



Pea brain!

Explorations in Estimation

Overview: Use two different techniques to estimate how many little things fit into a bigger thing

Grades: 4-8 (See links to national science and math standards at the end.)

Time: 45 minutes to one hour (for both volume and weight estimates)

Background: Scientists use estimation when they just need a “ball park figure” to get them started. They may ask how many stars exist in our galaxy or how many galaxies exist in our Universe. It would be complex and not necessary to find the exact number, and so a close guess would be sufficient. This is known as *order of magnitude*, which just means how many times bigger or smaller something is, for example, a grapefruit is about 1000 times bigger than a pea. Similarly, if a doctor needs to know how many red blood cells that you have, the doctor wouldn’t try to count every single one—there are far too many. In this lesson, we demonstrate two different techniques of estimating how many smaller things fit in a bigger container to help give students a sense of size.

This lesson can be combined with viewing the *Eat your peas* video on the Quarked website. In this video, Ushi estimates how many peas are inside of Danny’s brain. The adult human brain is between 1200-1500 cm³ in volume and weighs about 1400g. To come up with the number of peas in Danny’s brain of 10,000 in the video, Ushi made some assumptions. Some assumptions are normally necessary in scientific estimates. These assumptions can include an estimate of size, rather than using an actual measurement. Scientists should state these assumptions and explain how they used them to get the result, so that other people double check the accuracy of their estimate or prediction. In the video, Ushi makes an order of magnitude assumption, meaning that she only is trying to be accurate to a factor of 10 – like we would round up 98 to 100. Ushi uses 0.125cm³ = 0.5cm×0.5cm×0.5cm for the average size of a pea. This is an assumption, based on what we know about actual size peas from real observations, to make an estimate. Then she divides the volume of Danny’s brain (1,200 cm³) by the average size of a pea (0.125cm³) to get an estimate of 9,600 peas. Ushi then rounds it up to about 10,000 peas.

Scientists estimate all of the time. They do this for many reasons such as to figure out how long an experiment will take to do, how many people they need to do it, how many times they can repeat an experiment, if the experiment they are trying to do is possible, and have useful numbers for things that are impossible to measure or count. For example, you want to know how many fish there are in the ocean – you cannot count them all, so you come up with a system to estimate the number of fish. Particle physicists, like all scientists, use estimation for many things such as: to scale up the results of their tests – because the experiments can be very expensive to do on a large scale, and estimate some properties of matter (e.g mass) because they are difficult to accurately measure.

Objective: Estimate the number of peas that will fit into something the size of a small paper cup. Estimate A uses volume and Estimate B uses weight. Students can calculate the number of peas in a human brain by following the procedures outlined in Estimate C.

Estimate A: Estimate by Volume (if time is limited or you do not have access to a food scale, use Estimate by Volume as a stand alone activity)

Materials: Each pair of students needs

- Bag of dried peas (or dried mini-marshmallows, chickpeas, dried beans)
- Small paper cup container (e.g. Dixie cups)
- Calculator
- Pencil and paper
- Ruler

Procedure:

1. Have students guess how many peas will fit into the container and record on the worksheet.
2. Have students place their cup on the piece paper and trace around the bottom. Move the cup and place a line of peas across the middle (horizontally) of the circle and count the number of peas and record.
3. Place a line of peas across the middle (top to bottom or vertically) of the circle and count the number of peas and record. This number should be the same as the result in Step 2. These numbers are also the number of peas that fit in the diameter of the circle which is the same as length and width for this.
4. Have the students use a ruler to measure the height of the cup and then draw a line on the paper that is the same length as the height of the cup. Line up peas along the line, count the number of peas and record.
5. To estimate the number of peas that would fit in the cup, on the worksheet, multiply the answer from Step 2 with the answer from Step 3. Then multiply this with the answer from Step 4 and record.
6. Have the students fill the container with peas and then count the number of peas that fit in the container and record.

