POLAR TREC Learning Resources

Details

Completion Time: Less than a week

Permission: Download, Share, and Remix

Graphing Penny Isotopes

Overview

Students will individually weigh a random sample of pennies. The data will be graphed to look for patterns, then explanations will be sought to explain these patterns. Some of the key ideas are using graphical representations of data to help identify patterns. This is a key concept in all sciences, including in the IceCube Neutrino Observatory - data is graphed to try to identify "hot spots" of neutrino activity in the sky.

Objectives

Graphing data or representing in visual ways makes patterns more apparent than a list of data points. If used in a chemistry or physical science class, this lesson can help introduce the idea of isotopes - similar atoms with different atomic masses.

Lesson Preparation

- Each group should have a sample of pennies, around 20, with a good sample from pre- and post-1982. This should be transparent - students shouldn't be aware of the difference in dates at this point.
- Each group or perhaps pair of groups should have a digital scale, and TARE it to set it to zero with no pennies on it.
- Each group should have a computer with LoggerPro or similar graphing program (easier to use than Excel - different graphs are more straightforward to create).

Procedure

- Begin by having students examine the pennies and make observations (this could be a recap of "observation vs inference"). They may notice different dates, different patterns front and back (especially 2009), similar metal for each, etc. Use this as a springboard to how can we tell one penny from the other?

Materials

- Lots of pennies, from various years. A good sample of pennies from pre-1982 and post-1982 will be necessary for groups to identify the patterns.
- Each group should have a scale, ideally a digital scale that can measure to .01 grams or better.
- Computers with a graphing program such as LoggerPro from Vernier.

- Gently lead students to the idea that most have unique dates that can help identify them. They may notice little letters on the front - right underneath the date. These identify which mint stamped them.
- Student groups take data by finding the mass of each coin, and recording date and mass. They may wish to record other notes, such as patterns or mint as well, though these would probably show little correlation.
- Once they have data for all their coins, students should enter data into a graphing program and try different types of graphs (see sample graphs).
- A bar graph of date can show how many pennies of each year show up. This is familiar to most students, and though you won't see many patterns it's good to discuss.
- A histogram is basically a bar graph that can show frequency of how many times a particular bit of data shows up. It can show different "bins" of varying width. You can have a histogram of pennies by year in groups (bin sizes) of 10 years, 5 years, 1 year, etc. Set bin widths to different sizes to see what effect that has. You may see a pattern of higher numbers as years get closer to present.
- Now suggest a histogram of mass instead of year. If you set bin width to 1.0 g you'd see two bars next to each other - 2.0-3.0 and 3.0-4.0. The 2.0-3.0 bin should be larger. But this doesn't help - set the bin width narrower, maybe incrementally (.5 g, e.g.) or just jump to .1g bins. As you get finer, you should see two distinct groups of pennies around 2.5 g and around 3.0 g.
- Discuss this pattern - what could cause the difference in mass? Some students will be familiar with the actual cause, which is that the composition of pennies changed from mostly copper before 1982 to mostly zinc afterward. Don't acknowledge that this is correct yet, but include it as one hypothesis. Other ideas may be, older pennies are dirtier therefore heavier, or older pennies are more worn out therefore lighter, or maybe different mints or different patterns made different weights. Why are there no (or very few) pennies in between the 2.5g and 3.0 g masses?
- A line graph with date on X axis and mass on Y axis should show a change around 1982. Pre-1982, pennies should be around 3.0 g, and after, they should be around 2.5 g.
- Discuss this pattern - did every group see something similar? Could this be evidence to support or refute one of our earlier hypotheses? (e.g. supports material change, supports old dirty coins to an extent, refutes old worn-out coins).
- Demonstrate one more observation - if you drop a pre-1982 penny on a surface and compare the sound to a post-1982 penny, there is a noticeable difference in tone. One "clunks" and the other "rings" a bit. Finish by describing the reason - copper became more expensive, so a fully copper penny actually has more than 1 cent of copper in it, so they switched to cheaper (and lighter) zinc with a thin coating of copper on the outside.
- Wrap up the discussion by asking what kind of information we could gather from each of the different graphs? Which graph was most useful, which was less useful, are there other ways we could look at the data to see patterns? Could you see the patterns as easily just by looking at the numbers?

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Extension

For a chemistry class, or physical science class, this lesson could be extended to discuss the idea of isotopes and average atomic mass. Each penny is worth the same amount, but has different masses. By doing experiments we can find out that even though they're all pennies, there are differences in some of their properties. Have groups find the mass of all their pennies at once, and take an average to find the mass of an average penny in their sample - probably around 2.8 g. How many pennies actually had a mass of 2.8? Few, or none… but on average, some heavy and some light give us an average in between. What if you had more new pennies or more old pennies, how would that affect your average mass?

