Teacher's Guide

A Look into the Nanoworld: An introduction to nanoscale science and engineering

Grade Level: Middle & High school

Subject area(s): Physical Science

Time required: (4) 50 minute classes

Learning objectives: Understand: the metric system and conversions, size of the nanoscale, and careers in nanotechnology.

Summary: This is a four-part lesson that has students explore the nanoscale. The lesson includes: size and scale, metric system and conversions, measurement, nanotechnology applications, and careers in nano-science. The activities can be done in groups of 2-4 and requires viewing of videos.

Lesson Background: Nanoscale science and engineering is the study of matter at an exceedingly small scale i.e., objects of 1-100nm. At this scale, materials typically behave differently and are said to have unique properties. Scientists and engineers explore and utilize these unique properties to create new materials and devices. Below is a list of resources that the instructor may wish to explore to learn more about this field to prepare for the activities. You may also want to have the students visit one or more of the sites to learn about nanotechnology.

- Nanotechnology 101: https://www.nano.gov/nanotech-101
- Intro to nano from Nanowerk - https://www.nanowerk.com/nanotechnology/introduction/introduction_to_nanotechnology_1.php
- How does nanotechnology work from Nanowerk - https://www.nanowerk.com/how_does_nanotechnology_work.php#:~:text=Nanotechnology%20is%20the%20understanding%20and,matter%20at%20this%20length%20scale.
- How Nanotechnology works from How Stuff Works https://science.howstuffworks.com/nanotechnology.htm

Pre-requisite Knowledge: Students should know the SI system of measurement and be able to convert between different units.

Materials:
Laminated cards for size sorting (see resources)
Powers of Ten video by Charles and Ray Eames (https://www.eamesoffice.com/the-work/powers-of-ten/)
Zoom or *ReZoom* by Istvan Banyai (~$9 and $7)
Materials listed in Noodling Around or What's in your Neighborhood (your choice of lesson)

Safety Information: None

Vocabulary and Definitions:

1) *SI system*: international system of units that is a decimal system of weights and measures that form the metric system of units.
2) *Nanoscale*: measured in nanometers; typically referring to materials between 1 and 100 nm but others use up to several hundred nanometers.
3) *Nanometer*: $1x10^{-9}$ or one billionth of a meter.
4) *Nanotechnology*: Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. It is the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering.
5) *Carbon nanotube*: cylindrical molecules consisting of rolled-up sheets of single-layer carbon atoms called graphene. Depending on if they are single walled or multiwalled their diameters range from 1nm to more than 100nm. In length they can range from several micrometers and millimeters.

Advance Preparation: Print out the cards for the size sorting activity. It is recommended to laminate the cards for future use. Copy several pages from the Zoom book for Lesson 2 activity and make enough for several groups. Create or use online versions of metric conversion sheets.

Directions for the Activity:

Lesson 1 Measuring the Visible and Understanding the Invisible

Essential Questions:

1. What is a nanometer and how does it relate to the nanoscale?
2. What is a carbon nanotube?

Brief Overview: This lesson will review metric conversion and introduce students to the concept of the nanoscale and nanometer.

Procedure:

1) Size and Scale: Use the size and scale activity from either of the sources. Have pairs of students sort the cards.
   a) *Size and Scale: Learning about measurement* https://www.nnci.net/node/5305
   b) *NanoSense Size Matter Lesson 2: Size and Scale: The number line activity* http://nanosense.sri.com/activities/sizematters/sizeandscale/SM_Lesson2Teacher.pdf (answers) and http://nanosense.sri.com/activities/sizematters/sizeandscale/SM_Lesson2Student.pdf
2) Review and practice of metric conversions. Show or share with students an image of the SI System and also a chart of conversions. The *Measuring with Metric* by Point Pleasant Beach School District New Jersey is an excellent resource for conversion worksheets. Other worksheet suggestions are in the Resources section.
3) Have students watch the video: *Powers of 10* By Charles & Ray Eames

4) Have students watch videos on size and scale or read about the size of a nanometer (see Resource section). You may want them to work with one of the online interactives about size and scale listed in the resource section.
5) Student Activity: Have students compile a list of objects that they would like to measure and convert the size to nanometers. They should have a minimum of 5 objects.
6) Closing: Tell students the appropriate order of pictures from step 1.

