Activity 3.8 Precision and Accuracy of Measurement

Introduction

This concept of random and systematic errors is related to the precision and accuracy of measurements. Precision characterizes the system's probability of providing the same result every time a sample is measured (related to random error). Accuracy characterizes the system's ability to provide a mean close to the true value when a sample is measured many times (related to systematic error). We can determine the precision of a measurement instrument by making repeated measurements of the same sample and calculating the standard deviation of those measurements. However, we will not be able to correct any single measurement due to a low precision instrument. Simply stated, the effects of random uncertainties can be reduced by repeated measurement, but it is not possible to correct for random errors.

We can determine the accuracy of a measurement instrument by comparing the experimental mean of a large number of measurements of a sample for which we know the "true value" of the characteristic of the sample. A sample for which we know the "true value" would be our calibration standard. We may also need to characterize the accuracy of the measurement instrument by observing historical trends in the distribution of measured values for the calibration standard (this allows for determining the systematic error expected from environmental effects, etc.). The effects of systematic uncertainties cannot be reduced by repeated measurements. The cause of systematic errors may be known or unknown. If both the cause and the value of a systematic error are known, it can be corrected for by "subtracting" the known deviation. However, there will still remain a systematic uncertainty component associated with this correction.

Equipment

- Engineering notebook
- Gauge block
- Dial caliper

Procedure

1. Two students are asked to measure the length of a credit card. The accepted value for the length of the credit card is 85.105 mm.

   Student A uses a plastic ruler. Student B uses a precision measurement tool called a micrometer. To ensure good estimates of length, each student measures the length of the same card four times and records the following measurements.

	Student A	Student B
	85.1mm	85.301 mm
	85.0 mm	85.298 mm
	85.2 mm	85.299 mm
	85.1mm	85.301 mm
Mean		
Standard Deviation		

   a. Create a dot plot of each student's data. Use the same number line but different colors or indicators for each set of data.

   b. Which student's data is more accurate? Explain.

   c. Looking at the dot plot, which student's measurement instrument do you feel is more precise? Is this result expected given the measuring instruments used by each student? Explain.

   d. Find the mean of each set of measurements and enter each value in the appropriate cell in the table. Then answer the following questions.

      - What is the error of Student A's measurements? Show your work.

      - What is the error of Student B's measurements? Show your work.

- How do these error calculations support or refute your answers to parts *a* and/or *b* above?

e. Find the sample standard deviation of each set of measurement data (by hand, using a graphing calculator, or using Excel) and enter each value in the last row of the table.

f. View The Empirical Rule presentation. Then answer each of the following.

- Use the standard deviation to make a statement about the actual length of the credit card at the 68% confidence level using Student A's data. Give your answer in both plus/minus notation and using a compound inequality.

- Use the standard deviation to make a statement about the true length of the credit card at the 95% confidence level using Student A's data. Give your answer in both plus/minus notation and using a compound inequality.

- Use the standard deviation to indicate the precision of Student B's measurement data at the 68% and 95% confidence levels.

- How do the standard deviation values calculated for each student's data support or refute your answers to parts *a* and/or *b* above?

2. Your instructor will choose two dial calipers. One caliper should be labeled #1 and the other #2. Each student in the class will measure a gauge block with each of the two dial calipers and record the measurements to the appropriate number of significant figures independently (without looking at another student's recorded measurements). Be sure to keep the measurements for each dial caliper separate.
    a. Record all data for each dial caliper. Two tables are provided at the end of this activity in which to record the measurements.

    b. Find the mean and sample standard deviation of each set of data.

    c. Compare the accuracy of the two dial calipers. Your discussion should include the mean of each data set.

    d. Make a statement regarding the precision of Dial Caliper 1 at the 95% confidence level.

    e. Make a statement regarding the precision of Dial Caliper 2 at the 95% confidence level.

    f. Based on the accepted value of the length and the accepted value of the width, which dial caliper is more precise? Explain.

While classmates are measuring the gauge block, complete the following exercises.

3. In a group of six, obtain two different metric rulers. Place a piece of masking tape on each ruler. Write “Length” on the masking tape on one ruler and “Width” on the masking tape on the second ruler.

    a. Each person should measure and record the length of the same sheet of copy paper using the “Length” ruler. Then each person should measure and record the width of the same sheet of paper using the “Width” ruler. Each person should initial his/her measurements in the table. Be sure to use the appropriate number of significant digits.

	Length (cm)	Width (cm)	Initials
Mean			
Standard Deviation			

Assume that the sheet of paper that you just measured actually measures 27.92 cm x 21.36 cm.

a. Compare the accuracy of the measurements for the two rulers. Your discussion should include the mean of each data set.

b. Give a statement indicating the precision of each ruler at the 95% confidence level.

c. Based on the accepted value of the length and the accepted value of the width, which ruler is more precise? Explain.

Conclusion

1. Why is it important to know the accuracy and precision of a measuring device?

2. Do you think that the dial caliper manufacturer's claim that the "accuracy" of the instrument is ± .001 is appropriate? Why or why not?

3. Do you think that either of the dial calipers needs to be adjusted in order to accurately display measurements? Explain.

DIAL CALIPER 1

	Measurement	Initials
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		

DIAL CALIPER 2

	Measurement	Initials
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
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25		