MASS OF U.S. PENNIES
TEACHER NOTES

DESCRIPTION
Students will represent data through histograms for analysis and interpretation. Students will use an electronic balance to determine the mass of many, many U.S. pennies (a one-cent coin) of varying ages. The metallic composition of the penny has changed over the years. Different compositions can have significantly different masses. A sufficiently random selection of hundreds of pennies should allow the students to discover the years in which the composition changed.

STANDARDS
Next Generation Science Standards

Science and Engineering Practices

3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in arguments from evidence

Crosscutting Concepts

1. Observed patterns . . . guide organization and prompt questions.

Common Core Literacy Standards

Reading

9-12.3 Follow precisely a complex multistep procedure . . .
9-12.7 Translate quantitative or technical information . . .

Common Core Mathematics Standards

MP2. Reason abstractly and quantitatively.
MP4. Model with mathematics.
MP5. Use appropriate tools strategically.
MP6. Attend to precision.

ENDURING UNDERSTANDING
- Histograms represent data for analysis and interpretation.

LEARNING OBJECTIVES
Students will know and be able to:
- Record and tabulate measurements.
- Organize observations.
- Create and interpret a histogram.

PRIOR KNOWLEDGE
Students must be able to keep careful records of observations.

BACKGROUND MATERIAL
A histogram is a common data representation in particle physics. Histograms are graphical representations of a frequency table. You can find more information on histograms at http://quarknet.fnal.gov/toolkits/new/histograms.html.

IMPLEMENTATION
You should instruct the students to write down as many characteristics of each penny as they can. They can construct their own data tables.

We don't say it explicitly in the handout, but the students should draw two histograms: one for the masses and another for the year the coins were minted.

The mass histogram will very likely reveal that pennies come in two different masses: "light" and "heavy." However, there is nothing to suggest *why* the masses change. The answer to that question requires more investigation.

If they record the mass *and* mint year of each sample, they'll have enough information to begin to answer the question about *why* the mass changes. This experiment *cannot* yield any evidence to support any particular answer to why the mass is different. The experiment *can* suggest additional tools and measurements that the students should make in order to determine why the mass changes. This is the nature of science; one experiment leads to another.

Having students mass hundreds of pennies may take a long time. You might consider dividing up the job among several groups. Students can histogram their own sample of the entire batch and compare it to a histogram created with the entire, shared data set.

Your scale should have a minimum reading of 0.01g.

You might ask the students to write the procedure that they plan to use to answer question #4 and check it before proceeding.

Finally, the student activity is much richer if your penny collection sample was sufficiently random to expose two different masses. The mass of the U.S. penny changed significantly in 1982. You can ensure that your class "discovers" this by inspecting your penny collection to see if there are enough pre-1982 pennies to show the mass difference. You could also *not* inspect your penny collection and see what comes out of the student observations.

ASSESSMENT

Assessment for this activity can be widely varied. Ideas include:

- Assessing answers to the questions in the student activity.
- Requiring a formal lab report that conforms to your regular practices and requirements
- Asking small student groups to share their results in short presentations.
- Pairing up student groups for a preliminary discussion, followed by a class discussion.

Your assessment might also include feedback on how the students organized their data. Finally, you should consider how to assess the evidence behind student statements about the year that the penny's mass changed.

ADDITIONAL INFORMATION

We prompt the students to draw two histograms after they collect data. You may wish to provide more detail on this step if you think they need it. This may help:
http://quarknet.fnal.gov/toolkits/new/histograms.html

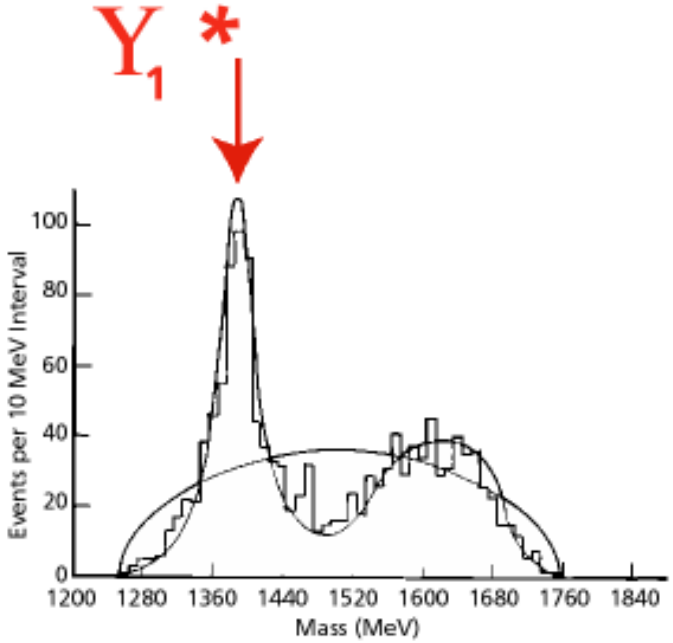
We based this activity on a similar online activity. You can find it at
http://ed.fnal.gov/students/hwtools/histogram/basic1.html.

The online activity provides several more complicated options than we present in this hands-on activity. You might allow students to explore the activity independently after they have some experience with histograms.

MASS OF U.S. PENNIES

Name(s) _____ Date _____

Particle physicists use graphs like the one shown on this page to look at the results of their experiments. By putting mass readings on a histogram, they can see that the peaks show separate particles.



Since we don't have ready access to particles or machines to make them, we are going to look at something more readily available: pennies. There are lots of pennies in circulation. Are they all the same? They all represent $0.01 and may be similar in color, but is that the only thing that they have in common?

Obtain a set of pennies from your instructor. Measure and record as many properties of each penny as you can observe. Organize your data in a table.

Draw at least two histograms to represent your data.

Answer the following questions on another sheet of paper. Show all calculations.

1. What is the most common penny mass in your penny set? In the class set?
2. How would you describe the masses of the pennies in your set? Be as specific as you can.
3. Can you suggest an explanation for the mass distribution that you see? What evidence can you provide to support your explanation?
4. Are there more pennies from more recent years or from prior years? Can you suggest an explanation for this? How would you test this idea?
5. Which year is represented by the most pennies? By the second most? By the third most? What would you graph instead of mass to make these answers immediately evident?