Lesson 2 Measuring the Visible and Understanding the Invisible
Essential Questions:

1) Do you multiply or divide when converting from one unit to another?
    a. *Answer: Depends if going up or down in scale. For each factor of ten down in scale students will multiply or move the decimal one place to the right. Going up by a factor of ten requires division by ten or moving the decimal one place to the left.) Each step up the staircase represents a division by ten or the movement of the decimal point one place to the left.*
2) How many nanometers are in a meter? *1,000,000,000 nm*

Brief Overview: This activity applies measurement to understand relative size.
Procedure:

1) Using either of the *Zoom* books, make copies of several of the pages. Hand out the pages to pairs or groups of students and ask them to determine the sequence they should be placed into. Have a class discussion of the page placements and ask students to defend their answers.
2) Share *Zoom* books in the groups and confirm the correct order. Discuss perspectives shown in *Zoom* and how these relate to the *Powers of Ten* video.
3) Complete one of the following activities: *Noodling Around Powers of Ten Activity* (https://www.nnci.net/node/5389) or *What's in your Neighborhood?* (https://www.nnci.net/node/5322)
4) Homework or in class: Complete your own series of conversions (at least 5). Include a "nano-"conversion. Use a base unit of your choice.
5) Homework: research two applications of nanotechnology in our lives. Tell students about the Project on Emerging Technologies inventory of products (resource section) to help them with their assignment. Create a poster or PowerPoint slide to share in class. Include at a minimum:
    a) What is the application?
    b) Why is it considered to be nanotechnology?
    c) What is unique about the application?
    d) How is it being used?
    e) Are there concerns about its use?

Lesson 3 Measuring the Visible and Understanding the Invisible #3
Essential Questions:

1) What is the relationship among mass, volume, and density? *Density describes the ratio of mass to volume of an object or substance. It is the weight of a substance for a specific volume. The relationship is directly proportional such as any change in volume will change its density. Also, a change in density will change the volume. Mass is the amount of matter*

an object contains and is the measure of the resistance of a material to accelerate when a force acts upon it.

2) What is the density of water? The density of water is a relative amount but is about 1 gram per milliliter. However, this number changes with temperature (think of how ice floats) or if there are substances dissolved in it (think of salt water).
3) How is nanotechnology applied in our lives?

Brief Overview: Students will complete density problems and laboratory exercises. Applications of nanotechnology will be discussed.

Procedure:

1) Focus Question for the groups: "Why see the unseen?" Support your claims for a question and answer class discussion.
2) Review density, mass, and volume. Review use of triple beam and digital scales.
3) Student Activity: Have students complete the mass, volume and density problems found at Measuring with Metric (or other problems of your choice).
4) Class Discussion: Share the group answers to focus question and include a class discussion.
5) Students will share their results from the homework assignment. Class discussion should include what the students found interesting, would they use the product, and are there ethical issues related to the product.

Lesson 4 Careers in Nanoscale Science and Engineering Portfolio

Goal:

This activity is designed to make students aware of various career opportunities in nanoscale science and engineering. Students will identify information about the field and explore the educational and skill requirements of the related occupation, potential salary, market forecasts for demand and other factors affecting employment.

Essential Questions:

1) What is the career path for jobs in nanotechnology? Or, are there many career paths?
2) Does a job in nanotechnology require a PhD?
3) Can you imagine yourself working in nanotechnology?

