Ways of Knowing You Know

Concepts

- Measurement
- Error

Materials

- TI-84 Plus
- CBL 2™ or EasyLink™ cable with some probes OR
- CBR 2™ with the *CBL\CBR*, *EasyData™*, or *DataMate* APPs
- I/O cable

Overview

This activity examines issues related to measurement and its relationship to error analysis.

Launch

When we measure, we are using a tool to get an approximate value that represents the value that is true.

How hot is it, really? How long is that, really? How much is in the bottle, really? Measurement is dependent upon your tool, and how well you need to know a measure is related to the situation. When you cut a piece of lumber for a wall in a house, or for a shelf in an expensive cabinet, your need to know the lengths vary.

If you have a 355ml can of pop, how much pop is actually in the container? How carefully do you think they measure, and how far off from the reported value could you be? If your can had 275ml of pop, is that close enough to the reported value of 355ml?

In this investigation, your team will design an experiment to determine the value of a measurement that they select. The item to be measured will be selected by your team, but must be measured by a probe, such as pH, light, motion, force, etc.

The measurement should be representative of the item measured—the height of a door, the temperature of the hall, the width of a parking space—and all the measured items are expected to be the same. That is, we will be determining the real value of the measurement of an average.

Plan (Method 1)

1. You may use *EasyData*™ and the EasyLink™ cable to collect the data.
   - Connect the probe while the calculator is turned off or at the Home Screen and the *EasyData*™ APP will automatically launch (Figure 1).
   - If this is not the case, press APPS, and then ⬇ to locate the *EasyData*™ APP, and finally press ENTER to run.

2. Setup the application to collect data in the 'Events with Entry' Mode by pressing Setup and selecting option 3 (Figure 2).

3. To run, press Start, and make sure what the reading represents before you press Keep to keep the value and enter a reference (Figure 3).
   - In this case, just use the numbers 1, 2, 3,… to help keep count.
   - Press OK, and move to the next of the similar objects.

4. When finished, press Stop to end the data collection, and then Main to return to the Main Menu.
   - If you are finished with *EasyData*™, press Quit to Quit the application and take note of the location of your data (Figure 4).

Note: This method may only be used with the CBR 2™, Light, Voltage, or Temperature probes.
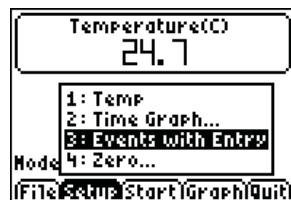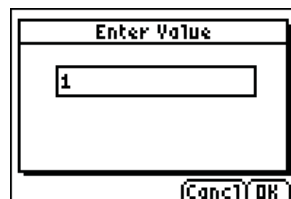

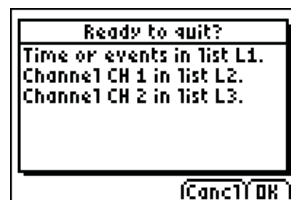**Figure 1**

Figure 2

Figure 3

Figure 4

Plan (Method 2)

1. You may use the GAUGE with the CBL 2™ or CBR 2™.

   - In this case, you will use the *CBL/CBR* APP on the TI-84 Plus as shown in Figures 5 to 10, connecting the appropriate probe as the directions explain.

2. This mode will automatically record your data in a list, but you should write it down as you get the values as a back-up.

3. Press ENTER and a Reference number for each measure will be recorded until you have the 21 data points.

4. Then press CLEAR, and 2nd QUIT 4 to leave the GAUGE mode.

5. The data will be located in the lists DREF and DIST, TREF and TEMP, or similar names for the light and voltage probes.
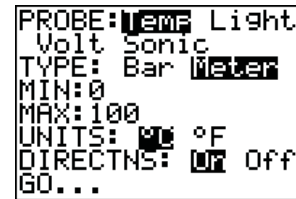
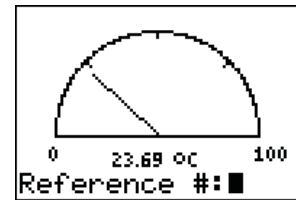**Figure 5**

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

Plan (Method 3)

1. The third method uses the LogData function of the *DataMate* APP.

   - If you do not have the *DataMate* APP on your calculator, connect to the CBL 2™, press [2nd] [LINK] [▶] [ENTER] on your calculator to set it to Receive (Figure 11).

   - Press the Transfer button on the CBL 2™.

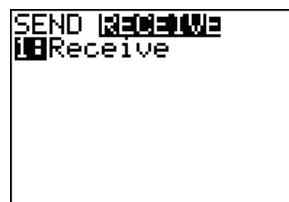2. Run the program with the probe attached to the CBL 2™, and record the data (Figure 12).

Figure 11

Figure 12

Execute

1. What Set-up Method are you using? _____

2. What item are you measuring? _____
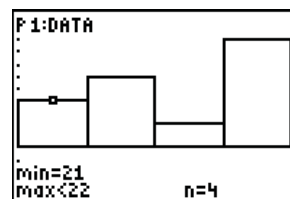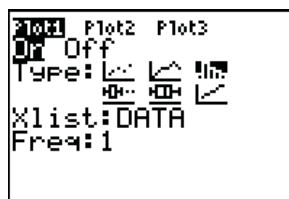
3. What units of measure are you using? _____

4. The 21 values:

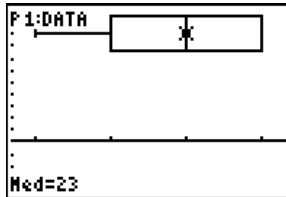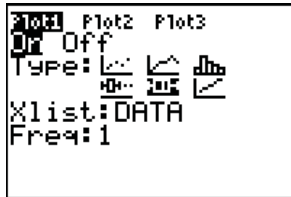| Measured Values	Measured Values	Measured Values

