Chapter 4
Sort It Out

Overview

Is a virus bigger than a bacterium? Is the distance from the Earth to the Moon greater than the diameter of the Earth? In this investigation students explore the relative sizes of things through a card-sorting activity. The goal is to raise students' awareness of metric distance scales and to promote the development of a series of conceptual anchors that they can use to estimate the sizes of objects.

Objectives

- To develop a sense of scale and the sizes of things.
- To use existing knowledge to make inferences about the sizes of different objects.

Process Skills

- Inferring
- Analyzing data

Activity Duration

30 minutes

Background

Developing a sophisticated understanding of the sizes of things involves many skills. They include knowing the names of the measurement units and what they mean, knowing how to compare sizes and convert from one measurement unit to another, and having a framework of size references to use when encountering a new size or distance. Research on how students learn scale (Jones et al. 2008) suggests that students learn relative sizes before they learn absolute sizes. This skill is tied both to the development of both number sense and proportional reasoning.

In this investigation students apply their knowledge of the relative sizes of known objects to infer the relative sizes of less-well-known objects and distances.

Materials

Each pair of students will need:

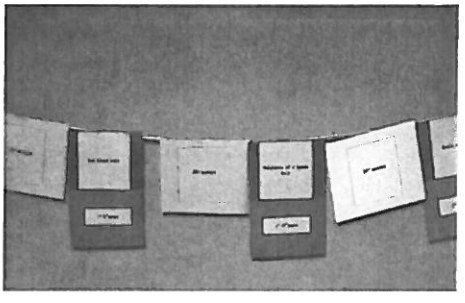
- Set of Student Investigation Object Cards
- Set of Metric Unit Cards
- Relative-Size Data Table
- Unlined index cards (1 per student)
- Colored pencils or markers

ENGAGE

Ask the students to predict which is larger: A cell or an atom? A fruit fly or a mite? The height of the Washington Monument or the height of the Empire State Building? After giving them a chance to share their responses, explain that the goal of this investigation is to consider the relative sizes and distances of different things.

Encourage the students to memorize the sizes and distances of a few objects and locations that they can use as mental anchors to apply throughout life. Examples of some common references for small objects are proteins (nanometers), viruses (10s of nanometers), cells (micrometers), fleas (millimeter), and a child (meter).

EXPLORE
Part I: Relative Size



Assign students to work in pairs for this activity. Explain that the goal for Part I is to order the set of Object Cards by size, from smallest to largest. Invite them not only to consider whether the object on the card is bigger or smaller than another, but also to think about how much larger (proportionally) one object size is than another. Pass out the cards and encourage the students to discuss the sizes as they reach consensus on their sorting rationale.

After they complete the sorting task, have the students explain their sorting rationale for a subset of cards (cell, molecule, and diameter).

EXPLAIN

After students complete their card sort, review the correct ordering of the cards. Encourage the students to share the reasoning they used to place one object as larger or smaller than another object.

Part I. Answer Sheet: Relative Size Data Table

Smallest	Object or Distance (Relative Order)	Actual Size (Average)
1	Diameter of a proton	10^{-15} m
2	Size of a hydrogen atom	50×10^{-12} m
3	Size of a typical small molecule	$2^{-10} \times 10^{-10}$ m
4	Range of virus sizes	2×10^{-8} -2×10^{-7} m
5	Diameter of a strand of DNA	2×10^{-9} m
6	Diameter of a typical cell	2×10^{-5} m
7	Diameter of a human hair	7.5×10^{-5} m
8	Thickness of a penny	0.0015 m
9	Width of an adult's hand	0.22 m
10	Height of a typical human	1.71 m
11	Length of longest snake	11.5 m
12	Length of a school bus	10 m
13	Width of a football field	47.97 m
14	Height of Empire State Building	381 m
15	Distance you could walk in 10 minutes	1,000 m
16	Distance from the Earth to the International Space Station	400,000 m
17	Distance from New York to London	5,590,000 m
18	Diameter of the Earth	12,800,000 m
19	Distance from the Earth to the Moon (center to center)	385,000,000 m*
20	Distance from the Earth to the Sun	150,000,000,000 m
Largest		

* This is mean value. The distance from Earth to the Moon varies ~10% over the course of the year (357,000 km to 407,000 km). *http://nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html*

Part II: Metric Measurements

Part of learning about metric measurements is learning the metric prefixes. This part of the investigation repeats the card-sort activity, but now students sort the metric units with different prefixes from smallest to largest. After the students have had a chance to predict the placement of the metric cards, review the different prefixes. Then have students reexamine their sorting order, making changes where needed.