Scientists have done experiments to determine that not all atoms of the same type are exactly the same. For example, though all hydrogen atoms have one proton (thus a number of 1), most have a mass of 1.0 but a very few have a mass of 2.0 or even 3.0. Thus, the atomic mass is actually the average of a sample of atoms. Because you will have mostly a mass of 1.0, with a few of 2.0 or 3.0, the average atomic mass of hydrogen is about 1.008 amu.

Other atoms have isotopes too, so most carbons (atomic # 6) have a mass of 12, there are other isotopes notably carbon 14 which appear and raise the average atomic mass slightly to 12.01. Chlorine (atomic # 17) has two most common isotopes of mass 35 and mass 37, in proportions of about 3:1, so the average mass ends up being about 35.5 amu.

Many atoms have isotopes that are stable and others that are unstable which break down through radioactivity into other elements. Determining proportions between different isotopes is very useful for determining age of materials and other properties.
For example:

- Proportion of C12 to C14 (radiocarbon dating) helps determine the age of an organic sample, in the thousands of years range.
- Proportions of uranium 235 to lead 207 (a product of uranium decay) can determine the age of very old rocks, in the billions of years range.
- Proportions of O16 to O18 in water molecules of ice core samples can help determine the temperature when the ice was formed - warmer global temperatures will produce precipitation with a higher amount of O18 in the water. This has been used to determine patterns of hot/cold over the past several hundred thousand years, to relate temperature to CO_2 concentrations and to find old ice ages for instance.

Resources

n/a

Assessment

Assessment of these topics could take place through discussion, homework questions, test questions, etc. The graphical analysis could easily be assessed by having students write a brief report, including each of the graphs they produced and a description of the pattern seen in each graph.

Credits

Modified from bits and pieces scoured from the internet and other sources, by Casey O’Hara, cohara@seq.org

National Science Education Standards (NSES):

Content Standards, Grades K-4

Content Standard A: Science As Inquiry
a. Abilities necessary to do scientific inquiry
b. Understandings about scientific inquiry

Content Standard B: Physical Science
a. Properties of objects and materials

Content Standard D: Earth and Space Science
a. Properties of earth materials

Content Standard E: Science and Technology
a. Abilities of technological design
b. Understandings about science and technology

Content Standards, Grades 5-8

Content Standard A: Science As Inquiry
a. Abilities necessary to do scientific inquiry
b. Understandings about scientific inquiry

Content Standard B: Physical Science
a. Properties and changes of properties in matter

Content Standards, Grades 9-12

Content Standard A: Science As Inquiry
a. Abilities necessary to do scientific inquiry
b. Understandings about scientific inquiry

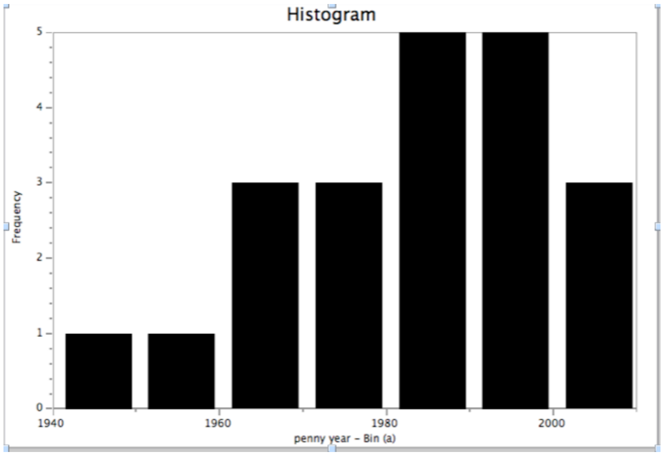
Content Standard B: Physical Science
a. Structure of atoms
b. Structure and properties of matter

Content Standard D: Earth ad Space Science
a. Geochemical cycles

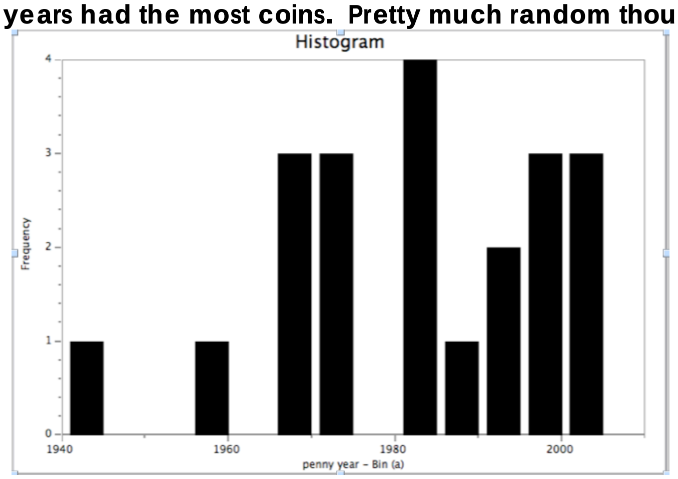
Other Standards
n/a

Sample graphs:

