Name_______________________________ Section_____________

Partner(s)____________________________ Date_______________

MEASUREMENT VARIATION

OBJECT

This activity focuses on the variability in measurements of a property and explores methods of expressing the variation. Let's explore!

PROCEDURE

1. Measure the height of five students in the laboratory. Use the heights of the four students in your group and the height of one member of another group. Record the data in the table below.

2. Have the same five students, independent of each other, measure the height of an object designated by the instructor. Record these data in the table below.

3. Calculate the average (mean) and range (high value - low value) for both sets of measurements.

Student	Student's Height	Object's Height
1		
2		
3		
4		
5		
AVERAGE		
RANGE		

4. Consider the two sets of data above. Describe and explain as many differences as you can between the two sets of measurements.

What information does the range provide for each set?

We want to investigate the variability that comes from making multiple measurements of an object. For the purposes of this lab, we will simulate that variability by taking five similar samples of the same object and assume that the measurements are repeat measures of the same item.

5. Obtain three sets of washers, making sure that one set is labeled with an A, one with a B, and the last set with a C. Measure the diameter of the five washers in each set with a RULER. Record the data in the table below. Calculate the average and range for each set.

Measurement	Set A	Set B	Set C
1			
2			
3			
4			
5			
AVERAGE			
RANGE			

6. Describe and explain any differences between the sets.

7. Graph the results above on a scatter plot with the set as the independent variable. See http://academic.pgcc.edu/~ssinex/scatter_plot.xls for information on how to set up the graph.

   Do the results provide any additional information about the three sets?

8. Calculate the deviation for each measurement (trial) in each set.

$$\text{Deviation} = \text{trial} - \text{average}$$

Calculate the sum of the deviations (Σdeviations) and the average of the deviations for each set.

$$\Sigma\text{deviations} = \text{dev}_1 + \text{dev}_2 + \text{dev}_3 + \ldots + \text{dev}_n$$

$$\text{average of deviations} = \frac{\Sigma \textit{deviations}}{\text{number of samples}}$$

Measurement	Set A	Set B	Set C
1			
2			
3			
4			
5			
Σdeviations			
AVERAGE			

Is there a difference between a positive and negative deviation? Explain.

Remember that we are interested in how well we can reproduce a measurement (that is, how confident we are of the value). Does the average of the deviations tell you anything about the precision of the individual measurements? Explain.

9. As you can tell, the Σdeviations and average of deviations will be zero or close to zero if you include the sign of the deviation in the calculations. This does not give you any meaningful information about the precision of the measurements. How can we get more valuable information from the individual deviations?

Removing the sign of the deviation and looking at the magnitude of the deviation without the direction will better represent the amount of deviation. We can accomplish this by taking the absolute value of each of the deviations; however, statisticians approach the problem by squaring the deviations.

Square each of the deviations for the three sets to calculate the $(\text{deviation})^2$. Record the values in the table below. Calculate the sum of the squared deviations for each set, $\Sigma(\text{deviation})^2$.

Measurement	Set A	Set B	Set C
1			
2			
3			
4			
5			
$\Sigma(\text{deviation})^2$			

How does the $\Sigma(\text{deviation})^2$ compare to the Σdeviations?

10. A useful statistic is the **standard deviation**, σ:

$$s = \sqrt{\frac{\sum (deviation)^2}{\text{n-1}}}$$

where n is the number of trials.

Calculate the standard deviation for each of the three sets.

	Set A	Set B	Set C
σ			

Which set has the largest standard deviation? Why?

Which set has the smallest σ?

11. Suppose you made a repeated measurement of an object that is 2255 cm long and determine that your standard deviation is 5.2 cm. Someone else making measurements of another object that is 543 cm has a σ = 2.2 cm. Is it fair to say that the second person's measurements are more precise than the first person's since the σ is smaller?

A comparison of the standard deviation is only fair if the sets have approximately the same mean. To remove this problem we can normalize the standard deviation to the mean. This new parameter is called the **coefficient of variation** (CV) (with an older name of relative standard deviation (RSD). We often use the **percent coefficient of variation** expressed by the equation below:

$$\% \text{ CV} = \frac{s}{\text{mean (or average)}} \times 100\,\%$$

The % CV tells you something about the measurement precision or how reproducible a measurement is.

Calculate the % CV for each set. Use the average from question 5.

	Set A	Set B	Set C
%CV			

Which set has the smallest % CV? Is it the one with the smallest σ?

12. Now, let's explore what happens to the deviations when we use a device that provides more information about a length.

Repeat the measurement of diameter for set A with a pair of calipers. Ask the instructor for assistance if you have not used calipers before. Calculate the deviations, σ, and % CV.

Trial	Diameter	deviation	deviation squared	
1				
2				σ = _______
3				
4				%CV= ______
5				
AVERAGE			Σ=	

How do the σ and % CV for the caliper measurements compare to values for the ruler measurements? What does this tell you about precision using the different devices?

13. In the pharmaceutical industry, multiple measurement of a chemical parameter, such as $\%CaCO_3$ in an antacid tablet, is often performed. Is variation expected? Is variation desirable or not? Explain.

If large variations occur, what are possible causes?