NATIONAL GEOGRAPHIC

RESOURCE LIBRARY I ACTIVITY : 1 HR 30 MINS

How the Nanoscale Measures Up

Through a series of hands-on activities that incorporate mathematics and visual media, students explore the nanoscale and how it compares to the macro and micro scales.

GRADES

6, 7, 8

SUBJECTS

Engineering, Mathematics

CONTENTS

10 Photographs, 3 Links, 3 PDFs

OVERVIEW

Through a series of hands-on activities that incorporate mathematics and visual media, students explore the nanoscale and how it compares to the macro and micro scales.

For the complete activity with media resources, visit:
http://www.nationalgeographic.org/activity/how-nano-scale-measures/

Program

MYSTERIES OF THE UNSEEN WORLD

DIRECTIONS

1. Activate students' prior knowledge about the metric system, emphasizing scale and units.

Distribute meter sticks and rulers to pairs or small groups of students. Discuss the anatomy of each measuring device, highlighting the terms *scale* and *units*. Have students point out the units they see. Ask: *Why are there two different scales on each side of the ruler?* Or: *Why is the scale on the ruler different from the scale on the meter stick? What is the difference?* Elicit from students that one scale represents the metric system (International System of Units, or SI) and the other scale represents the English system (also Imperial Units or U.S. Customary Units) of measurement. Ask: *Which system is most commonly used in the United States? What units are used to measure length in this system?* Elicit from students that the English system is more commonly used in the U.S. and length units include inches, feet, yards, and miles.

Tell students that most other countries use the metric system. The metric system is based on a decimal system and is used by scientists all over the world. These factors make it easier for scientists to work with very big and very little numbers and to communicate with one another. Explain that today's activity will use the metric system.

2. Build background on the macro, micro, and nanoscales.

Begin to introduce the difference between macro, micro and nanoscales. Ask: *How many metric system units can you think of for measuring length?* Have students share aloud and begin writing the different metric units on the board. Write the units out completely, noting that there are abbreviations you will discuss later. Also note that some of these are small units of measurement and others are large.

Write the terms "macro," "micro," and "nano" on the board. Ask: *Does anyone know what these terms mean? What is the difference between them?* Elicit from students that macro means an object can be seen with the unaided human eye; micro is smaller than macro and requires the use of an optical (light) microscope to be seen with the human eye; and nano is extremely small and requires the use of a very powerful electron microscope to be seen. To demonstrate, have students look at their meter sticks and explain that a nanometer (nm) is a unit of length equivalent to one billionth (10^{-9}) of a meter. There are one billion nanometers on a meter stick and between each millimeter line there are one million nanometers. Explain that today they will be learning more about each of these scales, especially the nanoscale.

3. Have students practice metric conversions.

Explain that in the activities they will be doing, they will measure a number of objects and classify them as being on the macro, micro, or nano scale. Distribute the Nano Metric Conversions worksheet and read aloud the directions. Depending upon their comfort level with the metric system, have students work individually or in pairs to complete Prompts 1-6 of the worksheet. Prompt 7 (Nanoscale Ruler Conversions) will be completed in Step 5. Assist students as needed and discuss the correct answers. Make sure students see the relationship between kilometers, meters, centimeters, and millimeters. Explain that they will learn more about micrometers and nanometers throughout the activity.

4. Have students dig deeper into the relative sizes of objects at different scales

Play the NISE Net video "How Small is Nano?" (2 min. 51 sec.) Tell students to pay close attention to the relationship between the scale of the images and the units millimeter, micrometer, and nanometer. Then have students work in pairs at computers to access and go through the sections on the "What is Nano" webpage. If you prefer, project the website for the whole class to go through together. Have students pay special attention to the "A Word on Measurements," "The Beginning," and "How Small is Small?" sections.

After students have watched the video and read the sections on the website, have student pairs spend five minutes discussing what they observed. Guide their discussion by asking: What is the relationship between millimeters, micrometers, and nanometers? Why is it important to understand the relative sizes of objects in our world?

