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One in a Billion

Lesson on understanding Nano size

6th Grade Science

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Background:

According to a 2006 study by Dr. Gail Jones, NCSU:

"Middle school students struggle with applying quantitative reasoning to science concepts outside of the human scale. Middle school science curriculum exposes students to tools and techniques that require an understanding of quantitative measurement and scale beyond their human experiences. In order for middle-grades students to learn and be engaged with the significant advancements in science and engineering, students will need to be able to understand scale from within an atom to the distances of galaxies. Discoveries at these extremes of scale are increasing at dramatic rates and educators are scrambling to find effective ways to educate the next generation of scientists as well as citizens" (Jones, 2006).

Overview:

This lesson plan is the second within a unit on Nanotechnology and it assumes students have already completed a unit on measurement and thus they are already familiar with the metric system and SI units of measurement. In the previous lesson ("Nano Scale"), students conceptualized scale from the Light Years to Nanometers. This included conceptualizing huge distances or numbers like one billion. "This is important because a nanometer is one-billionth of a meter and nanotechnology involves the building of materials at this tiny scale"(Jones, 2007). This lesson continues to build on student's understanding of scale for very small items or measurements. Understanding

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Classroom time:

55 minutes

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concepts in nanotechnology, nanoscience, or nanoengineering requires students to first understand how to model in nano units nm (1/billionth or 10^{-6}). This lesson will do this with two activities: one using food coloring and the other using Becker Bottles. The food coloring activity is courtesy of Dr. Gail Jones et. al., Chapter 3, *Nanoscale Science* , 2007 NSTA's Press. The Becker Bottles are from Flinn Scientific.

Objectives:

- To build an understanding and a mental visualization of one-billionth.
- Able to model a nano-particle solution

Science Standards:

Related Next Generation Science Standards (NGSS):

- **MS-PS1.A: Structure and Properties of Matter**
- MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.
- MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system.
- **MS-ESS2.A: Earth's Materials and Systems**
- **HS-PS1.A: Structure and Properties of Matter**

Science and Engineering Practice

- Using mathematics and computational thinking
  - Asking questions and defining problems
  - Developing and using models

Materials:

- Becker Bottles

Lab Kit (one per student pair)

- nine clear-plastic cups (or beakers)
- Two 10mL graduated cylinder
- 1 mL dropper
- Lab Sheet
- Scrap paper
- 50/50 solution of Food coloring and clear mouthwash
- 200ML of water

Related North Carolina Standards:

- NC SCOS Goal 6.P.2: Understand the structure, classifications and physical properties of matter.

Safety:

Each table should have a clean cloth available for students to wipe up any spilled solution. Safety goggles and an apron should be worn during the lab portion of this lesson.

Lesson Preparation:

- Teacher to watch Flinn Scientific's Video on Becker Bottles to be familiar with how they are used in class.
- Download and print **Lab Sheet** (enough for each student).
- Create a lab kit for each pair of students in advance with the following materials:

  Lab Kit (one per student pair)
  - nine clear-plastic cups (or beakers)
  - Two 10mL graduated cylinder
  - 1 mL dropper
  - Lab Sheet
  - Scrap paper
  - 15ml solution of 50% food coloring 50% clear mouthwash
  - 200ML of water

Teacher Instructions:

The following instructions and activity is modified in part from Dr. Gail Jones, et. al., 2007, NSTApress, Nanoscale Science, chapter three, pp 19-25.

Engage (15min)

Engagement activity I

1. Begin this activity by asking students, "*Which number is larger: one billion or one million?*" Then ask, "*Which quantity is bigger: one part per million or one part per billion?*" Students may respond that one part per billion is larger because they know that one billion is larger. Some students may understand that one part per billion is smaller than one part per million, either way, they likely do not have an accurate conception of the actual size of one part per billion.
2. Ask students to draw and label a table on a sheet of paper as below.