Part II. Answer Sheet: Prefixes and Metric Measurements

Prefix	Description	Decimal	Scientific	Unit in Meters
femto	quadrillionth	0.000000000000001	10^{-15}	femtometer
pico	trillionth	0.000000000001	10^{-12}	picometer
nano	billionth	0.000000001	10^{-9}	nanometer
micro	millionth	0.000001	10^{-6}	micrometer
milli	thousandth	0.001	10^{-3}	millimeter
kilo	thousand	1,000	10^{3}	kilometer
mega	million	1,000,000	10^{6}	megameter
giga	billion	1,000,000,000	10^{9}	gigameter
tera	trillion	1,000,000,000,000	10^{12}	terameter
peta	quadrillion	1,000,000,000,000,000	10^{15}	petameter

EXTEND

Prefix Creatures

Invite the student teams to create an imaginary creature based on an assigned prefix. The creature's name and some characteristic of the creature should be based on the prefix. Provide each team with a large index card. The front of the card should be used to make a drawing of the unknown creature, and the back should be used for a description of it. After the cards are complete, have student teams exchange cards and, as a class, order the cards from smallest to largest. For further extensions of this activity have the students write creative stories about the habitats of their creatures as well as the creatures' adaptations to the environment.

Example of a Prefix Creature: Duck-Billed Gigabeast

Evaluate the ordering of the imaginary creatures based on the correct ordering of the

name prefixes. Display examples of creative and imaginative creatures on the board.

Further Exploration

Community Speakers

To explore this lesson further, invite people who use measurement frequently in their jobs to visit the class and discuss techniques used for measuring in their fields. For example, surveyors have to measure land for new roads or neighborhoods, cartographers measure land to create maps, and foresters measure large tracts of land to estimate the amount of wood that can be harvested from a forest. Speakers from the community help stress the relevance of the topic as well as help students think abut future careers.

Web Investigations

For a visual comparison of different scales (large and small) explore the website A Sense of Scale: *http://www.falstad.com/scale*

EVALUATE

To test their knowledge of prefixes and metric units have students fill in the missing cells on the chart.

Prefix	Description	Decimal	Unit in Meters
1._____	quadrillionth	0.000000000000001	femtometer
tera	trillion	2._____	terameter
mega	3._____	1,000,000	megameter
milli	thousandth	0.001	4._____
giga	5._____	1,000,000,000	gigameter
pico	6._____	0.000000000001	picometer
7._____	thousand	1,000	8._____
nano	9._____	0.000000001	nanometer
peta	10._____	1,000,000,000,000,000	petameter
11._____	millionth	0.000001	micrometer

Note: This investigation is adapted in part from Tretter, T., and M. G. Jones. 2003. A sense of scale. *The Science Teacher* (Jan.) 2003: 22–25.

References

Jones, M. G., T. Tretter, A. Taylor, and T. Oppewal. Forthcoming. Experienced and novice teachers' concepts of spatial scale. *International Journal of Science Education.*

Jones, M. G., A. Taylor, and B. Broadwell. Forthcoming. Estimating linear size and scale: Body rulers. *International Journal of Science Education.*

Jones, M. G., A. Taylor, J. Minogue, B. Broadwell, E. Wiebe, and G. Carter. 2007. Understanding scale: Powers of ten. *Journal of Science Education and Technology Education* 16 (2): 191–202.

Student Investigation Object Cards

Directions: Distribute one object card to each pair of students.

Part I Directions: Place these cards in order of relative size from smallest to largest.	
Diameter of a cell	Diameter of a proton

Height of a typical human	Diameter of a strand of DNA
Diameter of the Earth	Size of a typical molecule
Size of a hydrogen atom	Width of a football field

Height of Empire State Building	Length of the longest snake
Distance you could walk in 10 minutes	Size of a typical virus
Width of an adult's hand	Distance from New York to London

Thickness of a penny	Distance from the Earth to the International Space Station
Diameter of a human hair	Length of a school bus
Distance from the Earth to the Moon	Distance from the Earth to the Sun

Name _____

1. Record your card sort into the data table below.

Relative-Size Data Table

Smallest	Object or Distance
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
Largest	

Metric Unit Cards

Directions: Sort the metric unit cards from smallest to largest.

femtometer	kilometer
nanometer	micrometer
millimeter	petameter

gigameter	terameter
picometer	