Review with students that objects at the macro scale are 1,000 times larger than objects at the micro scale. Objects at the micro scale are 1,000 times larger than objects at the nanoscale. Ask: *How many times larger are objects at the macro scale compared to the nanoscale? Which units (mm, µm, nm) do you think would be used at the macro, micro, and nanoscales?* Using the board to organize student responses, elicit from students that objects at the macro scale are 1 million times larger than objects at the nanoscale. Macro objects would be measured in millimeters (mm). Micro objects would be measured in micrometers (µm). Nano objects would be measured in nanometers (nm).

5. Use a nanoscale ruler to measure objects and practice converting them to macro and micro scales.

Explain to students that up to this point their metric conversions have gone from larger to smaller units. Now they are going to practice doing conversions from small to large.

Distribute the Nano Ruler handout to students and have them construct them according to the instructions on the handout. Read aloud Prompt 5 on the Nano Metric Conversions worksheet. Explain that the macro scale includes units greater than 1 millimeter. The micro scale includes units in millimeters and micrometers, but for this activity they will use only micrometers for the micro scale. The nanoscale includes units in nanometers. Have students work in pairs or small groups and set a time limit for them to complete the chart. After they complete the chart, discuss their answers and check for understanding.

6. Have students observe and compare objects at different scales

Continue to build background, engage students, and help them visualize the macro scale, micro scale and nanoscale in an exercise using the FEI Company images listed below. (The images are located in the activity resource carousel.) Download and print the images or prepare them for projection. If you choose to print the images in black and white, project the color images from the carousel first so students can see them in color.

Engage students in determining the sizes of the objects depicted. Have students work in small groups (using downloaded images) or as a whole class (using the images projected on a screen or white board). Tell students to note the scale bar at the bottom of each image. The scale may be noted in millimeters (mm), micrometers (μm), or nanometers (nm). Tell students that these scale bars are used much like the bar scales on maps—where 1 inch might equal 100 miles, for example. Have a map handy in case students are unfamiliar with map scales.

Have students use a piece of paper, a ruler, or other measuring device to determine the size of the object according to the scale on the image. Tell students to mark the scale length on their measuring devices, count the number of lengths that fit across the item, and multiply the two numbers to get the size. Have students record the name of the object and the object's size on a sheet of paper. If doing this activity as a whole class, you may wish to have one student record this information on the board or poster paper. Then have students rearrange the images in order, according to size—from largest to smallest. Remind students that the scales are different on different images—millimeters, micrometers, and nanometers. When students are done ordering the images, lead students in a discussion about their experience with the activity. Ask: *Did you have any trouble measuring any of the images? If so, what was difficult*

about working with the image(s)? What did you have to do to put the images in size order? (The image sizes had to be converted to the same scale to place them in order—from millimeters to micrometers, for example.)

- FEI Image 1: Ant – This is an image of the anterior (head) of an ant.
- FEI Image 2: Head Louse – This is an image of a head louse on two human hairs.
- FEI Image 3: MRSA Antibiotic Resistant Bacteria – This is an image of MRSA bacteria on the surface of a wound dressing.
- FEI Image 4: Nano Mirrors – This is an image of Digital Light Processing (DPL) a component used in video projectors.
- FEI Image 5: Pollen of Birch Tree – This is an image of pollen on a birch tree stick on the stigma of a passionflower.
- FEI Image 6: ZnO Nanowires – This is an image of zinc oxide nanowires produced at Lawrence Livermore National Laboratory. These wires only a few nanometers across have unique properties that make them useful in applications such as electronics, optics and photonics.
- FEI Image 7: Gold Particle – Growth twinning in gold nano-particle.
- FEI Image 8: Parasitic Mite – This external parasitic mite, the *Varroa destructor*, attacks the honey bees *Apis mellifera*.
- FEI Image 9: Reddit Alien – An "alien" etched using an electron beam.
- FEI Image 10: Nano Thumbs Up – DNA-directed self-assembled gold nanorods and nanospheres.

7. Have students reflect on and discuss what they learned about macro, micro, and nanoscales.

To conclude the activity, review the key points in a class discussion. Ask: *Why do scientists use the metric system?* Elicit from students that the metric system is like a standardized universal language. It allows scientists to communicate with one another and to work with really large and really small numbers. Ask: *Why is it important to understand the scale of an object? What is the difference between macro, micro, and nanoscale objects?* Elicit from students that by understanding different scales—including macro, micro, and nanoscales—they can measure and compare objects of different dimensions. Tell students that by doing so, the properties and behavior of different objects and materials can be better understood. Researchers who study nanoscale objects are now able to not only see nanoparticles (atoms and molecules) but to manipulate them and create new materials and products.