One Billion (10^6)	One Billion (10^{-6})

3. After students have made their table, Ask them "*Would you prefer to have* a *concentration of a toxic substance in your drinking water at one part per billion or one part per million? Please explain why.*" Listen to students' responses to get an understanding of their prior knowledge. Ask the students to give you some examples of"things"that could represent one billion" students should write in the empty table box under "One Billion (10^6)"

4. Once students have written down five to six examples of one billion, tell the students: "Many people have a difficult time understanding very large numbers and very small numbers. Today we are going to travel learn about very, very, small numbers. After the activity, you are going to complete your chart by filling in examples of one billionth.

Engagement activity II

1. Begin this next engagement activity by demonstrating the two Becker Bottles (Teacher: prior to class be sure to watch this [Video]() from Flynn Scientific as a helpful guide). Explain to students that the lid on the two Becker Bottles MUST remain tightly closed and students must not attempt to open the lid. Remind students to follow directions in lab and respect all materials, instruments, and specimens. Directions are on the lid of each bottle. "Becker Bottle One" list different parts per million colors and counts. "Becker Bottle Two" has a lid that listing one count of one part per million. The 3L bottle contains one million tiny yellow spheres. When you challenge students to find the one black sphere (1 ppm) among all the other colored spheres in the bottle, the concept of a million starts to become real. In the "Becker Bottle One" the other colored spheres (e.g., 10 ppm, 100 ppm) are significantly easier to find in the bottle. Allow students to hold both Becker Bottles in turn, make their observations and pass it to another student.
2. After all the students have had the opportunity to observe the two Becker Bottles, allow them one minute to turn-and-talk to one other classmate and discuss "how difficult was it to find the black sphere among all the other spheres?" Allow students another minute to discuss "what one part per billion (10^{-6}) would look like?"
3. After students have discussed 1 in a billion, verbally poll students for their answers. (correct answer: one black shere among 1000 "Becker Bottle Two" bottles).
4. Explain to students that many toxic chemicals are found in solutions at parts per billion even though toxicologist may only have very small solution sample to test. For example Botulinum toxin, also called "miracle poison," is one of the most poisonous biological substances known and is made by bacteria. It is produced in food that is not canned or processed correctly. In fact, if present in food at 30parts per billion of water, it is a lethal dose. However, if Botulinum is diluted to less than .3 parts per billion, it is the drug Botox, used to treat migraine headaches (Irimia, 2016). So as you can see, measuring very small quantities can be a matter of life and death. The next activity will help us understand what one part per billion looks like in solution.

Lab

Explore & Evaluate (30 minutes lab activity)

Students will need to have an understanding of solutions and how their concentrations are calculated in order to complete the activity. Ask students, "What does it mean to say that you have one in ten chances of winning a game?" Ask them, "Is there another way of stating that you have one in ten chances of winning a game? Students may say that out of ten people playing the game, only one person is going to win. Others may explain that one person has a 10% chance to win the game. This will lead you into a discussion on the term percent.

Ask the students, How many cents are in a dollar? They will say one hundred. Ask the students, How many years are in a century? (You may want to write the underlined words on the board so that students can see the words.) Ask the students, How often does the federal mint make centennial quarters? Then ask the students, From the terms we've discussed that are written on the board, what do you think the word "cent" means? After discussing that cent means one hundred, write the root word percent on the board and explain that percent means "part per hundred." Hold up a beaker with 95 grams of water (95 milliliters). Ask the class, If I wanted to make this a 5% sugar solution, how much sugar do I need to add to it? Write "95 grams of water" on the board. Once you have received the answer (5 grams), write "5 grams of sugar+ 95 grams of water= 100 grams of solution."Write the fraction "5 grams of sugar/100 grams of solution." If the students seem to have difficulty understanding percent then you may want to be prepared to add other examples. Check for understanding: Hold up a beaker of water and red food coloring (a 10% solution).Tell the students that this is a 10% solution. Ask them, How did I make this 10% solution out of water and food coloring? Further explain that 10 parts of food coloring were added to 90 parts of water. You could demonstrate this by putting 9 drops of water in a clear cup or test tube and then adding one drop of food coloring.

