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| **Introduction**  | In modern society, one of the essential things that we take for granted is measurement. The necessary tool became more of a fundamental concept when humans began to build shelters, cultivate fields or buy and sell items for other things. Inquiring statements such as “How long, How big, and How much” were often ways to “guesstimate” measurement. In the present day, all the different units we use for measurement are standardized. Every person knows precisely the length of a foot, or a meter, or an inch, or a centimeter. Of course, we do not all use the same system, but within any structure of measurement, we all concur on what each unit represents.In this project, much of the learning responsibility is placed on the student. The driving question is open ended enough that several answers and perspectives are possible. Students will be expected to conduct independent research with tools given to them and use the data to interpret the metric system from big to small.  |
| **Real Science Application**  | What is the use of scientific notation in everyday life? Scientific notation is needed any time you need to express a number that is very big or very small. Suppose for example you wanted to figure out how many drops of water were in a river 12 km long, 270 m wide, and 38 m deep (assuming one drop is one milliliter). It's much more compact and meaningful to write the answer as roughly 1.23 x1014 than it is to write 123120000000000. For one thing, the scientific notation is easier to read, and makes it much easier to tell at a glance what the order of magnitude is (rather than counting zeroes). For another, most of the digits in 123120000000000 are completely meaningless (unless your measurements were very precise). For instance, if the exact river length were really 12.123123 km (we just measured it to the nearest kilometer), then correct number of drops would be 124383242000000, and after the first three digits our result of 123120000000000 is quite inaccurate. So it's better to use a notation (like scientific notation) in which you can suppress the inaccurate digits. |

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| **Curriculum Alignment**  | This section contains the curriculum alignment of the lesson to the North Carolina  [Essential Standards](http://www.ncpublicschools.org/acre/standards/new-standards/) of Science or Math, and the [Next Generation Science Standards](http://www.nextgenscience.org/next-generation-science-standards) (NGSS) or [Common Core Math](http://www.corestandards.org/Math/).

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| Content Area | Grade Level | NC Essential Standards | NGSS / Common Core Math |
| Science | 9th -12th | Content Standard A: Science as inquiry |  |
| Math | 9th – 12th |  | [CCSS.Math.Content.8.EE.A.4](http://www.corestandards.org/Math/Content/8/EE/A/4/) |

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| **Learning Outcomes**  | Students will express their ideas clearly both verbally and in writing the relationship of the size and the scale of objects. Students will collaborate together to comprehend and understand the metric system, including the very small nano-scale. |
| **Time Required and Location**  | 45 minute class period in classroom.  |
| **Materials Needed**  | Teacher List* Lesson plan

Student ListPer group for the NanoWater activity* white paper1ml dropper
* Mouthwash
* 200ml of water
* 9 small clear cups
* 2 graduated cylinders
* marker

Per group:* 1 Metric Tape
* 1 Ruler
* large sheet of butcher paper and a pencil OR chalk and a clear spot on a sidewalk (optional if it’s a nice day outside)

Per student:* Worksheet/datasheet
 |
| **Safety**  | Following the directions of the teacher/instructor of the activity. Keep all items away from mouth and any other cavity of the body. |
| **Student Prior Knowledge**  | The Metric System conversions. (Kilo, hecto, deka, deci, centi, milli.) |
| **Teacher Preparations**  | * Become familiar with conversions of the metric system. Also, become familiar specifically with the prefixes nano and micro.
* If necessary, reserve area outside of the building with space for sidewalks and chalk.
* Print out worksheets for students.
 |
| **Activities**  | Direct the students to begin class by doing the “NanoWater” activity as warm up. (See Attached lesson) Ask the students a few questions to peak their interest.1. Which number is larger: one billion or one million? Then ask, which quantity is bigger: one part per million or one part per billion?
2. Would you prefer to have a concentration of yucky substance in your drinking water at one part per million or one part per billion?

Divide students into groups of 4. Each groups should have a set of the listed materials. Explain that the mouthwash is pure or 100% solution. Line up nine small clear cups at the top of a white sheet of paper and number the cups 1-9. Explain the concentration in each cup by describing the concentration in the first 2 cups to the whole class. Have the students make the solution while explaining that cup #1 is to have 10% original solution and 90% water (1ml solution and 9 ml of water.) Demonstrate the process for cup #2, 10% (1 ml) of the ingredients in cup #1 and 90% (9 ml) of water. Have students continue the process/pattern of adding 1ml of the previous solution with 9ml of water until all 9 cups have a solution in them.Have the students try to write the fraction of the solution for each cup. In addition also ask the students questions such as In which cup did the solution first appear colorless?, What concentration is the solution in this cup?, and What is the concentration of cup 9? [15 minutes]After NanoWater is completed, show students a chart that displays metric prefixes for key powers of ten (from kilo to nano). This should help open a discussion on the words “micro” and “nano” and help focus on nanometer and micrometer. Have students explain what they think the words mean and the context in which they’ve heard it. [5 minutes]Measurements for a Tailored Suit: Explain to the students that they have been invited to a very big fancy party and need a tailored suit. The activity and worksheet will all you to collect your data. The activity is taking measurements of specific areas of the body in preparation for a tailored suit. Once the students take their own measurements, students will convert the data from meters into other metric units. Allow students to work diligently in their groups to complete the activity and worksheet. [25 min]As a teacher, provide a quiet class environment for students to begin planning their response. Circulate in the classroom to answer any questions that arise and to support strong planning before writing. |
| **Assessment**  | Each student will turn in their completed worksheet at the end of the lab so the teacher can assess the student’s ability to understand the metric system and its conversions, as well as relate the size and scale of objects to various metric units, including the very small nano-scale. Points can be given for correctly:* Making measurements using the metric system
* Converting measurements to other metric units
* Explaining their conclusions
 |
| **Modifications**  | Create a small group of students who struggle with comprehension and, particularly, have a limited understanding of scientific notation and very small numbers. Guide a read-aloud session, discussing nanometers and micrometers. Might be a good idea to use examples as parts per billion. Example: According to the chemical companies which say that toxins in the water ranging from 1 ppb to 80 ppb won’t harm people, 1 ppb is the same as 1 pancake in a stack of pancakes 4000 miles high or 1 second in 32 years. (This kind of gives students a vision).. |
| **Alternative Assessments**  | The intended audience is for eighth grade math students. Teacher should follow specific students’ 504 and IEP plans for students with modifications. |
| **References** | <http://www.nisenet.org/catalog/metric-system-big-small-middle-and-high-school-curriculum-lesson> |
| **Comments** | This lesson was developed by research accumulated during a fellowship done with the ASSIST in reference to Nanotechnology and Nanotechnology in the classroom.  |
| **About the Author** | Tremain Holloway is the Lead Math Teacher at Middle College High School on the campus of Durham Technical Community College. He was a NC Teaching Fellow and 2014-15 Kenan Fellow. |

