Teacher Preparatory Guide

How big is a Nanometer?

Overview: This scaling unit will be a teacher guided introduction and discussion on the nanometer and its role in nanotechnology. The students will be introduced to the concept of measurement on the nanoscale and what instruments are necessary to view objects of this magnitude. Students will also learn how to convert larger metric measurements of length into nanometers and vice versa.

On day two, students will participate in a hands-on activity to ascertain the size of everyday objects in nanometers. Students will measure various objects of their choice and convert these measurements into nanometers. The third day of the lesson will entail instructing students on how to complete a research assignment on nanotechnology. In groups of four, students will investigate what consumer products presently utilize nanotechnology. Students will be responsible for creating a 7-10 minute class presentation to demonstrate their learning. (Posters, plays, poems, songs, etc. are all acceptable. Encourage students to be creative!)

Purpose: The purpose of this activity is to help students conceptualize the magnitude of a nanometer compared to other metric units of length. At the end of this activity, students will be able to state the size of a nanometer, convert between nanometers and other metric units of length, and give concrete examples of nanotechnology use in everyday life. At the conclusion of this unit, students will create a 7-10 minute class presentation to demonstrate their learning.

Time Required Two – three 45-minute class periods

Level Middle or High School Science or Mathematics

Materials

- How Big is a nanometer worksheets (per student)
- Calculators (class set)
- Graph paper: to help students organize their calculations, especially important for students with math learning disabilities
- Centimeter Rulers (class set)
- Student notebook

Safety Information There are no safety concerns for this activity.

Advance Preparation The teacher should make sure all necessary materials are available.

Teacher Background The meter is the basic unit of measurement for length. Depending on the prefix, the magnitude of this metric unit can increase or decrease. Most people are familiar with the approximate size of a meter because they have a working approximation of how long a meter is. For example, the space between the floor and the handle on most doors is about a meter. In

Developed by Chantelle Smith, Paul Longwell, Stephen Stilianos, Dr.Zuleika Torres, Dr.Ronald Redwing, and Mary Shoemaker
Development and distribution partially funded by the National Science Foundation

NNIN Document: NNIN-1204
Rev: 07/2010

addition, they recognize that a yardstick (which is 3 feet) is about 3 inches shorter than a meter stick.

In addition, people are able to determine the length of larger and smaller objects by comparing them to their working approximation of a meter. For example, an object that is 30 kilometers in length is about 30,000 meter sticks laid end to end. Until recently, the smallest unit of length students commonly heard was the micrometer or 0.000001 meters. Students knew that bacteria and cells (objects they could see with a compound light microscope) were usually measured using micrometers.

However, with the advent of nanotechnology, students need to create a working approximation to help them envision how small an object measured in nanometers really is. For example, if the distance from New York to California were a meter long, how many nanometers would it be from New York to Pennsylvania?

Teacher Resources These resources can be used to acquire background knowledge about objects on the nanoscale and nanotechnology.

Site	Topics
• *University of Wisconsin, Materials Research and Engineering Center* http://mrsec.wisc.edu/Edetc/nanoscale/index.html	Size and Scale Resources
• *National Library of Virtual Manipulatives* http://nlvm.usu.edu/en/nav/category_g_3_t_4.html	Measurement (Grades 6 - 8)
• *Center for Nanoscale Chemical- Electrical- Mechanical Manufacturing Systems* http://www.nanocemms.uiuc.edu/content/education/teacher_materials.php	Materials for Teachers
• *How Stuff Works* http://science.howstuffworks.com/nanotechnology3.htm	How Nanotechnology Works
• *National Nanotechnology Initiative* http://www.nano.gov	What is Nanotechnology
• *BBC News* http://news.bbc.co.uk/1/hi/sci/tech/3920685.stm	Myths and Realities of Nano-Futures

Teaching Strategies Students should follow along with the teacher directed presentation for the first half of the *How Big is a Nanometer?* worksheet. Careful attention should be paid to the presentation outline listed after the instructional procedure for day one. The second half of the worksheet should be completed on day two in groups of two or three students. Students should be provided with graph paper, calculators, centimeter rulers and any other materials that will scaffold their learning. The student presentation component of the activity will be created using a rubric that the teacher will review with students prior to assigning the assessment.

Cleanup Students should return materials to their designated collection areas in the classroom at the conclusion of each day's lesson.

