Teacher's Guide

The Metric System from Big to Small

Purpose: This lesson will review the metric system and relate the size and scale of objects to various metric units, including the very small *nano*-scale.

Level: Middle school and high school (Pre-algebra, Algebra, Biology)

Time required: Two 50-minute class periods or one 90-minute block period

Teacher Background

History of measurement: Like many things we take for granted today, measurement was born out of necessity. As soon as humans began to construct shelters, plow fields, or trade items for other items, it became necessary to measure. They asked, "How long? How big? How much?

When humans began living and working with others, they found that they needed to set some *standard* so that the units of measurement would be the same for everyone. For instance, when Noah was building his ark, a cubit was a measure of length. It was the distance from the end of the elbow to the tip of the middle finger. But, whose elbow, whose finger? Eventually, societies had to agree on what *exactly* a cubit was, a foot was, a yard was, a meter was, etc.

Today, all the different units we use for measurement are *standardized*. Everyone knows exactly how long a foot is, or a meter, or an inch, or a centimeter. We don't all use the same system, but within any system of measurement, we all agree on what each unit represents.

Did you know?

During the reign of Henry the III of England, there was a law called the "Assize of Bread and Ale." This law stated that anyone caught cheating when selling bread (and other things) to someone could be severely punished. A baker could lose his hand or a finger should it be proven that he short-changed a customer. To guard against being accused of cheating, bakers started adding an extra piece of bread to a customer's order just to be safe. Thus, if someone ordered a dozen rolls (normally 12) the baker would give them 13 rolls. This was, and still is, called a Baker's Dozen. Even though our laws are a lot more lenient now, the tradition of getting 13 items in a dozen continues.

How the meter came about: We can thank the French for standardizing the meter. The French Academy of Sciences, in 1791, decided that the standard length of a meter should be one ten-thousandth of the distance from the Equator to the North Pole. Originally, marks on a platinum-iridium metal bar in Paris were used as the official standard for a meter. Today, with better technology, the meter is defined as, "*The metre is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second."* (see 3rd Resource on next page)

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Materials for each group of 2–3 students

- large sheet of paper (butcher paper or something similar) that can be used to draw a full-sized outline of a student or clean place on sidewalk.
- sidewalk chalk
- markers, pens, pencils, paper
- metric tapes and/or rulers
- string, about 3 meters long

Advance Preparation

1. PURCHASE LARGE PIECES OF PAPER
   Purchase large pieces of paper (such as butcher paper), one for each student group to draw a full-sized outline of one their bodies.
   One possible source of this paper is:
   Discount School Supply
   P.O. Box 60000
   San Francisco, CA 94160-3847
   1-800-627-2829
   http://www.discountschoolsupply.com/Product/ProductList.aspx?category=785&Welcomeid=504&at=5
   Alternatively, you could cordon off a large concrete or asphalt area, such as an outdoor basketball court, an unfrequented school parking area or sidewalk, and get enough chalk for every student to mark an outline on the pavement.

2. PRINT STUDENT WORKSHEETS
   Print enough student worksheets for all students.

Directions for the Activity

Teaching Strategies This activity works best in groups of 2–3 students. *Before* beginning the lab activity, describe the *QUICK Activity* below and encourage students to share their explanations with the rest of the class. Then, review the metric system with the class.

QUICK Activity

Materials

- A spool of thread

It's the Middle Ages and as a poor peasant, your family receives 3 feet of gold thread from the king each year that you can use to buy food and shelter for you and your family. You must send one member of your family (in this case one member of your group) to the king to get your thread. During the Middle Ages, a foot was defined as the distance from the back of your heel to the tip of your big toe. Have each member of your group measure off three feet of string. Decide who in your group will go to get the gold thread. Explain your reasoning and discuss how this system could be made fairer.

A standard measure would be fairer because foot size varies and some peasants would get more or less thread depending on foot size.

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Metric Prefixes for some Powers of Ten				
Factor	**Power of ten**	**Prefix**	**Symbol**	**Example**
1 000 000 000 000	10^{12}	*tera-*	T	terahertz
1 000 000 000	10^{9}	*giga-*	G	gigabyte
1 000 000	10^{6}	*mega-*	M	megabyte
1 000	10^{3}	*kilo-*	k	kilogram
100	10^{2}	*hecto-*	h	hectometer
10	10^{1}	*deka-*	da	dekagram
0.1	10^{-1}	*deci-*	d	deciliter
0.01	10^{-2}	*centi-*	c	centimeter
0.001	10^{-3}	*milli-*	m	milliliter
0.000 001	10^{-6}	*micro-*	μ	micrometer
0.000 000 001	10^{-9}	*nano-*	n	nanometer
0.000 000 000 001	10^{-12}	*pico-*	p	picogram
0.000 000 000 000 001	10^{-15}	*femto-*	f	femtosecond
0.000 000 000 000 000 001	10^{-18}	*atto-*	a	attomole

QUICK ACTIVIY

An additional quick activity would be to distribute cards (see attached) of the prefixes with symbols and the power of ten associated with each prefix. Have students first sort the powers and then match to the correct prefix. Alternatively, give students the prefix to sort then distribute the power cards have them match.

List any last minute details that the students must remember. Now, begin the lab.

