Water Drops on a Penny

Background: This activity is commonly used to develop data for teaching graphing skills and sometimes for teaching the necessity of controlling variables in an experiment. Some of the specific activities are modified from ones seen at Woodrow Wilson workshops and from activities done by Brad Williamson of Olathe, Kansas. Art Christensen and Barbara Christian have outlined some of the possibilities offered by activities with water drops on pennies in their September 1997 article “Dealing with Data” in *The Science Teacher.* The following series of activities can be used for addressing graphing skills and controlling variables while also laying the basic groundwork for an understanding of the special properties of water. Different combinations of the following activities can be chosen by the instructor to tailor the lesson to their particular goals/objectives. See Addendum 1 for specific background on creating box plots.

Materials: variety of droppers and/or pipets
pennies
overheads with graph paper grid photocopied on them (example attached)
water
ice
hot water (45-50^{o} C is hot enough for good results and still safe)
water with a few drops of dish soap mixed in (try not to create bubbles)
rubbing alcohol
vegetable oil or mineral oil
paper towels

Day 1

Objectives: To learn stem-and-leaf plots and box plots.

Procedure:

1. Give every student a pipet or eyedropper but make sure a variety of sizes and shapes are used. Do not specify what side of the penny to use. Let students decide how to hold the droppers, including how high to hold them. Encourage diversity.
2. Have the students drop water on a penny counting the number of drops a penny holds. (The drop that causes the water to overflow does not count.)
3. Collect the class data and project it to the class as the students finish. Use this data to show the students how to do stem and leaf plots and box plots.
4. Discuss the value of each type of presentation.

Sample Day One Data:

Number of Drops of Water A Penny Will Hold
29,49,43,48,53,33,20,55,46,45, 28,51,30,11,51,31,47,33,52,18, 19,40,58,15,28,29,45,35,33,35

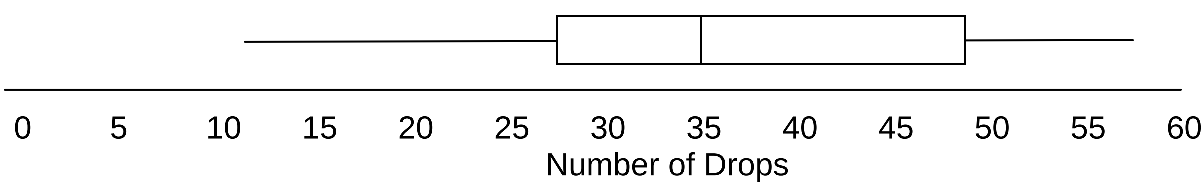
Stem and Leaf Plot for the Number of Drops of Water A Penny Will Hold

Tens	Ones
0	
1	1,5,8,9
2	0,8,8,9,9
3	0,1,3,3,3,5,5
4	0,3,5,5,6,7,8,9
5	1,1,2,3,5,8

Summary Data for the Number of Drops of Water A Penny Will Hold

# of Trials	30
1st Quartile	29
Median	35
3rd Quartile	48
Min, Max	11, 58

Box Plot of Number of Drops A Penny Will Hold

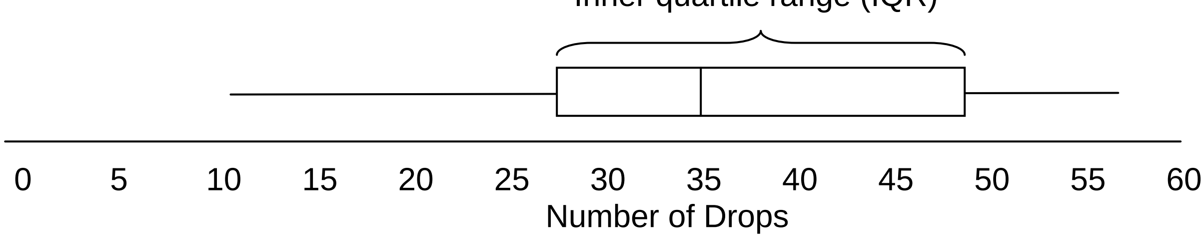


Day 2

Objectives: To demonstrate the need for controlling variables and to learn how to establish experimental protocols.

Procedure:

1. Bring back for discussion the box plot from the previous day. Point out that the spread of the graph, in particular, the inner quartile range* or IQR (the middle 50% of the data) can be used as a measure of the consistency of the data. The more condensed the box plot is, the more consistent the data.