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**Measurements for a Tailored Suit**

Guess what? You are invited to a big fancy party and need a tailored suit! This worksheet will provide the tailor with all the measurements needed to make your special suit. Plus it will help you learn about the metric system.

Procedure:

1. Lie down on a large piece of paper or on the ground. Your partner will do step 2.

2. Draw an outline around your partner so that it looks like what police do at a crime scene involving a body on the ground. Make sure that the line is close to the body!

3. Measure each body part in metric unit. Record your measurements in the proper column.

4. Convert each measurement into all the other metric measurements in the table.

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| **Body Part** | **Meters****(m)** | **Centimeters****(cm)** | **Millimeters****(mm)** | **Micrometers****(µm)** | **Nanometers****(nm)** |
| Top of head to bottom of heel |  |  |  |  |  |
| Tip of Shoulder to tip of Middle finger |  |  |  |  |  |
| Top of hip bone to bottom of heel |  |  |  |  |  |
| Back of heel to front of big toe |  |  |  |  |  |
| Center of knee cap to bottom of foot |  |  |  |  |  |
| Diameter of widest part of head |  |  |  |  |  |
| Tip of elbow to tip of middle finger |  |  |  |  |  |
| Shoulder width |  |  |  |  |  |



**“NanoWater”**

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| **Try this!** **(1-2 minutes)**1. Inquiry Question: *Which number is larger: one billion or one million?* Then ask, *which quantity is bigger: one part per million or one part per billion?*
2. Ask Students, *Would you prefer to have a concentration of toxic substance in your drinking water at one part per million or one part per billion?*

**What’s going on?**Some students will respond that one part per billion is larger because they know that one billion is larger. Many people have a difficult time understanding very large numbers as well as very small numbers. In the next activity, we are going to travel to the opposite end of the spectrum and learn about very, very, small numbers. My hope is that the students will comprehend that one part per billion is smaller than one part per million, however, they may not have an accurate conception of the actual size of one part per billion.  | indicator_solution_in_one_cup |

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| **Now try this! (5 minutes)**1. On top of a white sheet of paper, line up nine small clear cups (Number the cups 1-9).
2. Show students the original mouthwash container and explain that this is solution is 100%.
3. Explain the concentration in each cup by describing the concentration in the first 2 cups to the whole class. Have the students make the solution while explaining that cup #1 is to have 10% original solution and 90% water (1ml solution and 9 ml of water.) Demonstrate the process for cup #2, 10% (1 ml) of the ingredients in cup #1 and 90% (9 ml) of water.
4. Repeat the process/pattern in step #2 until all 9 cups have a solution in them.

**What’s going on?**In cup #1 there is .1 amount of solution or 1/10. In Cup #2, there is .01 or 1/100 solution. In Cup #3, there is .001 or 1/1000 solution. Do you see the pattern? The following cups in order from 4 – 9 will go 1/10,000; 1/100,000… 1/1,000,000,000.  | labeled_cups_and_droppers |

**How is this nano or ASSIST?**

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| neutralizing_acids_and_bases | **This activity was demonstrated by Dr. M. Gail Jones author of *Nanoscale Science Activities for Grades 6-12.***  |

## Learning Objectives

1. Participants will build an understanding and a mental visualization of one-billionth

## Materials

* *White Paper*
* 1 ml dropper
* Mouthwash
* 200 ml of water
* 9 small clear cups
* 2 graduated cylinders

## Notes to the presenter

**Before doing this activity,** please do the following:

* *Make sure students have some understanding of scientific notation as well as converting fractions to decimals and vice versa.*

**Tips:** Try to ask questions similar to:

* In which cup did the solution first appear colorless?
* What concentration is the solution in this cup?
* What is the concentration of cup 9?

**SAFETY:** Be careful not to get the mouthwash in your eye! If this happens wash your eye out immediately. If irritation continues please consult a doctor.

*Cleanup:*Follow Teachers directions to disregard items safely as a cleanup procedure!

## Related educational resources

For further research:

* Extreme Science from Nano to Galactic by Dr. M. Gail Jones, Amy R. Taylor, and Michael Falvo.

Credits and rights

This activity was adapted from *Nanoscale Science Activities for Grades 6-12*, developed by Dr. M. Gail Jones. The original program is available on Page 19 of the book referenced above.

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