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Lesson 1, Day 1 - Instructional Procedure
The Nanometer and its Role in Nanotechnology

Time (minutes)	Instructional Activity
10	Teacher will introduce the day's activity and have students complete questions in their notebooks to ascertain what they know about nanotechnology. Ask the students: "Where have you seen the word nano before?" Ask the students: "What do you think the words nano and nanotechnology mean?" (What is Nanotechnology) Ask the students: "The word nanometer is used often when talking about nanotechnology, what do you think is the significance of this word?"
25	Teacher will compile student answers in the Know (K) part of a KWL chart (What I Know, Want to Know, and Learned). Teacher will define and introduce the key terms used in nanotechnology. During the teacher directed presentation, the concept of a nanometer and its role in nanotechnology will be introduced. (Nanoscience and engineering are defined based on the nanoscale so it is important to understand the size). During this portion of the lesson, students will complete the *How Big is a Nanometer* lesson plan Day 1 handout with questions pertaining to the presentation.
5	Students will write at least two questions that they want answered about nanotechnology in their notebooks.
5	Time permitting, the teacher will write down all of their questions in the Want (W) part of the KWL chart. If not, this activity can be done the following day to commence that lesson.

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Outline for Teacher Directed Presentation

Metric Units of Length

- Kilometer, Meter, Centimeter, Millimeter, Micrometer and Nanometer
- Unit abbreviations (km, m, cm, mm, µm, nm)
- Comparing units of length
  1 meter = 100 cm = 1000 mm = 1,000,000 µm = 1,000,000,000 nm

or

Unit	**Length**
kilometer (km)	1,000 m (1×10^{3} m)
meter (m)	1 m
centimeter (cm)	0.01 m (1×10^{-2} m)
millimeter (mm)	0.001 m (1×10^{-3} m)
micrometer (µm)	0.000001 m (1×10^{-6} m)
nanometer (nm)	0.000000001 m (1×10^{-9} m)

Nanoscale

- Measured in nanometers
- Why compound light microscopes can't be used to see objects on the nanoscale? (the materials are below the range of visible light so light microscopes cannot be used)
- Instruments used to see on the nanoscale
  Scanning Electron Microscope (SEM)
  Transmission Electron Microscope (TEM)

Nanotechnology

- What is Nanotechnology?
  http://www.nnin.org/nnin_what.html
  http://www.nano.gov/html/facts/whatIsNano.html
- Consumer products that use nanotechnology
  Sunscreen
  Stain-resistant Clothing
  Antimicrobial bandages
  http://www.nnin.org/nnin_k12nanotechproducts.html
- Future uses of nanotechnology
  Less invasive, more precise surgery using "nanorobots"
  Cancer treatment (gold nanoparticles)
  Drug delivery systems (buckyballs)

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Name_____ Date_____ Class_____

How Big is a Nanometer?
Student Worksheet for Day 1 (*with answers*)

Purpose To introduce the nanometer and its role in nanotechnology. Students will be introduced to the concept of measurement on the nanoscale and what instruments are necessary to view objects of this magnitude. Students will also learn how to convert larger metric measurements of length into nanometers.

Question(s)

1. What is a nanometer?
2. What instruments are useful for measuring objects on the nanoscale?
3. What is nanotechnology?
4. How large or small is a nanometer?
5. What types of objects should be measured in nanometers?

Directions Complete each blank with the appropriate definition from the teacher presentation.

Key Terms

Meter *The international standard unit of length, equal to the length of the path traveled by light in vacuum during a time interval of 1/299,792,458 of a second. Abbreviated m.*

Nanometer *A unit of length equal to one-billionth of a meter, or 10^{-9} meter. Also known as millimicron (μm); Abbreviated nm.*

Scanning Electron Microscope (SEM) *A type of electron microscope in which a beam of electrons, a few hundred angstroms in diameter, systematically sweeps over the specimen; the intensity of secondary electrons generated at the point of impact of the beam on the specimen is measured, and the resulting signal is fed into a cathode-ray-tube display which is scanned in synchronism with the scanning of the specimen. Abbreviated SEM.*

Transmission Electron Microscope (TEM) *A type of electron microscope in which the specimen transmits an electron beam focused on it, image contrasts are formed by the scattering of electrons out of the beam, and various magnetic lenses perform functions analogous to those of ordinary lenses in a light microscope.*

Compound Microscope *A microscope which utilizes two lenses or lens systems; one lens forms an enlarged image of the object, and the second magnifies the image formed by the first.*

Nanotechnology *Techniques that produce or measure features less than 100 nanometers in size.*

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Directions: Answer each question according their specified instructions. You may work in pairs.