5. Identify the following values for your data set:

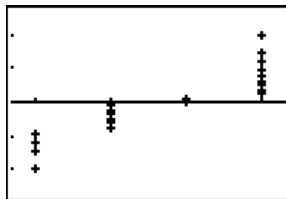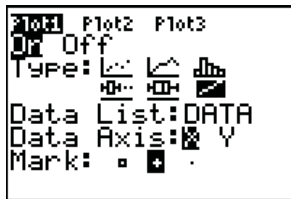|	
Mean	
Median	
Mode	
Maximum	
Minimum	
Standard Deviation	
Average	

6. Produce a Histogram of your data, including a Window.

7. Produce a Box and Whiskers of your data, including a Window.

8. Produce a Z-Distribution of your data, including a Window.

9. Produce a scatterplot of your data, including a Window.
   Hint: make a list (NO) to number your measurements.
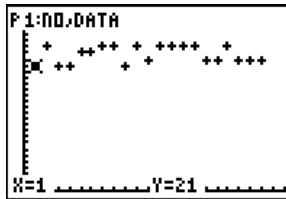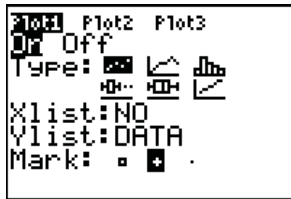
10. Calculate the Error. $\dfrac{|Observed - Actual|}{Actual} \cdot 100$, where 'Actual' is the True
    value that you determine (explain why you picked that value) and
    'Observed' is the Mean of your data.

11. Using the Mean and Standard Deviation for your data, create a Histogram and Normal Distribution curve for the density measures.

- Sixty-Eight percent of your data should fall within the interval between the mean and one Standard Deviation up or down from the mean. Adjust the value of M to increase the height of the curve.
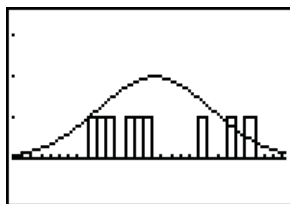- Check it out using the vertical lines.

```
Plot1  Plot2  Plot3
On  Off
Type: ⌐ ⌐ ⌐
      ⌐ ⌐ ⌐
Xlist:DATA
Freq:1
```

```
Plot1  Plot2  Plot3
\Y1∎normalpdf(X,
x̄,Sx)M*Sx/0.4
\Y2=
\Y3=
\Y4=
\Y5=
\Y6=
```

```
Vertical  x̄
Vertical  x̄+Sx
Vertical  x̄-Sx
```

```
ShadeNorm(x̄-Sx,x̄
+Sx,x̄,Sx)
```

12. Perform a T-Test to evaluate your data at the p = 0.1 level (10%). Use a value for *u₀*—the Actual value—that you determine, and explain why you picked that value.

- Perform both Calculate and Draw.
- Determine if your data survives the test at the 10% level. (In the example the level is 1.1% since p =0.0118, lower/better than the p = 0.1 level.)

```
EDIT  CALC  TESTS
1▪Edit…
2:SortA(
3:SortD(
4:ClrList
5:SetUpEditor
```

```
EDIT  CALC  TESTS
1:Z-Test…
2▪T-Test…
3:2-SampZTest…
4:2-SampTTest…
5:1-PropZTest…
6:2-PropZTest…
7↓ZInterval…
```

```
T-Test
 Inpt:DATA  Stats
μ₀:23.5
List:DATA
Freq:1
μ:≠μ₀  <μ₀  >μ₀
Calculate  Draw
```

```
T-Test
μ≠23.5
t=-2.770508771
p=.0118010659
x̄=22.76190476
Sx=1.220850601
n=21
```

Conclude

1. Discuss the various methods of analyzing these data.

- Which of the above analysis methods best demonstrates the consistency in the data that you collected and why?
- What are these graphs, calculations?
- Who uses them and why? Do you? Why? When? Where?

Teaching Notes

When the groups design their experiments, make sure they understand "sameness."

- Measuring the heights of 21 student desks would be fine if they are all the same brand of desk, and they are not damaged or abused in such a way that their heights have changed.
- Measuring the temperature of the air as a measure of the quality of a thermostat would be fine if the air that is measured is in the same room as the thermostat and after the blower has finished heating the air.

Direct the group through the various methods of looking at the data after the experiment has been designed and conducted.

Technological Pitfalls

The *EasyData™* will drive the CBL 2™ or the EasyLink™, but the EasyLink™ is limited in the number of probes that can be used. That is, some probes will not work with the *EasyData*™ APP.

The *CBL/CBR* APP is only good for the four probes (motion, light, voltage, and temperature). Unfortunately, when they use Reference #, if the data is not entered fast enough, the system will lock up.

- To undo the lockup, press [2nd] [QUIT] and [2nd] [OFF] and [ON] over and over in different combinations until the screen returns to the GAUGE setup.
- Once you are at this screen, if you back out, then the data will still be in the lists, but if you start the data collection again, the data will be lost.

TI-Navigator™ Use

Collect information from the groups about their item to be measured and the probe they plan to use using Screen Capture. Discuss the feasibility of the experiments.

Have one group submit their data list, and send it to the whole class. Let each group pick one of the methods to manipulate it, and then take another screen shot for the class to see and discuss.

Have each group set up their display of choice for their data and screen shot it for the edification of the class.