COUNT YOUR LUCKY STARS: SAMPLING IN ASTRONOMY

ACTIVITY G-6

GRADE LEVEL: 4-12

Source: This activity was written by Gary Tomlinson of the Public Museum of Grand Rapids. In its present form it is ©1999 by the Astronomical Society of the Pacific. An earlier (and significantly different) version appeared in *Science and Children* magazine. Some ideas have been adapted from the activity "How Many Stars in the Milky Way" by Kara C. Granger from the booklet *AstroCapella*, published by the Laboratory for High Energy Astrophysics at NASA's Goddard Space Flight Center. The Star Sheet is from the book *Look to the Sky*, by Jerry DeBruin and Don Murad, published by Good Apple Books. To order *Look to the Sky*, call Frank Schaffer Publications, at 1-800-421-5539 or 1-800-609-1735.

What's This Activity About?

Because the sky is full of objects, astronomers must frequently resort to sampling techniques to get counts in a reasonable amount of time. This is very similar to what pollsters do to get a sense of public opinion.

What Will Students Do?

Students will practice using a sampling window on some everyday objects, and then construct a sampling window to estimate the number of stars in the sky visible to the unaided eye. Students will discuss how to estimate the effect of different variables on their star counts, such as sky brightness, dark adaptation, cloud cover, etc.

Tips and Suggestions

- You can laminate the star sampling window to make it last longer.
- If your students have access to a dark, rural location, the number of stars visible can vary significantly in the sky. Thus, the darker the location, the more important it is to average the results from several counts made in different directions.
- Students who have not yet studied angular measures (degrees, square degrees) may need an introduction to these units.

What Will Students Learn?

Concepts

- Sampling data and estimating counts
- Distribution of stars in the sky
- Calculating area

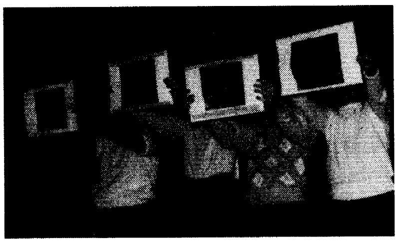
Inquiry Skills

- Observing
- Predicting
- Calculating
- Inferring

Big Ideas

- Scale
- Structure
- Models

COUNT YOUR LUCKY STARS: SAMPLING IN ASTRONOMY



by Gary Tomlinson
Public Museum of Grand Rapids

with additional ideas and materials by
***Jerry DeBruin,** University of Toledo and*
***Kara C. Granger,** Northwestern H.S., Hyattsville, MD*

Introduction

When you hear that our Milky Way galaxy has 200 billion stars in it or that 50,000 people watched a fireworks display, you can be sure that those numbers were not found by counting every star or fireworks fan. Instead, such numbers are estimated using sampling techniques. This activity will help students understand the process of sampling and estimation, and then use these techniques to determine the number of stars visible to the unaided eye in our night sky.

Concepts

- Sampling and estimation techniques can provide a very close approximation of the true size of populations that are too big to count.
- The number of stars visible to the naked eye depends on a number of factors.
- To arrive at an accepted value for a quantity scientists wish to measure, experiments must be repeated many times.
- To achieve the "best" value of such a quantity, variables must be controlled.

Objectives

Students will:

- Learn to use sampling techniques to estimate a very large population.
- Estimate the number of stars visible to the naked eye.
- Explore identification and control of variables.

Materials

- Ruler
- File folders or other cardboard
- Scissors
- Pencils
- Star Page (for each student or team of students) found on pg. 63
- Six pages of the classified ad section of a newspaper (ads should cover an entire page)

ACTIVITY 1: STARS ON A PAGE

1. Give each student (or teams of students) one Star Page with the sampling window.
2. Cut out the sampling window on the solid lines then fold it in half so the pattern is on the outside. Cut out the interior dashed lines, and then unfold the window.
3. Have each student or team drop the window onto the Star Page. Make sure the window lands completely within the outer boundaries of the Star Page. Otherwise, drop the window again.
4. Count the number of stars within the window. (You may need to tape or fasten the window where it landed in some non-permanent way, so that younger students will not bump the window while counting.) Count any stars that have at least 50% of their areas within the window.
5. Note that it takes 36 windows to cover the entire page of stars. Therefore, have each student or team of students multiply number of stars they

counted by 36 to arrive at their estimate for the total number of stars on the Star Page.