1. Which is ***longer***? Circle your choice for each one.

a) 1 meter or *1 kilometer*
b) 1 millimeter or *1 meter*
c) *1 centimeter* or 1 micrometer
d) 1 nanometer or *1 micrometer*

2. The basic unit of length in the SI or metric system is the __*meter*_ and is represented by a lowercase __*m*__.

3. Match the following units of length with their abbreviations.

_*d*__ kilometer
_*c*__ micrometer
_*e*__ millimeter
_*b*__ nanometer
_*a*__ centimeter

a. cm
b. nm
c. µm
d. km
e. mm

4. Complete each statement.

a) 1 m = __*100*__ cm
b) 1 m = __*1,000*__ mm
c) 1 m = __*1,000, 000*__ µm
d) 1 m = __*1, 000, 000, 000*__ nm

5. Complete each statement.

a) 1 centimeter is equal to __*0.01*_____ or 10^-*2* of a meter.
b) 1 millimeter is equal to __*0.001*_____ or 10^-*3* of a meter.
c) 1 micrometer is equal to __*0.000001*____ or 10^-*6* of a meter.
d) 1 nanometer is equal to __*0.000000001*_ or 10^-*9* of a meter.

6. Complete the chart below.

Meter	Centimeter	Millimeter	Micrometer	Nanometer
1	*100*	*1000*	*1,000,000*	*1,000,000,000*
0.1	*10*	*100*	*100,000*	*100,000,000*
0.01	*1*	*10*	*10,000*	*10,000,000*
0.001	*0.1*	*1*	*1000*	*1,000,000*
0.001	*0.01*	*0.1*	*100*	*100,000*

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7. Based on your answers for the chart above, what do you notice? Why is this happening?
Answers will vary.

8. Which is ***smaller***? Circle your choice for each one.

a) 90 meters or *105 centimeters*
b) 12 centimeters or *102 millimeters*
c) 4000 meters or *440, 000 micrometers*
d) 1200 millimeters or *1 meter*

9. Using what you have learned and the above chart, determine the size of the following objects. *Show all your work.*

a) The head of a pin is 2 millimeters wide. What is its width in nanometers? In meters?
(2,000,000 nm; 0.002 m)

b) A human hair is about 120 micrometers wide. What is its width in nanometers? In centimeters?
(120,000 nm; 0.0120 cm)

c) DNA has a width of 2 nanometers. What is its width in centimeters? In meters?
*(*0.0000002 *cm; 0.*000000002 *m)*

d) An ant is 5 millimeters in width. What is its width in centimeters? In nanometers?
*(*0.5 cm*;* 5,000,000 *nm)*

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Day 2 Instructional Procedure
How Big is a Nanometer?

Time (minutes)	
5	Teacher will introduce the day's activity and have students complete warm up questions to ascertain what they recall from the prior day's lesson. Ask the students: "What is a nanometer and how big is it?" Ask the students: "Why do you think we are learning about the nanometer and nanotechnology?"
10	Teacher will distribute the How Big is a Nanometer lesson plan Day 2 handout. Teacher will review how to convert centimeters, millimeters, and micrometers to nanometers.
20	Students will complete questions 1-2 of the handout in pairs.
10	Students will complete questions 3-5 independently. The teachers will use these questions to gauge student understanding of the size of nanometers.

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Rev: mm/yy

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How Big is a Nanometer?
Student Worksheet for Day 2 (*with answers*)

Purpose A hands-on activity to ascertain the size of everyday objects in nanometers. Students will measure various objects of their choice to convert these measurements into nanometers.

Question(s)

1. What is a nanometer?
2. What instruments are useful for measuring objects on the nanoscale?
3. What is nanotechnology?
4. How large or small is a nanometer?
5. What types of objects should be measured in nanometers?

Directions: Complete questions 1 and 2 in pairs. **Answer questions 3-6 individually.**

1. Use the ruler and line below to answer the questions.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

a) What is the length of the line in centimeters? *~3.5* cm
b) What is the length of the line in millimeters? *~35* mm
c) What is the length of the line to the nearest nanometer? *35000000* nm

2. Choose five objects in the classroom to measure.
Measure these objects in centimeters.
Convert your centimeter measurements to millimeter, micrometer and nanometer measurements.

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Object Name	Measurement in Centimeters	Measurements in Millimeters	Measurements in Micrometers	Measurement in Nanometers

Answer the following questions on your own.

3. What did *you* learn while doing this activity?
Answers will vary but should include how small a nanometer is and what a nanometer is.