Activity Directions:

Hand out the Nano Careers activity sheet. A list of possible careers in nanotechnology is in the student sheet or see the *NNCI Career Brochure for High School Students* (https://nnci.net/nnci-career-brochure-high-school-students). You may want to direct students to the brochure or make copies. Assign students careers for them to research. They will work in groups and you may wish to have them perform the activity as a Jigsaw where each student researches aspects of the career. They will then combine that information into a group career portfolio and report out to the whole class.

Assessment: Students should not be assessed on the size sorting cards as most people cannot correctly sort the objects at the nanoscale. The purpose of the activity is for students to understand how small the nanoscale is. Correct answers on the conversion activities should be assessed. The homework assignment on the applications of nanotechnology should be judged on the completeness of addressing the five questions and the quality of the poster or PowerPoint. An example rubric is below.The same rubric can be edited and used to evaluate the Nano-careers activity.

Rubric for Nanotechnology Applications Assignment				
	Poor/low (5)	Below Standard (7)	Standard (10)	Exceeds Standard (15)
Applications of nanotechnology	Did not include answers to five questions.	Answered some of the five questions	Answered all five questions.	Answered five questions and provided additional info
Information presented	Little info about the applications	Some info about applications	Adequate info about applications	Complete and accurate info about the applications.
Presentation	Poorly created poster/PPT with little info	Poster/PPT depicts info with graphics	Poster/PPT nicely displays info with good graphics	Poster/PPT exceeds expectations for display of info with excellent graphics
Language	Poor writing and word use; technical terms not explained	Fair writing and word use; attempts to explain technical terms	Good writing and word use; adequately explains technical terms	Excellent writing and word use; Clearly and accurately explains technical terms

Additional Resources:

- NIST Education resources on the metric system: https://www.nist.gov/pml/weights-and-measures/education-resources-metric-system-si
- Lab Activity: Measuring with Metric. Point Pleasant Beach School District New Jersey. https://www.ptbeach.com/cms/lib02/NJ01000839/Centricity/Domain/113/Biology%20Labs%20and%20handouts/Metric%20Measurement%20Lab%20Activity%202014%20edit.pdf
- How Big is a Nanometer? https://www.nnci.net/node/5388
- SI System and Nanoscale Science https://www.nnci.net/node/5385
- Nanometres and nanoscale from Science Learning Hub: https://www.sciencelearn.org.nz/resources/1651-nanometres-and-nanoscale
- How Small is Nano? https://www.nnci.net/how-small-nano
- How Small is a Nanometer? Wonderville.ca https://www.youtube.com/watch?v=EFQW3XASDbk
- Nanocareers from Wonderville.ca https://wonderville.org/asset/nano-careers
- The Project on Emerging Nanotechnologies. This site has an inventory of consumer products. https://www.nanotechproject.tech/

- NNCI Career Brochure for High School Students. https://www.nnci.net/nnci-career-brochure-high-school-students
- Where are the Nanotechnology Career Opportunities? www.dummies.com/education/science/nanotechnology/where-are-the-nanotechnology-career-opportunities/
- Micro Nano Technology Education Center. https://micronanoeducation.org/
- Nanotechnology Applications and Career Knowledge Network. https://nano4me.org/students
- NNCI Careers in Nanotechnology (includes videos). https://www.nnci.net/careers-nanotechnology
- Test your nano IQ- from Nanowork https://www.nanowerk.com/nanotechnology/quiz.php
- Nano Careers video from Wonderville. https://wonderville.org/asset/nano-careers. (May require establishing an account but it is free)
- Do you Know What Nano Means? from Wonderville. https://wonderville.org/asset/nano-careers
- Career Cruising Classroom Activity. https://www.nctc.edu/_documents/counseling-testing/career-cruising-classroom-activities.pdf

Next Generation Science Standards:

- MS-PS-1A Structure and properties of matter
- Cross-cutting: Scale, proportion, and quantity
- HS-PS-1A Structure and properties of matter
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Math Standards:

- MS-8.EE.A.3 Use numbers expressed in the firm of a single digit times an integer power of 10
- HSN-Q.A.1 Use units as a way to understand problems….interpret scale.

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