6. Assign each student a different square on the sample star page and have students count the actual number of stars in their assigned square. If you have fewer than 36 students, ask for volunteers to count more than one square. It may be helpful to number the squares so everyone knows which square to count. Add these 36 counts together to get the actual number of stars on our page. How does the total compare with the estimates of the students?

7. Have students brainstorm about how their estimate could have been improved. If there is time, repeat the activity with the improved procedure.

   NOTE: One way to arrive at a better estimate is to have each student or group repeat steps 3-5. By having a student take several samples and then take an average, the number of errors in the sample would be reduced. Another way would be to average several samples from different students or groups. Either way, you average out landing on less and/or more populated areas and, therefore, arrive at a better estimate. In science, experiments are frequently repeated, either by the original group or by other people, to improve the statistical validity of the results.

ACTIVITY 2: DOES SAMPLING WORK IN THE REAL WORLD?

1. Divide the class into six teams.

2. Using six of the sampling windows from Activity 1, toss each window onto a newspaper classified ad page. Make sure each window is completely within the printed page. If not, toss again.

3. Count the number of characters in each window. Count each character showing over 50% (letter, symbol, or punctuation mark) as one. Spaces do not count.

4. Now measure the area of the printed newspaper page in square inches. Since your window is 1 inch on a side, its area is 1 square inch. Ask students how many sampling windows it would take to cover the entire newspaper page.

5. Average the six sample counts and multiply this average by the number of windows in the entire printed page obtained in step 4. This is an estimate of the total number of characters on the page.

6. To compare your estimate to the "real" answer, cut the newspaper into a number of squares equal to the number of students you have. Have each student count the number of characters on his or her square and add the counts. How do the estimates compare to the "real" counts?

7. Have the students discuss what factors could lead to errors in this activity. In real world applications of sampling techniques, often the estimate and the "real" answer do not exactly agree. Identifying reasons that could make the estimate not be as accurate as possible is an important part of science. Possible sources of errors could include:
   - miscounting the number of characters
   - slight variations in the size of the sampling window
   - movement of the window during counting
   - the difficulty of determining if a character is 50% within the window
   - the possibility the window landed on an area with fewer or more characters than average.

ACTIVITY 3: COUNTING THE STARS VISIBLE IN THE SKY

A. BACKGROUND

Counting the number of stars visible in the real sky, like the examples in the previous activities, involves sampling, estimation, and the identification and control of variables. For stars, these variables include:

1. The sensitivity of the human eye from one person to the next

2. How dark-adapted the observer is (i.e. how long the person's eyes have spent getting accustomed to the dark)
3. Conditions at the location of the observer (i.e. how much air and light pollution there is)
4. The clarity of the sky (how much cloud cover there is, etc.)
5. The time after sunset (or before sunrise) the sample was taken
6. The area of the sky selected for sampling (all parts of the sky are not evenly populated with stars).

Except for #6, these are variables for which the group may want to control. For a good sample of how many stars the students can see, you want an average based on several different areas of the sky. If possible, it would be good to repeat the observations on several nights, to control for the condition of the sky. In addition, you may want to try to calibrate "the detectors" (i.e. the observers) by first having all students observe the same area of the sky at the same time. You could then get an indication if one "detector" or detection location is better than another and see how such variables could affect your results. (These are all topics for discussion before you undertake the activity.)

The other problem is figuring out how to get students to sample the same amount of sky, i.e. how to make a sampling window for the sky (which we cannot touch or paste things to)? There is a way to make a window that, when used appropriately, will insure that each student is looking approximately at the same square area of the sky. To do so, we need to rely on two concepts:

- How big is the sky? We measure the angular extent of the sky not in square inches or centimeters but in square degrees. The full sphere of the sky around the Earth (or any sphere) contains about 41,253 square degrees.
- As the human arm grows, so does the length of the fingers and hand. By designing a window based on the size of the hand used at arm's length, everybody should be looking at the same square area of the sky.