4. What type of objects do *you* think a nanometer is used to measure? Why?
Answers will vary but should include small objects like viruses, blood cells and atoms.

5. Would *you* use a nanometer to measure the size of your car? Why or why not?
Answers will vary but should say no because there would be too many nanometers in measuring a car - meter or centimeter would be more appropriate.

6.Would *you* use a nanometer to measure the size of a red blood cell? Why or why not?
Answers will vary but should say yes because of the small size which requires small units of measurement.

Day 3 Instructional Procedure: Nanotechnology in Our Everyday Lives

Time (minutes)	Instructional Activity
5	Teacher will introduce the day's activity and have students complete the following warm up question. Ask the students: "What do sunscreen, stain resistant material, and makeup have in common?" (all contain nanoparticles and are considered to be "nanoproducts)
25	Using the KWL chart, teacher will remind students of the questions they wrote about nanotechnology. Teacher will explain the assignment: to find examples of nanotechnology in our lives (current consumer products). Teacher will distribute a rubric for the presentation and a resource list to facilitate student research efforts. Teacher will model how the presentation should be conducted. At the conclusion of the presentation, the teacher should address student concerns and/or questions.
10	Students will form groups of four to choose four questions from the KWL chart that they want to investigate. Students will submit their choices to the teacher.

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They will research their consumer products that use nanotechnology and create a 7-10 minute class presentation for a future class period.

5 Teacher will look over choices to make sure there aren't too many duplicates of topics.

Resources:

Project on Emerging Technologies (includes product inventory)
http://www.nanotechproject.org/
Nanotechnology in Consumer Products
http://www.nanoforum.org/dateien/temp/Nanotechnology%20in%20Consumer%20Products.pdf?23012007110310
Consumer products http://www.nnin.org/nnin_nanoproducts.html

Assessment

Assessment *for* Learning

Student responses to warm up and handout questions will be used to gauge understanding throughout the activities. The teacher will clarify misconceptions when necessary. The group presentation will demonstrate student understanding of the importance of nanotechnology.

Assessment *of* Learning

Description	What is Assessed	Feedback
The students will complete the *How Big is a Nanometer* handout for days one and two. Students will learn about the nanometer and its role in nanotechnology. Students will also learn about the appropriate use of the nanometer in measurement and the instrumentation necessary to view nanoscale objects. At the end of the unit, students will create group presentations to demonstrate what they learned about nanotechnology.	Student understanding of a nanometer's magnitude and practical usage will be assessed. Students will also be assessed on their ability to accurately convert larger metric measurements of length into nanometers and vice versa. Group presentations will display student comprehension of prevalence and future implications of nanotechnology in human lives.	Students will be graded on complete and accurate answers to the handout questions. Student presentations will be assessed using a teacher created rubric.

National Math Education Standards: Grades 6-8

A. Number and Operations

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
  - ✓ Work flexibly with fractions, decimals, and percents to solve problems
  - ✓ Develop an understanding of large numbers and recognize and appropriately use exponential, scientific, and calculator notation

D. Measurement

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- Understand measurable attributes of objects and the units, systems, and processes of measurement
    - ✓ Understand both metric and customary systems of measurement
    - ✓ Understand relationships among units and convert from one unit to another within the same system

National Math Education Standards: Grades 9-12

A. Number and Operations

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
    - ✓ Develop a deeper understanding of very large and very small numbers and of various representations of them

D. Measurement

- Understand measurable attributes of objects and the units, systems, and processes of measurement
    - ✓ Make decisions about units and scales that are appropriate for problem situations involving measurement.

Pennsylvania Math Education Standards

2.1 Numbers, Number Systems, and Number Relationships

8 A. Simplify numerical expressions involving exponents, scientific notation and using order of operations.

11 A. Use operations (e.g., opposite, reciprocal, absolute value, raising to a power, finding roots, finding logarithms).

National Science Education Standards: Grades 5-8

- Science in Personal and Social Perspectives
    - ✓ Science and technology in society
    - ✓ Understanding about science and technology

National Science Education Standards: Grades 9-12

- Science and technology Standards
    - ✓ Science and technology in local, national, and global challenges
    - ✓ Understanding about science and technology

Pennsylvania Science Education Standards

3.1 Unifying themes

10 D. Apply scale as a way of relating concepts and ideas to one another by some measure.

- Apply dimensional analysis and scale as a ratio.
- Convert one scale to another.

12 D. Analyze scale as a way of relating concepts and ideas to one another by some measure.

- Analyze and apply appropriate measurement scales when collecting data.

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