Measurement Lesson Plan

8A1: Basic Measurements

On a fresh sheet of paper, titled "8A1 Basic Measurements:

1. Measure the width of your table at least three times with any tool available. "Name the tool, explain your method in detail, and write down your measurements with appropriate sig. figs. and units."
2. Compare your results with the class and then write explanations for at least three reasons why all of these measurements are not the same.
3. Write definitions (in your own words) for resolution, precision, & accuracy.
4. Evaluate (measure or estimate) the resolution, precision, & accuracy of the tool used above: . (i.e. meter stick: resolution= ±0.0005 m, precision = ±0.001 m, and accuracy = ±0.002 m
5. Explain your method or reasons for the above evaluations.

Notes: Resolution is the finest that one can discern a difference in reading. Precision is the finest that one can repeatedly measure the same thing. Accuracy is determined by comparing to an accepted standard.

8R1: Instrument Validation Report

Before an instrument can be relied upon to produce meaningful data it must be validated. We must demonstrate that the instrument's measurements really do reflect changes in the variables and what other variables might also erroneously affect measurements. Specifically, we need a detailed and reliable evaluation of the instrument's resolution, precision, and accuracy as well as possible sources of error.

Your task is to design one or more experiments to validate an instrument of your choice and then write a, thoughtful, & professional report fully documenting this information.

1. Choose an instrument from those set out by the instructor. (For example: GPS. Wind meter, IR distance meter, Vernier SS Thermometer probe, Vernier Barometer probe Sound meter, & Photogate intervalometer.
2. Become familiar with the instrument and its sources of variance, error, or malfunction.
3. Design an experiment that will measure its precision. This will require repeating measurements that should produce the same reading but in several ways and multiple times. Identify as many sources of error or variance as you can.
4. Design an experiment that will compare its readings to some accepted standard so that you can evaluate its accuracy. For example the GPS readings might be compared with a USGS survey marker or some other accurately known location.
5. Repeat these experiments until you are confident that you can report work that others would also measure if they repeated your work.
6. Report in detail. This should include what you were trying to do, how you went about it, your actual data, your analysis or calculations, and your conclusion. You can use the Lab Report format from class as a guide.
7. Specifically you must evaluate (for future reference): the instrument's **resolution**, **precision**, and **accuracy** as well as **sources of error**.
8. Be sure this report is professional. Check your spelling and grammar. Be sure it is detailed and well developed, double-spaced, titled, and well edited. Use a 10 or 12 pt standard font in black ink.

Measurement Terms

Variables

In general this means, "properties subject to change."

More specifically we mean "characteristics with respect to which measurements is a sample will vary."

We collect data to ask, "What is the value of the variable?"

Amount of rain, number of leaves per tree, a person's height, class rank, wind velocity, ratio of carbon to nitrogen in soil, hair color are examples of variables.

Data Types: Nominal, Ranked, Continuous Measurement, Discrete Measurement, actual values or derived values

- Nominal data are those that cannot be assigned quantitative properties. Rather, these data can be thought of as classifications, categories, or attributes. Examples: number of species of plants, hair color types, or country of origin.
- Ranked data reflect a hierarchy in a classification; they can be ordered or ranked. Examples: order of birth, social position, or class rank.
- Measurement data are the most common type of observation. These are characterized by values that are expressible in numeric order, and the intervals between pairs of values are meaningful.

Continuous – Discrete

- Continuous variables can assume any number of values between two points. For example: length, area, volume, and temperature.
- Discrete variables can only assume certain fixed values. For example: number of fish in a catch, eggs in a nest, or balls in the target can.

Actual values – Derived values

- Actual values are obtained directly by measurement. Examples: length, time interval, & mass
- Derived values are obtained from actual values by calculation. Examples: speed, volume, & density.

Accuracy – Precision

For data to be as good as possible, they have to be accurate and precise. We want data that are as close to the actual value as possible. This is our requirement for accuracy. We would also prefer that if we were to repeat our data collection procedure the repeated values would as close to each other as possible. This is our need for precision.

Precision relates to quality and resolution of the device or method with which we measure variables; Accuracy, with how we calibrate the device or method once we have obtained precision.

We can indicate the degree of precision (not accuracy) or our measurement by the last digit of the values we report. The implied limit to the precision of our measurement is one digit beyond the last reported digit. For example: the recorded temperature measurement of 4.22 °C implies that the value fell somewhere between 4.215 and 4.225 °C. If the count of fish caught by a ship is reported as 36,000, we imply that the value fell between 35,500 and 36,500 fish.

Precision is often reported in a plus-or-minus format. For example, the preceding two examples could be reported as 4.22 ±0.005°C and 36,000 ±500 fish. In other words, the precision would be reported as: ±0.005°C and ±500 fish.

Accuracy can be determined by comparison of a set of measurements to an accepted standard and is also reported as a percent error.

Resolution – Repeatability

Resolution is the minimum difference in reading that can be distinguished.

Instruments that provide a continuous readout such as a ruler, scale, or dial are known as “analog” since they are analogous or similar to the real world variable they are used to measure. Resolution, in this case, is limited by the user’s ability to discern a different reading and is usually reported as plus-or-minus half of the smallest discernable interval. For example, on a typical meter stick the smallest interval you feel confident reading might be a millimeter, and then the resolution could be reported as ±0.005 m.

In this modern time, more and more instruments are becoming digital. Here a discrete or digital readout is provided even when the variable being measured is continuous. Resolution, here, is plus-or minus half of the value of the right-most digit. For example, a typical 3½-digit multimeter might report a voltage of 1.539 V and then the resolution could be reported as ±0.0005 V.

Systematic variation – Random variation (or error)

A measurement has high accuracy if it contains relatively small systematic variation. It has high precision if it contains relatively small random variation.
Systematic variation or bias would result if a balance were precise but miscalibrated. For example, a balance that still reads 3 grams while empty will probably bias all subsequent measurements upward by 3 grams. However, a balance that has little precision will sometimes read high and sometimes low and the variation will average out. This is an example of random variation.

User error can fall into both types. If you typically read a scale with your head toward the low end of the scale, parallax may cause your readings to be low. This would be a systematic bias. On the other hand, even if you try to keep you head directly over the reading you will still experience some variation. However, this will probably be high as often as it is low and is termed random. Averaging multiple measurements can reduce random variation but not systematic variation.