B. PROCEDURE

1. Have students measure the length of their hand from the heel to the tip of the longest finger. It might be easier to have them make marks on a piece of paper at the heel and tip of the finger and measure the distance between the two marks.
2. On a closed file folder, students should mark off the length of their hand, centered along the bottom of the fold of the file folder. Then they should measure up, 1/2 the length of the hand to make a rectangle to cut out. In this way, when the file folder is opened, the student has a square window with each side equal to the length of his or her hand.
3. When holding this window at arm's length, all students should be looking at a square "piece" of the sky measuring about 17 degrees on a side. Because students with longer arms have larger hands, this figure has been found to be roughly the same for most people. The area in the window (17 degrees by 17 degrees = 289 square degrees) is how much of the sky each student sees.
4. Have the students go outside on a clear night, choose a section of the sky, and count the number of stars they see within their window. Remind the students that they need to hold the sampling window at arm's length when making their observations. Have them note the conditions at the time they are making each observation. Include:

- how long they waited to let their eyes adapt to the dark
- how bright the light of human civilization was in the sky (were there a lot of lights from nearby or from the city in which the students live)
- how cloudy or hazy it was
- whether they measured near the zenith (top of the sky) or near the horizon.

If you do this experiment in a planetarium, be sure to have each student stand as close to the center of the room as possible (to minimize differences in distance to the walls of the planetarium).

5. Average these numbers from all your students. (If possible, have students do several measurements, and to repeat their measurements over several evenings. As explained below, you may want to ask your students to take one measurement at the zenith, and one closer to the horizon.)
6. Since there are 41,253 square degrees in the entire sky and the window shows 289 square degrees, then the number of windows it takes to cover the entire sky is:

   (41,253 sq. degrees/sky)/(289 sq. degrees/window) = 143 windows/sky.

   Multiply the average obtained above by 143 to get an estimate of the number of stars visible in the entire sky.
7. Have the students discuss how good their estimate is. Also, ask them how much of the sky around the Earth we can actually see from any location.

Remember we estimated the number of visible stars in the entire sky. Since from any location on the Earth, we can only see 1/2 of the sky at any one time, the estimate of the number of stars visible above the horizon would be 1/2 of the number obtained above. Estimates are that from a clear, dark location with good eyes, an observer could see between 2,500 to 3,000 different stars at one time (i.e. about 5 to 6 thousand different stars are visible to the naked eye in the entire sky).

One factor that would have an effect on this activity would be the age of the "detector" (observer). As people age, the amount of light the human eye passes through the lens to the retina decreases. At age 65 only about a third of the light gets through that a 25-year-old eye allows. This means an older person will see fewer stars. The faint ones would not be visible to them.

Dark adaptation is another factor students should discuss. The longer a person spends in darkness, the more dilated their pupil becomes thereby letting in more light and making fainter stars visible. Complete dark adaptation requires a person to remain in the dark without any extraneous light for about 1 to 1½ hours. However, the majority of dark adaptation occurs in the first 20 minutes. Have students make an estimate of how good their dark adaptation was when they made their measurements. In addition, the amount of light in the sky from human civilization can have a strong effect on how many faint stars were visible in the window.

Our atmosphere can also affect the number of stars visible within a sample area. If it is cloudy or hazy, students will miss some of the stars. (In fact, if there is significant cloud cover, the activity should probably be put off until the sky is more clear. This gives you a chance to tell the students that astronomers often have similarly frustrating experiences. A team of astronomers may have applied for time on a large telescope a year in advance, prepared equipment and observing strategy for months, only to arrive at the observatory and find that it is too cloudy to do their work.) Even when the sky is clear, however, the air we breathe will have an effect on the number of stars we see. When we look straight up we are looking through the least amount of air possible. Students should see fewer stars near the horizon because the additional amount of air absorbs more light, making faint stars more difficult to detect.

C. GOING FURTHER

1. Have students take two samples on each night: One when they are not dark-adapted and another 20 minutes later when they are and compare.
2. Have students who live in the city under light pollution compare their estimates to students who live in the country far from street lights and neighbors' homes (or partner with another school with students from a different type of setting and compare).
3. Have students discuss how they would continue their sampling activity if they had a good telescope to use, instead of just their eyes.