Statistical Uncertainty

Learning Standards: LS2-1, LS2-4, LS2-2

Part I – Types of Error

Introduction:

Scientists make measurements of the natural world – both to describe the natural world and to understand the fundamental laws that govern the operation of it. These measurements allow scientists to quantify conditions and describe natural phenomena. However, there can be uncertainty in scientific findings about the natural world, because of limited accuracy and precision of measurements (aka measurement error) and the variability that occurs in nature (aka natural variability). Scientists use statistical methods to help interpret their measurements and measure the amount of uncertainty. Statistics involves analyzing numerical data from a specific set of observations in order to make broader generalizations about the natural world. Scientists use statistics to help interpret and understand multiple measurements of a single condition or limitation.

Materials Needed:

- Measuring tape
- Graphing paper
- Calculator
- Different colored pens or pencils

A. Observational Error

Directions:

1. Student teams (four students each) create a data table in which to record their measurements in the following manner:

Part I A	
Body Part Measured	Measurement Value
Height of volunteer	____ inches

2. Each student measures the height of the volunteer independently, and then passes it to another teammate to do the same while they record their individual answer (each team should have three separate measurements).

Discussion:

1. Were the numbers for all three measurements exactly the same? If they are not identical, why?
2. How can all the measurements be used to calculate the best answer?
3. Describe the process used to obtain the answer.
4. Summarize the discoveries made about making measurements.

B. Observational and Processing Error (Part I)

Directions:

1. Repeat the steps from Part II A, except in addition to measurements for height (new measurements separate from Part II A should be obtained), team members should also take measurements of the left arm of the student volunteer (have the volunteer hold their arm straight out from their body, and then the other three team members will make their measurements from the volunteer's shoulder to the tip of their middle finger). Your data table should look like this:

Part I B	
Body Part Measured	Measurement Value
Height of volunteer	_____ *inches*
Length of volunteer's left arm	_____ *inches*

2. Next the students will create a graph to plot their data points (student height on the x-axis and length of the left arm on the y-axis) to plot the regression. They should be able to draw a straight line between all the points.

Discussion:

1. What is the slope of your line?
2. Do most of your points fall on the line? Why do you think this might be?

C. Observational and Processing Error (Part II)

Directions:

1. Repeat the steps from Part II B; have team members record the height of the volunteer, but now instead of having them take a second measurement for the length of their left arm, have them measure instead the thumb of the volunteers left hand (from the crook where it joins the hand to the tip of the thumb). Your data table should look like this:

Part I C	
Body Part Measured	Measurement Value
Height of volunteer	_____ *inches*
Length of volunteer's left thumb	_____ *inches*

2. Next the students will use the graph they created in part II B to plot their data points (student's height on the x-axis and length of student's left thumb on the y-axis) to plot the regression; for this part students should use a different color than in the previous section. Unlike the previous section, after students plot their data points this part should show that none of them fall on the line, even though that's the best descriptor, because unlike arm length and height, height and thumb length are not correlated.

Discussion:

1. What is the slope of your line?
2. Do most of your points fall on the line? If they don't, why do you think this might be? (Hint: think about how this section is different from the one you just did)
3. Calculate the distance from each of your points that does not fall on the line, to the line itself; this value is known as the error.

Part II – Natural Variability

Introduction:

In addition to the statistical uncertainty associated with measurement errors, natural systems have variability. In such cases, there is no one "true" value, and scientists use statistical tools like those you developed in the previous section to describe the natural variability that occurs.

Directions:

1. Work in groups. Each group suggests three natural or biological attributes in the classroom to measure, such as student heights, arm length, etc. Write down the three natural or biological attributes.
2. Select one of your three natural or biological quantities and report it to the class.
3. Your teacher will make a list of the proposed natural or biological quantities. As a class, vote on the attribute that you will measure (majority rules).
4. As a class, develop a data sheet/table to record your measurements. Then in the group of four formed in the previous activity, follow the procedure for measuring the selected natural or biological attribute, and record the measurements on a data sheet.

5. Using the procedure in the previous section, calculate the value of the selected parameter.
6. Write a one-paragraph summary of the calculations and the result.
7. Each group will share their results with the class.
8. Complete the discussion questions.

Discussion:

1. How did the group select the natural or biological attributes to be measures?
2. How might the group's result have changed if you had conducted 200 measurements of the natural or biological attribute? 1,000 measurements?
3. How do you think your results would have differed if you had selected a different calculation method?

Supplementary Materials and Resources for Real Data

- Tagging of Pelagic Predators – http://gtopp.org
- Southern California Acoustic Telemetry Tracking Network – https://secoora.org
  - Collaborative group of researchers who sue acoustic telemetry to study behavior or marine life in Southern CA. This technology allows them to detect each other's transmitters on individual receivers, so it allows a sharing of information.
  - Let's you look at long-term tracking data (on a map) for species such sharks and turtles!
- Ocean Biodiversity Information System – https://obis.org
- NOAA Data in the Classroom – https://dataintheclassroom.noaa.gov
  - Allows students to investigate Earth processes using real data for: El Niño, Sea Level, Water Quality, Ocean Acidification, and Coral Bleaching