HOW TALL IS TALL?

Facilitator's Guide • Section 3.1

STOP for science

SCIENCE TOPIC OUTREACH POSTERS

INTRODUCTION

Young students love to make comparisons, and one of the earliest quantitative concepts they encounter is that of size. Some things are small and others are BIG! And there is nothing quite like the engaged argument about which is biggest. But the question of exactly how one measures size can actually be complicated. The "How Tall is Tall?" exercise introduces a rather simple question: What is the tallest mountain on Earth?

The primary points covered in the poster are:

- **The surface of the Earth is very smooth.** Although there are tall mountains, they are actually relatively small compared with the size of the Earth.
- **Measurements of mountain heights are relative.** There are different ways of defining the highest mountain, and each has an interesting and important meaning.
- **The Earth is wider at the equator.** Points along the equator are farther from the center of the Earth than points at the poles.
- **Measured from sea level,** the level at which ocean water resides, Mt. Everest is the tallest mountain on the planet.
- **Measured from base to tip,** Mauna Kea is the tallest mountain because its base is far below sea level.
- **Measured from the center of the Earth,** Mt. Chimborazo is the tallest mountain. It resides on the equator, which bulges out due to the rotation of the Earth.
- **The tallest mountain in the solar system** is Olympus Mons, on Mars.

BACKGROUND SCIENCE

Living on the surface of the Earth, it is difficult to get a sense of its shape. It is not without reason that people first came to understand that the Earth is not flat only about 2000 years ago despite inhabiting its surface for nearly 30 times that long; its curvature is slow, because the Earth is incredibly large. For the same reason, it is difficult to picture how smooth the surface is. We see tall mountains and deep valleys that make it seem like the Earth is a pretty poor excuse for a sphere. But just how lumpy and jagged is the surface of the Earth? One way to think about answering this is to consider how tall its tallest mountains are.

Gravity does its best to make the Earth a sphere. With every piece of the planet pulling on every other piece, the combined effect is to pull everything toward the center, forming a sphere. But its rocky crust is certainly not featureless. The top layer contains rigid plates that float on top of a less rigid zone, and mountains form where these plates collide. Volcanoes produced from hot spots below these plates can also form mountains. How do the heights of these structures compare with the size of the Earth itself? And just how tall do they get?

BACKGROUND SCIENCE (continued)

To answer these questions, we need to think about how to measure the heights. This isn't as simple as it seems. As with most measurements, one needs a reference point, and for mountains there are several reasonable starting points to consider. The base of the mountain may be a good starting point, but for Mauna Kea this is on the ocean floor. Measuring from sea level may seem more reasonable, but is it? Because the Earth rotates, its size is actually larger at the equator than at the poles; the same effect that seems to pull a rider on a Merry-Go-Round away from the center ("centrifugal force," which is really not a force at all, but rather a tendency to not want to be pulled into a circular motion) acts to make the Earth oblate. Thus, at the equator, sea level is much higher than at higher latitudes. Mt. Everest has its peak farther above sea level than any other mountain, but Mt. Chimbarzo's peak is farther from the center of the Earth than any other of the planet's mountains.

FUN FACTS

- Hawaii may be a warm ocean paradise, but at nearly 14,000 feet (over 4,000 meters), Mauna Kea is often snow-capped in the winter. You can ski or snowboard its slopes, then drive down to the ocean and go surfing the same day!

- If Mt. Everest is the most difficult peak to climb (with its incredible height requiring many climbers to bring their own oxygen), Mauna Kea is surely the most difficult base to reach. It is 3.75 miles (6 km) below the surface of the Pacific Ocean!

- The Earth isn't quite round, because its spinning motion makes the equator bulge out by more than 25 miles (40 km) in diameter. That seems like a lot, but it isn't much compared to the size of the Earth. If the planet were shrunk down to the size of a basketball, the diameter at the equator would exceed that at the poles by about half the thickness of a dime.

- Because of the high altitude and calm island conditions, Mauna Kea provides excellent conditions for astronomical observations. It is the site of some of the world's most powerful telescopes.

- Mt. Everest lies between Nepal and Tibet. In Nepal, the mountain is called Sagarmatha, meaning "forehead of the sky." In Tibet, the mountain is known as Chomolangma, meaning "mother of the Universe."

COMMON QUESTIONS OR MISCONCEPTIONS

- The concepts introduced here may lead the students to think that the point is that there is no "right" answer to a question such as "what is the tallest mountain?" This is not the point to be taken. Rather, the point is that one has to define exactly what is meant by a question before one can provide the answer.

- It is a common misconception that rotation results in an outward "centrifugal force" that tends to pull objects away from the center of rotation. In reality, the inertia of a moving body tends to keep it in motion in a straight line. To get it to go in a circle, a force has to be applied that pulls it toward the center (a so-called "centripetal force"). In the absence of that force, the object won't go in a circle. If you are spun around in a circle holding on to a thick rubber string, the string will expand until the tension is enough to make you deviate from the straight-line path of your inertia.

DEMONSTRATIONS AND ACTIVITIES

- **Who is tallest?** Start an activity of having students measure each other's heights (or choose a few students and do this as a demonstration), but emphasize relative measurements. Let the shorter student stand on a chair (carefully!) or a step. Have one student remove his/her shoes while the other leaves them on. Let the discussion develop into what a "fair" measurement is.

- **How tall is our school?** For most buildings, this will need to be an approximate exercise (which is an important lesson by itself). Have students count bricks or windows, or find some other reasonable way to scale to the full height. Many buildings are not built on perfectly flat ground, so doing this at different places around the school will yield different heights. (Schools built into hills will be especially fun!) Clever students will want to include the basement (if there is one).

- **Walking on a train.** Challenge the students with a thought experiment: Suppose they are on a train that is moving at 60 mi/hr (88 ft/s, or 27 m/s), and are running toward the front of the train at 6 mi/hr (8.8 ft/s, or 2.7 m/s). How much of the train will they run through in 10 seconds? How far will they be from their starting point? (Answer: They will have moved through 88 feet (27 m) in the train, but they will be 968 feet (297 m) from where they were when they started running (since the train will have moved 880 feet, or 270 m).

- **Always on the move.** Following the same idea as above, consider how far students move while sitting in their seats for an hour. It's all relative. They don't move at all relative to the classroom floor. But the Earth is moving around the Solar System at a speed of about 67,000 mi/hr (110,000 km/hr). And the Solar System is moving around the center of the Milky Way galaxy at a speed of about 500,000 mi/hr (800,000 km/hr). (It is worth considering the observation of author and humorist Kurt Vonnegut Jr.: "Every passing hour brings the Solar System 43,000 miles closer to the globular cluster M13 in Hercules—and still there are some misfits who insist that there is no such thing as progress.")

RESOURCES

http://adventure.nationalgeographic.com/everest.html

http://science.nationalgeographic.com/science/earth/surface-of-the-earth/mountains-article/

http://marsprogram.jpl.nasa.gov/gallery/atlas/olympus-mons.html