Going Further Relate the metric system to various objects that students are familiar with by using the activity *Size and Scale—Learning about Measurement.* This lesson, provided by the National Nanotechnology Infrastructure Network (NNIN), can be downloaded at the following website: http://www.nnin.org/nnin_k12sizeandscale.html.

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Name:_____ Date:_____ Class:_____

Student Worksheet
(with answers)
The Metric System from Big to Small

At your school, tryouts for the school basketball team are coming up. The new coach, who just came here from Spain, has decided that in order to tryout for the team you must be at least 153 centimeters tall.

Materials

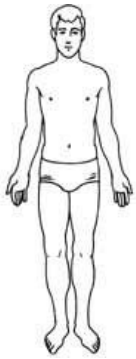
- large sheet of butcher paper and a pencil OR chalk and a clear spot on a sidewalk
- metric tapes and rulers
- string, (~3 m long)

Question Can you try out for the team?

Make a Prediction

Example prediction: I think I can try out for the team because I am 5 feet 4 inches tall, which is 160 centimeters.

Procedure



1. Choose one person in your group to lie down on a large piece of paper or on the ground, like the drawing below. 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 murder. Make sure that the line is close to the body!
3. Look at the table on the next page. Will you be able to make these measurements? If not, repeat steps 1-2 to make the image clearer.
4. Measure each body part using metric units. Record your answer in the table on the next page.

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Record Your Observations

(Note: Students must use the units symbol or scientific notation for each measurement for it to be understood!)

Data Table: The Metric System from Big to Small

Body Part	Meters (m)	Centimeters (cm)	Millimeters (mm)	Micrometers (μm)	Nanometers (nm)
Top of head to bottom of heel	*1.68 m*	*168 cm*	*1,680 mm*	*1.68×10^6 μm*	*1.68×10^9 nm*
Tip of shoulder to tip of middle finger	*0.69 m*	*69 cm*	*690 mm*	*6.9×10^5 μm*	*6.9×10^8 nm*
Top of hip bone to bottom of heel	*1.01 m*	*101 cm*	*1,001 mm*	*1.001×10^6 μm*	*1.001×10^9 nm*
Back of heel to front of big toe	*0.27 m*	*27 cm*	*270 mm*	*2.7×10^5 μm*	*2.7×10^8 nm*
Center of knee cap to bottom of foot	*0.46 m*	*46 cm*	*460 mm*	*4.6×10^5 μm*	*4.6×10^8 nm*
Circumference of widest part of head	*0.57 m*	*57 cm*	*570 mm*	*5.7×10^5 μm*	*5.7×10^8 nm*
Tip of elbow to tip of middle finger	*0.45 m*	*45 cm*	*450 mm*	*4.5×10^5 μm*	*4.5×10^8 nm*
Shoulder width	*0.73 m*	*73 cm*	*730 mm*	*7.3×10^5 μm*	*7.3×10^8 nm*

Analyze the Results

1. Complete the table by converting this measurement into the other metric units. For example, if your subject's length is 1.9 meters, then you would convert the 1.9 meters to 190 centimeters, 1900 millimeters, etc. Micrometers and nanometers can be written using scientific notation.
2. Once all of the measurements are taken and the table is complete, take the data from the table and label the full-size figure on the butcher paper with the unit of measurement you feel

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appropriate for each body part. Be sure to plan out beforehand how you will label the diagram to make sure it is easily readable and neat.

3. After completing the labeled diagram, show it to your teacher for approval then, in your groups, answer the questions below.

Draw Conclusions

1. Compare your measurements across each row. How are they similar? How are they different?
   They all have the same numbers, but they have the decimal point in a different place.

2. How should you determine which metric unit is best to use for a particular body part measurement?
   You should use the metric unit that makes the number easy to read and say. For example, 1.9 meters is easier to read and say than 1,900,000,000 nanometers.

3. Why do you think the scientific community and most countries in the world use the metric system rather than the English system (the system we use in the U.S.)?
   The metric system makes it easy to convert one unit to the other. For instance to change meters to centimeters, you only have to move the decimal point two places to the right. Changing 39 inches to yards or feet involves much more calculation.

In your opinion, which system is better, the English system or the metric system? Why? *Answers will vary. Example answer: I like the English system better because I am already used to it.*

Resources You may wish to use these re-sources either as background or as a resource for students to use:

- http://inventors.about.com/library/inventors/blmeasurement.htm
- http://en.wikipedia.org/wiki/History_of_measurement
- Resolution 1 of the seventeenth CGPM (1983): Definition of the metre http://www.bipm.org/jsp/en/ViewCGPMResolution.jsp?CGPM=17&RES=1

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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
- using scientific notation for micrometers and nanometers
- explaining their conclusions

National Science Education Standards (Grades 5–8)

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science

- Diversity and adaptations of organisms

National Science Education Standards (Grades 9–12)

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

California Science Education Standards (Grades 7)

Grade 7, Content Standard 7: Investigation and Experimentation

a. Select and use appropriate tools and technology to perform tests, collect data, and display data.
c. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.

California Science Education Standards (Grades 9–12)

Investigation and Experimentation, Content Standard 1

a. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data.
c. Formulate explanations by using logic and evidence.

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