Teacher's Guide

Understanding Nanotechnology Size and Scale

Grade Levels: 4 & 5

Subject area: General Science

Time required: (2) 50 minute class periods

Learning Objectives: 1. Understand the metric system of measurement; 2. Understand how small a nanometer is. 3. Understand unexpected properties at the nanoscale.

Lesson 1 Summary: This first lesson will be interactive with a worksheet that students complete as they learn. They will be introduced to a ruler that compares centimeters, millimeters, nanometers, and inches. Using this ruler, the students will measure various items in their classroom and hear about the size of things they cannot see with their eyes. The lesson will end with a three minute video "*Intro to Nanotechnology"* At the end of this lesson, students will understand that nanotechnology is the science and technology of small things. They will review the metric system and complete a worksheet. This will reinforce for them that the system is based on units of ten. Students will learn that a nanometer (nm) is 1/billionth of a meter ($1x10^{-9}$). This fact is demonstrated by completing worksheet questions such as: how many nanometers is the width of a typical piece of hair? How many nanometers does a fingernail grow each second? Using a ruler that is printed on cardstock, students will then measure classroom items such as a glue stick, pencil, crayon, and similar in both centimeters and nanometers. Students will receive a second worksheet that explains how engineers and scientists use a scanning probe microscope to "see" the nano-world. The entire lesson is summarized by a humorous Video entitled, "*Intro to Nanotechnology*"

Lesson Background: Nanoscale science and engineering is defined as the understanding and control of matter at dimensions between 1 and 100 nanometers, where unique phenomenon enable novel applications. The fields of nanoscience and nanotechnology promise to have extensive implications for all of society. Understanding how small the nanoscale is proves to be a difficult concept for students because it is at the scale of atoms and molecules. Students at the elementary level often have difficulty understanding the size of things they cannot see. The resource section provides links to introductory materials to help the teacher learn more about nanotechnology and its impact on society. Additional educational videos on size and scale are also included in the resource section. The teacher may also want to explore using additional size and scale activities to reinforce the concepts learned in this lesson. These lessons are listed under "Optional nanoscale measurement lessons" below.

Pre-requisite Knowledge: Students should be able to measure objects using a ruler, should be know the difference between metric and imperial systems, be able to distinguish between units of measurement.

Materials: Lesson 1

- Tape measure or measuring stick that shows both the metric system and the Imperial system (yards and inches.)
- Ability to play a YouTube video
- Student worksheet
- Printed rulers from template (1/student); preferably on cardstock
- Assorted classroom materials for measuring

Safety Information: No safety issues for this activity

Suggested Teaching Strategies: This is a teacher led activity with the students interacting through questions and exploration. The procedure below provides a script that the teacher may follow. There are scripts for each of the two lessons.

Optional nanoscale measurement lessons:

- Cutting Down to the Nanoscale: https://education.mrsec.wisc.edu/cutting-it-down-to-nano-outreach-activity/
- Exploring Size: Measure Yourself: https://www.nisenet.org/catalog/programs/exploring_size_-_measure_yourself

Color key for script:
Purple type: what student sees on their worksheet
Green type: teacher instructions
Red type: correct answers for students to write on their worksheets
Blue type: teacher's spoken script

Script for the Activity:
Welcome to the world of Nanotechnology! What is it? On one hand, it is not Physics; Biology; or Chemistry. On the other hand, it is ALL of them.
Pass out the worksheet and explain that you will tell them when to fill in the spaces by taking notes.
1. Nanotechnology is the science and technology of small things.
Today, you have the unique opportunity to learn how small a nanometer really is. You will learn how things are measured in the nanotechnology world. Perhaps, more importantly, you will learn why the science of nanotechnology is so exciting, useful, and life changing to you.
Let us start out by learning about how small the world of nanotechnology is.

2. A nanometer is a measurement that is a part of the metric system. The metric system is based on units of ten.
Although you are taught the metric system at school, most of us are growing up in households where we talk about size and weight in feet, inches, and pounds. However, the metric system makes sense when you think about it; it is all about knowing how to build on units of ten.

When you hear the word *cents,* when talking about money, how much money is a cent? How many cents are in a dollar? How many years are in a century? When students provide the correct answer of 100, move on to question #3.

3. How many centimeters (cm) are in a meter? 100 cm
How big is a meter? Show the tape measure and mark off a meter by pointing to it on the tape measure. Explain how the meter is divided into centimeters and then millimeters. Illustrate to the students where a yards is on the tape measure. Show them that the yard is divided into feet (3) and inches (12). Emphasize that yards and inches **are not based** on units of ten.

4. How many millimeters (mm) are in a centimeter? 10 mm
Show on the tape measure where a centimeter is broken into millimeters and how they compare to an inch. Millimeters are very small. However, "small" does not even begin to describe the size of a nanometer!

5. A nanometer (nm) is 1/billionth (1,000,000,000) of a meter.
Have a student come to the white board and show what a billion looks like written out in zeros.

