea. Think about the relative size of these items.

◆ Scanning Electron Microscope

The scanning electron microscope is a special type of electron microscope that creates images of a sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern. In a raster scan, an image is cut up into a sequence of (usually horizontal) strips known as "scan lines." The electrons interact with the atoms that make up the sample and produce signals that provide data about the surface's shape, composition, and even whether it can conduct electricity. Many images taken with scanning electron microscopes maybe viewed at www.dartmouth.edu/~emlab/gallery.

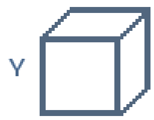
For Students:
What is Surface Area?

Surface area is the measure of how much exposed area an object has. It is expressed in square units. If an object has flat faces, its surface area can be calculated by adding together the areas of its faces. Even objects with smooth surfaces, such as spheres, have surface area.

◆ Square Surface Area Formulas

The surface area of a cube may be expressed by the formula:

x = 6 times Y times Y

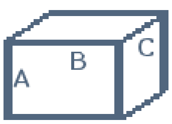


The drawing to the left shows a cube, where Y equals the length of each side. Because it is a square, all sides are equal in length. To determine the surface area of the cube, you first have to find out the area of one side. The area of one side is Y x Y or Y^2. To find the surface area of the cube, you need to multiply the area of one side by 6. If, for example, the length of Y equalled 10 mm, then the area of one side would be 100 square mm and the area of the cube would be 600 square mm.

◆ Rectangular Surface Area Formulas

The surface area of a rectangle may be expressed by the formula:

x = 4AB + 2AC



With a rectangle, all the sides are not equal…but there are three different lengths to be measured. If the drawing above, these are represented by A, B, and C. To determine the area of the front of the rectangle, we'll need to multiply A x B. Since there are four surfaces on the rectangle that are equal in size, we need 4 x A x B as one part of our formula to determine the surface area of the dimensional rectangle. We'll also need to determine the area of the two smaller surfaces. In this case, we'll need to multiply A x C. And, because there are two of these "faces" to the rectangle, we need 2 X A X C for the full surface area formula. If, for example, the length of A equalled 10mm, and B equalled 30mm and C equalled 15mm then:

A times B = 300mm, so 4AB= 1200 square mm

A times C = 150mm, so 2AC= 300 square mm

So the surface area of the dimensional rectangle is 1500 square mm

◆ Why Surface Area Matters

At the nanoscale basic properties of particles may vary significantly from larger particles. This might include mechanical properties, whether the particle conducts electricity, how it reacts to temperature changes, and even how chemical reactions occur. Surface area is one of the factors that changes as particles are smaller. Because chemical reactions usually take place on the surface of a particle, if there is an increased surface area available for reactions, the reaction can be very different.

Student Worksheet 1:
Surface Area Activity

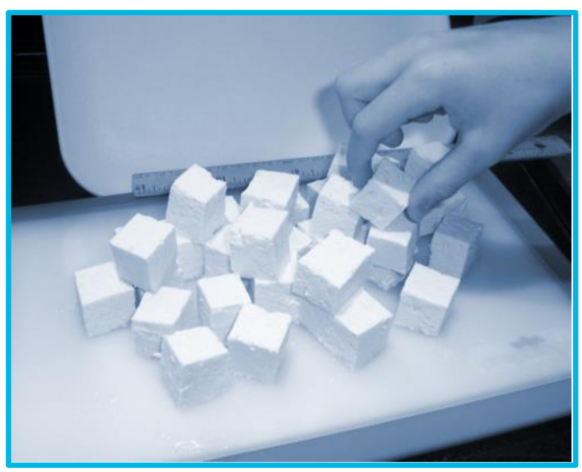
You are part of a team of engineers who has been given the challenge of evaluating how surface area changes as a material is made smaller. You have been provided with some sheets to read as well as a block of either tofu or gelatin, a cutting surface, a ruler, and a dull knife.

You will need to determine the surface area of the full block, and then the cumulative surface area of smaller blocks you create by cutting the original block in half, and quarters -- down to all blocks created at about ½ inch in width.

Use the chart below to indicate your findings:

# Blocks	**1 Block**	**2 Blocks**	**4 Blocks**	**8 Blocks**	**16 Blocks**	**32 Blocks**	**64 Blocks**
Surface Area:							



Student Worksheet 2:
Nanoscale Applications Activity

◆ Brainstorming Stage

Meet as a team and discuss what you learned about nanotechnology and surface area. Then as a group think about an application for nanotechnology that might improve a product, process, or help humanity. You can pick an industry such as automotive, or think about a product such as fabric for clothing, or whatever you choose!

◆ Presentation Stage

Prepare a proposal to a potential funding organization who you will request research funding. You'll need to explain why you think your new nanotechnology application may work, and how it will improve a product or process. This is a formal presentation and you may wish to prepare charts or presentation posters -- anything that might impress your potential funders. Be prepared to answer questions from your audience!

◆ Funding

Each student in the class may vote for one proposal by any team other than their own to be funded. Those presentations with the most votes come in first place!

◆ Evaluation Phase

Complete the following questions as a group:

1. What application did you develop for nanotechnology?

2. What application of nanotechnology did another team present that you found the most interesting? Why?

3. What is the most interesting aspect of nanotechnology you learned during this lesson?

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry
As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of the activities, all students should develop an understanding of
- Properties of objects and materials

CONTENT STANDARD E: Science and Technology
As a result of activities, all students should develop
- Abilities of technological design
- Understanding about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives
As a result of activities, all students should develop understanding of
- Types of resources
- Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science
As a result of activities, all students should develop understanding of
- Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry
As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of their activities, all students should develop an understanding of
- Properties and changes of properties in matter

CONTENT STANDARD E: Science and Technology
As a result of activities in grades 5-8, all students should develop
- Abilities of technological design
- Understandings about science and technology

For Teachers:
Alignment to Curriculum Frameworks

◆National Science Education Standards Grades 5-8 (ages 10 - 14) (cont.)

CONTENT STANDARD F: Science in Personal and Social Perspectives
As a result of activities, all students should develop understanding of
- Risks and benefits
- Science and technology in society

◆Principles and Standards for School Mathematics (ages 6 - 18)

Measurement
- understand measurable attributes of objects and the units, systems, and processes of measurement.
- apply appropriate techniques, tools, and formulas to determine measurements.

Problem Solving
- build new mathematical knowledge through problem solving.
- solve problems that arise in mathematics and in other contexts.
- apply and adapt a variety of appropriate strategies to solve problems.
- monitor and reflect on the process of mathematical problem solving.

Connections
- recognize and apply mathematics in contexts outside of mathematics.

Representation
- create and use representations to organize, record, and communicate mathematical ideas.
- select, apply, and translate among mathematical representations to solve problems.

◆Standards for Technological Literacy - All Ages

The Nature of Technology
- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society
- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

Design
- Standard 9: Students will develop an understanding of engineering design.

For Teachers:
Alignment to Curriculum Frameworks

◆Standards for Technological Literacy - All Ages (cont.)

Abilities for a Technological World

- Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- Standard 14: Students will develop an understanding of and be able to select and use medical technologies.
- Standard 19: Students will develop an understanding of and be able to select and use manufacturing technologies.