What is a Nanometer?

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Lesson Focus

Lesson focuses on how to measure at the nano scale and provides students with an understanding of how small a nanometer really is."Students learn about electron microscopes, participate in hands-on activities to measure common classroom objects in the metric scale, and then convert the result to nanometers.

Lesson Synopsis

The "What is a Nanometer?" lesson explores how small a nanometer really is. Students work in teams and measure a range of everyday classroom items, first using metric rulers and then convert the results to the nano scale.

Age Levels

8-12.

Objectives

- Learn about nanotechnology.
- Learn about scale.
- 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:

- measurement
- nanotechnology
- problem solving
- teamwork

Lesson Activities

Students learn how working at the nanoscale requires scientists and engineers to work at a much smaller scale. Students measure common classroom objects and convert the measurement to nanometers. They also learn about electron microscopes and find out about products that have been improved through the application of nanotechnology.

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)

Recommended Reading

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

Optional Writing Activity

- Write an essay or a paragraph with three examples about how the invention of the electron microscope has impacted the world.

For Teachers:
Teacher Resource

◆ Lesson Goal
The "What is a Nanometer?" lesson explores nanotechnology and focuses on how to measure at the nano scale. The lesson provides students with an understanding of how small a nanometer really is. Students learn about electron microscopes, participate in hands-on activities to measure common classroom objects in the metric scale, and then convert the result to nanometers.

◆ Lesson Objectives
- Learn about nanotechnology.
- Learn about measurement.
- Learn about engineering design.
- Learn about teamwork and working in groups.

◆ Materials
- Student Resource Sheet
- Student Worksheets
- One set of materials for each group of students:
  - Ruler, eraser, pencil, pencil sharpener, other classroom objects of your selection.

◆ 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. Measurement 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 measurement in nanometers of various classroom objects.
3. Evaluation - Students complete evaluation/reflection sheets

◆ Time Needed
One 45 minute session

◆ Optional Modelmaking Extension
Have students build a model representing how when working at the nano scale, surface area can be increased. This could be done with basketball that has table tennis or ping pong balls attached all over the surface. This will help visually illustrate how surface area can be manipulated at the nano scale.

Teacher Resource: Measuring Nano - Sample Completed Worksheet:

You are part of a team of engineers who has been given the challenge of measuring ten objects in your classroom at the nano scale -- in nanometers (nm).

Measure each object in millimeters, and then convert using the following formula:

1 millimeter = 1,000,000 nanometers

or

1 centimeter = 10,000,000 nanometers

So, if used crayon was 4 centimeters long, it would also be 40,000,000 nanometers in length.

◆ Measuring Phase

Complete the following measurements as a group: *(examples below)*

Classroom Object	Original Measurement	Measurement in Nanometers
1. Dull edge child's scissor	11 centimeters	110,000,000 nanometers
2. New pencil with eraser	19 centimeters	190,000,000 nanometers
3. Used crayon	9 centimeters	90,000,000 nanometers
4. Pencil Eraser	5.5 centimeters	55,000,000 nanometers
5. Pencil Sharpener	2.55 centimeters	25,500,000 nanometers
6. Index card height	12.55 centimeters	125,500,000 nanometers
7. Used piece of chalk	23.5 millimeters	23,500,000 nanometers
8. Calculator	92.75 millimeters	92,750,000 nanometers
9. Doorknob	50.25 millimeters	50,250,000 nanometers
10. Roll of tape	47.55 millimeters	47,550,000 nanometers

Student Resource:
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.

Student Resource:
How Small is Small?

It can be challenging to envision just how small a nanometer is!

◆ What is a Nanometer?

A sheet of paper is about 100,000 nanometers thick. But how big is that? The chart below should help you understand how small a nano really is. Notice that a centimeter is $1/100^{th}$ of a meter. That also means that a meter is 100 times as big as a centimeter. If an object were a meter wide, it would also be 1,000,000,000 nanometers wide. So something that is only 1 nm wide is very small indeed.

	Symbol	Relative Size
meter	m	about three feet or one yard
centimeter	cm	1/100 of a meter, about half of an inch
millimeter	mm	1/1,000 of a meter
micrometer or a micron	μm	1/1,000,000 of a meter, often called a micron
nanometer	nm	1/1,000,000,000 of a meter

Student Worksheet
Measuring in Nanometers:

You are part of a team of engineers who has been given the challenge of measuring ten objects in your classroom at the nano scale -- in nanometers (nm).

Measure each object in millimeters, and then convert using the following formula:

1 millimeter = 1,000,000 nanometers

or

1 centimeter = 10,000,000 nanometers

So, if used crayon was 4 centimeters long, it would also be 40,000,000 nanometers in length.

◆ Measuring Phase

Complete the following measurements as a group:

Classroom Object	Original Measurement	Measurement in Nanometers
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Student Worksheet (continued)
Measuring in Nanometers:

◆ **Evaluation Phase**

Complete the following questions as a group:

1. What was the most surprising thing you learned about nanotechnology during this activity?

2. Do you think you would be able to see an element that was 10 nanometers wide without the aid of technology?

3. If a sheet of paper is about 100,000 nanometers thick, how do you think an engineer would go about moving an element that is only 30 nanometers thick -- such as the gold particle to the right?

4. Do you think that engineers working at the nano scale have a harder time doing their work than engineers who are working with larger objects, such as batteries, rockets, or sheets of steel? Why?

5. Do you think that nanotechnology might have the most impact on the development of materials, improvements in energy options, or in advances in healthcare? Why?

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 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

◆**Next Generation Science Standards Grades 2-5 (Ages 7-11)**

Matter and its Interactions

Students who demonstrate understanding can:

- 5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen.

For Teachers:
Alignment to Curriculum Frameworks

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

Number and Operations Standard

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
- Understand meanings of operations and how they relate to one another
- Compute fluently and make reasonable estimates

Measurement

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

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

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.

◆ **Common Core State Standards for School Mathematics Grades 2-8 (ages 7-14)**

Measurement and data

\- Measure and estimate lengths in standard units.

- CCSS.Math.Content.2.MD.A.1 Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.

\- Represent and interpret data.

- CCSS.Math.Content.2.MD.A.3 Estimate lengths using units of inches, feet, centimeters, and meters.

For Teachers:
Alignment to Curriculum Frameworks

◆ **Common Core State Standards for School Mathematics Grades 2-8 (ages 7-14)**
Measurement & Data (continued)

- Solve problems involving measurement and conversion of measurements.
  - CCSS.Math.Content.4.MD.A.1 Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table. For example, know that 1 ft is 12 times as long as 1 in. Express the length of a 4 ft snake as 48 in. Generate a conversion table for feet and inches listing the number pairs (1, 12), (2, 24), (3, 36), ...
- Convert like measurement units within a given measurement system.
  - CCSS.Math.Content.5.MD.A.1 Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real world 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.

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

Abilities for a Technological World
- Standard 13: Students will develop abilities to assess the impact of products and systems.