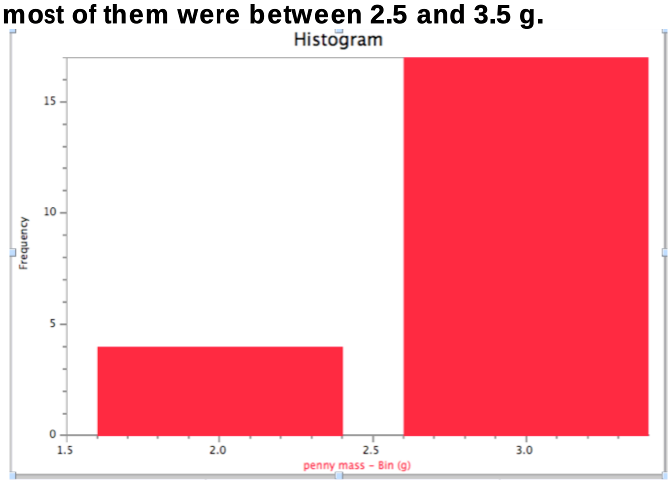
Histogram of year vs frequency, with bins of 10 years at a time. Seems like most of our pennies are from the '80s and '90s.



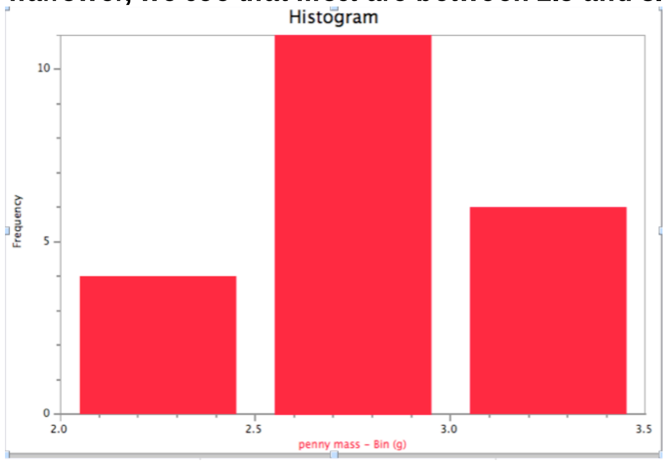
Histogram of year vs frequency, with bins of 5 years at a time. You can see a little more specifically which years had the most coins. Pretty much random though.



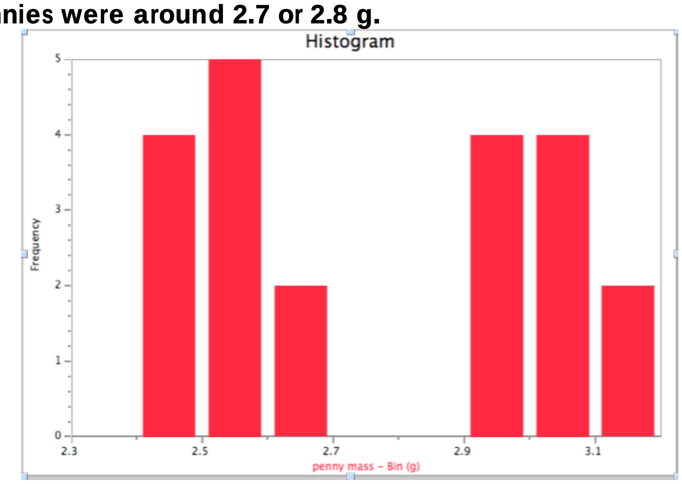
Histogram of mass vs frequency, with bins of 1.0 g wide. Looks like a few coins between 1.5 and 2.5 g, and most of them were between 2.5 and 3.5 g.



By making the bins narrower, we see that most are between 2.5 and 3.0 g.



Finally by making them even narrower, we can see two distinct groups - 2.4-2.6 g, and 2.9-3.1 g. No pennies were around 2.7 or 2.8 g.



Line graph of year vs mass. Note the drop in mass around 1982.