Now that sounds small! Let us compare that to something you know. If you are brave enough, pull out one strand of your hair, and put it on the desk in front of you. Look at the end of the piece of hair.

a. a human hair is 60,000 to 80,000 nm in diameter.
Can you imagine trying to split your hair strand one time? Now think about doing that 60,000 times! Now look at your fingernails.

b. a fingernail grows one nanometer (nm) per second. Count one second while looking at your nail – did you see your nail grow? Definitely not!

Now let us talk about a person that is two meters tall. Demonstrate on the tape measure how tall that is. If a meter has one billion nm in it, how many nanometers is someone who is two meters tall?

c. a two-meter person is 2 billion nanometers (nm) tall

d. an oxygen atom is less than $1/10^{th}$ of a nanometer (nm) in diameter.

Now that is very small. If a nanometer is 1/billionth of a meter, and an oxygen atom is $1/10^{th}$ of a nanometer, it makes you wonder how you can even measure something that small. How do scientists and researchers even do it?

Pass out the handout on the scanning probe microscope.

What is the name of the method blind and visually impaired people use to read things? Braille.
How does that work? Braille is touch reading and writing where raised dots represent the letters of the alphabet. It is read by moving the hand or hands from left to right along each line.

They have learned the system of braille that uses their sense of touch. On the hand out, there is a picture of someone using braille to read. Braille is not only used in books, but it is on signage as well. The next time you are in an elevator, take notice of the braille symbols next to the buttons you push for each floor. That is how visually impaired people can tell what button to push.

Review the scanning probe microscopy handout with them referencing the diagram. Have the students close their eyes and then take one finger and run it down their arm from shoulder to fingertips. Did they feel the different surfaces as they ran their fingers over their arm? That is similar to the probe shown in the diagram.

Hand out the printed rulers and instruct the students to fold the ruler lengthwise as shown by the arrows. Review the parts of the ruler: inches divided into smaller measurements on one side, centimeters, millimeters and then nanometers on the other side. Ask students:

Can we see each individual nanometer? That is why these rulers show that each centimeter contains 10 million nanometers.

6. Using your ruler, measure three things in the classroom in both centimeters and nanometers. Write the name of the object followed by its size.

Provide an example by measuring something. If the students are all tending to measure the same things, suggest other objects to measure like their shoe, a friend's ear, someone's glasses, etc.

Example answers:

My pink eraser - 4 cm or 40 million nm
My crayon - 9 cm or 90 million nm
My pointer finger - 6 cm or 60 million nm

Have the students share their measurements.

7. I would like to end this session with a fun video called "Intro to Nanotechnology". This video will summarize the things you have learned today.
https://www.youtube.com/watch?v=GmUeCf_bI-s&t=83s

Other videos to use:
How Small is Nano? https://www.youtube.com/watch?v=bQzFpP4FSN4
How Small is a Nanometer: https://www.youtube.com/watch?v=EFQW3XASDbk
What is Nano? https://www.youtube.com/watch?v=DHvzIGxkItw

Lesson 2 Summary

Understanding Products and Byproducts of Nanotechnology

Overview: This second lesson will build upon lesson one. The students will review the size of the nanoscale and their rulers that compares centimeters, millimeters, nanometers, and inches. The interactive lesson will incorporate worksheets and demonstrations to teach

about the nanoscale. In addition, students will learn about various products made with nanotechnology and that the byproducts of nanotechnology, specifically about pollution that can enter our waterways.

At the end of this lesson, students will understand that nanotechnology has improved the performance of many household products. The students will understand through review of the "Intro to Nanotechnology" video that properties of a material change when they are at the nanoscale level. This concept will be reinforced by demonstrating the peeling of an orange, showing that the peel takes up more surface area when laid out flat versus in a sphere. Additionally, students will watch a demonstration on food coloring diluted in water. This will illustrate that although the color becomes fainter, it is still visible. This concept will correlate with pollution in our waterways. The students will complete a worksheet showing where some pollution originates. They will learn about how nano-silver is used in socks to reduce the odor of sweaty feet. The nano-socks will be an example of a possible negative byproduct (nano-silver) and its adverse effect on our waterways when entering the system via clothes washing.

Materials:

- Tape measure or measuring stick that shows both the metric system and the Imperial system (yards and inches)
- 4 clear plastic cups
- Food coloring
- Eye dropper
- Nano-Socks (Google silver infused socks or antimicrobial socks)
- 2-3 oranges
- Ability to show internet video

Color key for script:
Green type: teacher instructions
Red type: correct answers for students to write on their worksheets
Blue type: teacher's spoken script

Script for the Activity:
1. Today you are going to see how scientists are using nanotechnology. We are going to watch the again the video "*Intro to Nanotechnology*". This time, I would like you to pay specific attention to the video segment where the scientist is cutting the big chunk of gold into slices.
Play video. When video is compleeted, ask:
What did te scientist say when he was cutting up the large gold bar?
At the nanoscale you get UNEXPECTED PROPERTIES.