It is suggested that students work in pairs. Each pair should have nine small cups or beakers placed on a blank white piece of paper to help them see the color change. Explain that they will perform a series of dilutions, each larger by a power of ten. This is referred to as a serial dilution.
Distribute Lab sheet. You may need to get them started by reading through the procedure and walking them through cups 1 and 2. You may also need to help them calculate the con-centrations for these cups. Explain and write on the board that cup 1 has a 10% solution or 1 /1 O solution. If they add 1 ml of a 1/10 solution to9 ml of water the solution will now be 1/10 of 1/10which equals 1/100 (a 1% solution),or 1 part per hundred. Have them calculate the concentration of cup 2.

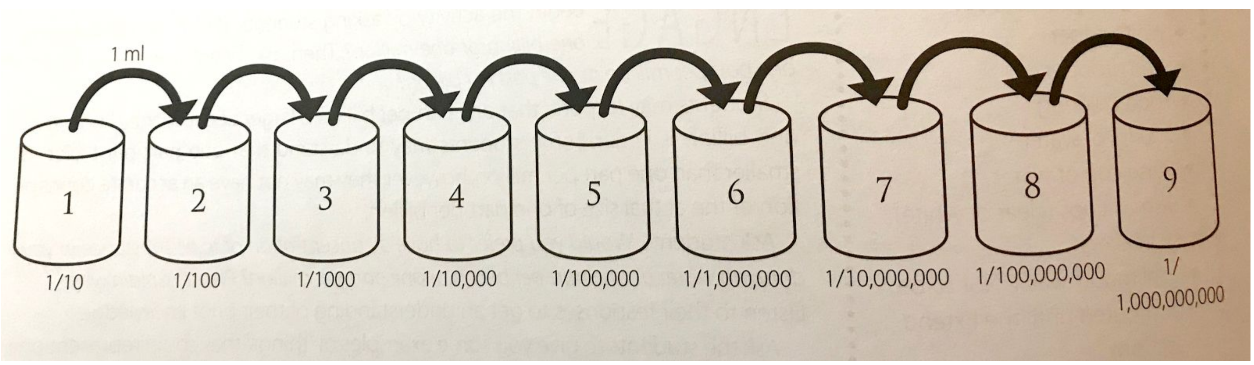

Image from Dr. Gail Jones, et. al., 2007. Nanoscale Science, NSTApress

Discuss and Reflect

1. The last five minutes of class, have the students clean up their lab table and bring their attention to the teacher.
2. Instruct the students not to turn in their lab until they are dismissed. Prior to dismissal, ask the students the following questions.
    - What is the numerical expression for nano? (answer= 10^{-9})
    - Why is “nano” the same thing as 1 part per billion? (answer = a nano is 1/billionth of a unit, for example an example a nanometer is 1/billionth of a meter).
    - What was the hardest thing to understand in this lab today, how did you resolve it?

Assessment:

Teacher is to assess students by making observations during the lab activity as well as an assessment of their individual lab sheets that are turned in for grading.

Extensions:

Conceptualizing size and scale by students
http://www.uwyo.edu/wisdome/_files/documents/jones.pdf

Website on Nano instrumentation:
https://www.nanowerk.com/nanotechnology/nanotechnology-videos/nano_videos.php?cat=manu

Resources:

Information regarding Botulinum toxin
R. Gottschling M.(2016) Taxonomic revision of Rochefortia Sw. (Ehretiaceae, Boraginales). Biodiversity Data. Web. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3028942/

Becker Bottles:
Flynn Scientific
(https://www.flinnsci.com/products/chemistry/chemical-demonstration-kits/becker-bottles-demonstration-models/)

Jones, M. (2006). "Conceptualizing Size and Scale." PDF
http://www.uwyo.edu/wisdome/_files/documents/jones.pdf

Jones, M. (2007). *Nanoscale science*. Arlington, Va: NSTA Press.