Tip

Preview and queue up the interactive before beginning the activity. To better assist students during the activity, practice using the scroll bar for zooming in and out and clicking on objects to reveal more information.

Modification

Depending upon student comfort with using the metric system, more time and facilitation could be provided by dividing the activity up into multiple class sessions.

Informal Assessment

Use students' completed Nano Metric Conversions worksheet to assess their comprehension.

Extending the Learning

Have students expand their understanding of the micro scale by completing a microscopy lab.

OBJECTIVES

Subjects & Disciplines

- Engineering
- Mathematics

Learning Objectives

Students will:

- Distinguish between macro, micro, and nanoscales and sort objects accordingly
- Select the appropriate metric units for characterizing common objects
- Measure and perform conversions using metric units

Teaching Approach

- Learning-for-use

Teaching Methods

- Cooperative learning
- Discussions
- Experiential learning
- Hands-on learning
- Information organization
- Multimedia instruction

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Learning and Innovation Skills
    - Communication and Collaboration
  - Life and Career Skills
    - Initiative and Self-Direction
- Critical Thinking Skills
  - Analyzing
  - Applying
  - Understanding

National Standards, Principles, and Practices

NCTM PRINCIPLES AND STANDARDS FOR SCHOOL MATHEMATICS

• **Measurement (6-8) Standard 1:**
Understand measurable attributes of objects and the units, systems, and processes of measurement
• **Measurement (6-8) Standard 2:**
Apply appropriate techniques, tools, and formulas to determine measurements
• **Number & Operations (6-8) Standard 1:**
Understand numbers, ways of representing numbers, relationships among numbers, and number systems

NATIONAL SCIENCE EDUCATION STANDARDS

• **(5-8) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(5-8) Standard E-2:**
Understandings about science and technology

Preparation

What You'll Need

MATERIALS YOU PROVIDE

- Crayons
- Meter sticks
- Microscopes
- Digital cameras
- Prepared microscope slides of (red blood cell, common bacterium, virus (optional)
- Pennies
- Rulers (metric)

REQUIRED TECHNOLOGY

- Internet Access: Required
- Tech Setup: 1 computer per classroom, 1 computer per small group, Projector, Speakers
- Plug-Ins: Flash

PHYSICAL SPACE

- Classroom

GROUPING

- Large-group instruction
- Small-group instruction

BACKGROUND & VOCABULARY

Background Information

Comparing objects at the macro, micro, and nanoscales is an important aspect of many scientific endeavors and fields of study. Visualizing and understanding the behavior and properties of objects at the nanoscale can be challenging. A nanometer (nm) is a unit of length equivalent to one billionth (10^{-9}) of a meter. For comparison, a single sheet of paper is approximately 100,000 nanometers thick and a strand of DNA is 2.5 nm across. Advances in microscopy and nanotechnology allow scientists to not only observe particles as small as atoms and molecules, but to manipulate them and create new materials and products with unique properties. Advanced imaging tools and techniques now enable non-scientists to observe and better understand the micro and nanoscales.

Prior Knowledge

["Students should have some familiarity with the metric system and its common units of length."]

Recommended Prior Activities

- Properties of Matter: Macro to Nano Scale

Vocabulary

Term	Part of Speech	Definition
diameter	*noun*	width of a circle.
macro-	*prefix*	large.
metric system	*noun*	series of standard weights and measurements used by most countries (except the United States, Liberia, and Burma) and throughout the scientific world. Also called the International System of Units or SI.
micro-	*prefix*	small.
micrometer	*noun*	a unit of length equal to one millionth of a meter—also called *micron*.
nanometer	*noun*	(nm) billionth of a meter.
nanoscale	*noun*	length scale whose relevant unit of measurement is the nanometer (nm), or a billionth of a meter. Also called the nanoscopic scale.

For Further Exploration

Instructional Content

- Nanozone: Size Wheel

Websites

- Nano.gov: National Nanotechnology Initiative—Nanotech 101
- Nanoscale Informal Science Education Network: K-12 Resources

FUNDER

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