2. We are going to learn about how properties of things change at the nano scale. Before we do that, let us review measuring with the metric system.
Display the measuring tape and call on the students to tell you:

How many centimeters are in a meter? 100 cm
How many millimeters are in a centimeter? 10 mm
How many nanometers are in a meter? 1,000,000,000 nm
How many nanometers are in a centimeter? 10,000,000 nm

Remember, we cannot see things that small, but scientists have learned how to incorporate nanotechnology into products that we use every day. You all know what silver is, right?
Have the students provide examples of silver products: Examples: jewelry, silverware, silver picture frames etc.

3. Now you are going to see an example of using silver at the nanoscale — and what that size silver can do for a common, unpleasant problem — stinky feet!
Display the nano-socks and pass them around.
What happens when your feet become too hot? They sweat. Do sweaty feet typically smell good? No! That is because the sweat helps bacteria grow which causes our feet and socks to smell.
Scientists have discovered that silver at the nano scale, kills the bacteria that cause odor. They use nano-sized silver in socks, shirts, and hospital uniforms.

Pass out the sheet on nano-silver. Select two or three students to each read a portion of the sheet out loud to the class. Have the students answer the three questions at the bottom of the sheet. Lead their answers to show how at the nanoscale silver is entering our waterways through the washing of clothes.

4. Have one of two students each peel an orange. Direct them to place the peels flat on the desk/table when they are finished. While they are peeling, say:

Notice how much surface area the orange takes up on the table. Now that the peel is off, look how much more surface area the peel has compared to when it was still attached to the orange.

That is similar to how the properties change at the nanoscale. As things get smaller, their surface area increase compared to their volume. I would like now demonstrate how properties change at the nanoscale by using water and food coloring.

5. Put two drops of red food coloring in a glass half filled with water. Have the students observe the color of the water. Now fill up the glass with water, and observe the color again. Next, pour half of the water into another glass which is half filled with observe. Observe the color. Repeat until water is very faintly pink.

How does this process show how pollution spreads? I call this "Traveling Pollution." Eventually, the color will be nonexistent to our eyes, but the food coloring will still be there on a **very small** level.

6. Now, I want you to think of how pollution can start at the very large level and then we will discuss how it eventually becomes nano-scale.

How many of you have personally seen evidence of pollution around lakes, rivers, streams or oceans?
Have students provide examples of discarded tires, soda cans, fast food bags, old appliances, and general garbage.
Then pass our the worksheet with photos of the factory, home, and construction site.
Have the students provide examples of what types of things could be made at a factory.
Cars, toys, food, candy, electronics, etc.

What types of pollution can come out of a factory via the exhaust systems, liquid run off, or garbage bins? Allow the students time to write down examples on their own. Then call on individual students to solicit examples like: Smoke, fumes, grease, waste

What type of pollution can come from our homes? Allow the students time to write down examples on their own. Then call on individual students to solicit examples like: Oil and gas from our garages, smoke from our fireplace chimneys, exhaust from venting, chemicals from our washing machines.

What type of pollution can come from a construction site? Allow the students time to write down examples on their own. Then call on individual students to solicit examples like: Smoke from machines, oil and gasoline, debris from building materials.

7. Some of this pollution can seep into the ground and get into our groundwater. Additionally, this pollution can run into our streams that lead to our rivers.
Point of the sketch of the rocky stream and the water cycle at the bottom of the page. Explain how pollutants can be carried along.

As we learned earlier, materials can change properties at the nanoscale. Pollution that is no longer visible to our naked eye, can still exist at the nanoscale. Remember the example of the silver in the nano socks? The silver kills the bacteria that causes odor, but when it washes off in the laundry, very small amounts of the silver can get into our streams and rivers. This shows how, with all new technologies, there are trade-offs or perhaps byproducts that are not desirable. We like are feet not to stink but maybe not have silver in our water.

A very important aspect of scientist's work is to take into account the potential side effects of their discoveries and inventions. With this knowledge, they can make the proper adjustments as needed.

Additional Resources:

- What is the Nanoscale – Size and Scale: https://education.mrsec.wisc.edu/what-is-the-nanoscale-size-and-scale/
- Nano 101: https://www.nano.gov/nanotech-101
- An Introduction to Nanotechnology: From Understanding Nano: https://www.understandingnano.com/introduction.html
- Serial dilutions: http://gk12.coe.drexel.edu/modules/doc/Matthew_Cathell/Dilution_Activity_1.pdf
- Nanosolutions: https://education.mrsec.wisc.edu/nanosolutions-activity/
- Nanosilver: Naughty or Nice? Science News for Students: https://www.sciencenewsforstudents.org/article/nanosilver-naughty-or-nice
- Dragonfly TV – Nanosilver: https://www.youtube.com/watch?v=72MYWTnn6Yo

Next Generation Science Standards

4-EES2 Earth's Systems
5-PS1 Matter and its interactions
5-LS2 Ecosystems
Mathematics:
4.MD.A1 Know relative sizes of measurement units within one system. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit.
5.MD.A.1 Convert among different-sized standard measurement units within a given measurement system.

Contributors: Jody Jackson and Trevor Thornton Arizona State University

Supporting Programs: National Nanotechnology Coordinated Infrastructure Site at Arizona State University NSF # ECCS 0335765 and National Nanotechnology Coordinated Infrastructure NSF # ECCS 1626153