Results and Discussion

Questions for discussion with your group might include:

- How close is your estimate to the actual number of peas?
- Did you guess too high or too low?
- Why do you think the numbers might be different?
- What could you do to get a more accurate estimate?

Estimate B: Estimate by Weight

Materials: Each pair of students needs

- Bag of dried peas (or dried mini-marshmallows, chickpeas, dried beans)
- Small paper cup container (e.g. Dixie cups)
- Calculator

- Pencil and paper
- Food scale

Procedure:

1. Have students fill the cup with peas, weigh it and record their answer on the worksheet.
2. Have students weigh 10 peas (use more if necessary and then change your calculation) and divide this number by 10 to get the weight of one pea, and record.
3. On the worksheet, divide the weight of the cup filled with peas (Step 1) by the weight for one pea (Step 2) and record. This is an estimate of the number of peas in the cup.

Results and Discussion

Questions for discussion with you group might include:

- How close is your estimate using weight the actual number of peas?
- Are the estimates using volume and weight the same?
- Was one estimate more accurate than the other? Why?
- How could you make the estimate by weight more accurate?

The estimate by weight is likely to be more precise because of empty space between the peas in the volume estimate (peas are not square), and the cup is not completely cylindrical, so it can be difficult to estimate volume accurately.

The estimate by weight is sensitive to the quality of the scale available – small differences in the weight of a small object (one pea) result in large errors when you multiply it many times. The calculation of the number of peas in a cup would be more accurate if you subtract the weight of the cup from the weight of the cup filled with peas and then divide this number by the weight of one pea.

Estimate C: Pea Brain (extension activities)

To estimate the number of peas in a human brain using weight: divide the average weight of a human brain (1,400g) by the weight of one pea (Step 2 in Estimate by Weight).

To estimate the number of peas in a human brain using volume: have students calculate the volume of one pea by measuring the dimensions of the cup to estimate its volume (length x width x height or diameter x diameter x height) and then divide this number by the number of peas that fit in the cup. This is an estimate of the volume of one pea. Divide the average volume of a human brain (1,300 cm³) by the volume of one pea.

Follow up activities:

- a. This activity goes along with the *Eat your Peas* video from the Quarked web site www.quarked.org where they discuss how many peas would fit into your brain.
- b. Lesson plan *How small can you cut?* looks at ways to estimate scale.
- c. To learn more about particle physics and how detectors work, check out the www.fnal.gov site.

NATIONAL STANDARDS

This lesson plan addresses the following national standards in science and math:

Science

Standard A – Science as Inquiry

Students should develop abilities necessary to do scientific inquiry and an understanding about scientific inquiry.

Standard E – Science and Technology

Students should develop abilities of technological design.

Standard G-History and Nature of Science

Students should develop understanding of the nature of science.

Math

Understand numbers, ways of representing numbers, relationships among numbers, and number systems

- Count with understanding and recognize "how many" in sets of objects;
- Connect number words and numerals to the quantities they represent, using various physical models and representations;

Compute fluently and make reasonable estimates

- Use a variety of methods and tools to compute, including objects, mental computation, estimation, paper and pencil, and calculators.
- Develop and use strategies to estimate the results of whole-number computations and to judge the reasonableness of such results;

Understand measurable attributes of objects and the units, systems, and processes of measurement

- Recognize the attributes of length, volume, weight, area, and time;
- Compare and order objects according to these attributes
- Understand how to measure using nonstandard and standard units

Apply appropriate techniques, tools, and formulas to determine measurements

- Measure with multiple copies of units of the same size, such as paper clips laid end to end;
- Use tools to measure;
- Use repetition of a single unit to measure something larger than the unit, for instance, measuring the length of a room with a single meterstick;
- Develop common referents for measures to make comparisons and estimates.
- Select and use benchmarks to estimate measurements;

Data Analysis and Probability Standard - Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

- Pose questions and gather data about themselves and their surroundings;
- Sort and classify objects according to their attributes and organize data about the objects;
- Represent data using concrete objects, pictures, and graphs.