* As a rule of thumb the standard deviation is about ¾ of the IQR

2. Ask students what about their techniques the previous day may have contributed to increasing the spread of the data (and the data less consistent). Answers should include the different pipet sizes, using different sides of the penny and other dropping technique items.
3. Have the students specify the procedures they will all use in an attempt to improve the consistency of the data.
4. Now have the students collect data using the new procedures.
5. Collect the class data and project it to the class as the students finish. As on the first day, use this data to create stem and leaf plots and box plots. Place the new box plot on the same graph as the plot from the 1st day.
6. Compare the plots and use them to discuss the necessity of procedures and maintaining constants when collecting data.

Sample Day Two Data:

Number of Drops of Water A Penny Will Hold
29,39,43,38,33,33,30,35,46,45, 28,51,30,31,51,31,47,33,52,18, 19,40,48,25,28,29,45,36,35,35

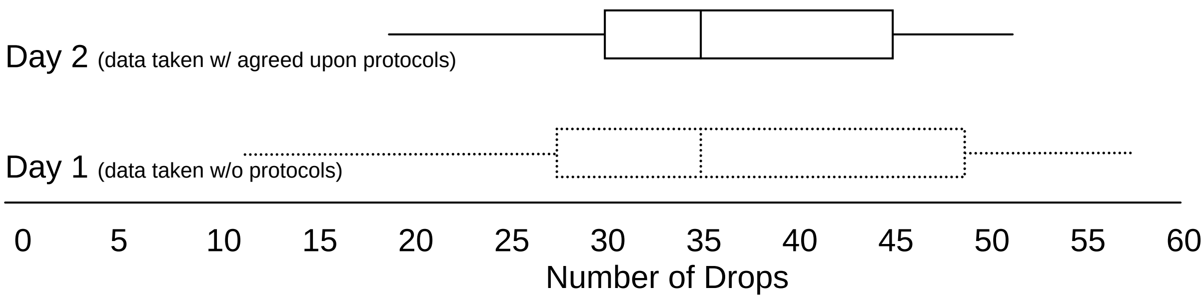
Stem and Leaf Plot for the Number of Drops of Water A Penny Will Hold

Tens	Ones
0	
1	8,9
2	5,8,8,9,9
3	0,0,1,1,3,3,3,5,5,5,6,8,9
4	0,3,5,5,6,7,8
5	1,1,2

Summary Data for the Number of Drops of Water A Penny Will Hold

# of Trials	30
1st Quartile	30
Median	35
3rd Quartile	45
Min, Max	18, 52

Box Plot of Number of Drops A Penny Will Hold



Day 3 & 4

Objectives: To discover the unique properties of water.

Procedure:

1. Assign (or let each lab group choose) a test liquid to compare to room temperature tap water. Good ones to compare to room temperature tap water are:
    a. ice water
    b. hot water (approximately 50^o C – still safe to use)
    c. soapy water
    d. vegetable oil
    e. rubbing alcohol
2. Before students begin collecting data have them make a prediction as to which liquid will stay on the penny better. Students often predict that vegetable oil will stay on better since they consider it thicker (more viscous) than water.
3. Have students collect data, make sure they collect at least 15 pieces of data for their box plots.
4. Give them overheads (with graph grids) and overhead pens to produce the graphs for their groups so they can compare their results with others in the class.
5. Many of these comparisons produce rather dramatic graphs and provide fertile background for rich discussions about the unique properties of water. You may also want to retain some of the best graphs to refer back to during future discussions of polar versus nonpolar covalent bonds, hydrogen bonds, cohesion, adhesion, hydrophobic molecules, etc.

Addendum #1

BOX plots
(Box-and-whiskers)
by Kathleen Wilhite, Olathe, KS

What:

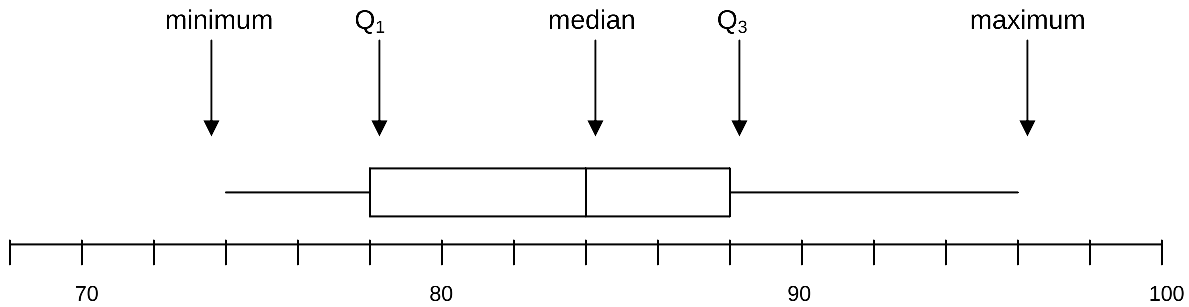
The box plot, also known as box-and-whiskers, is a relatively new data display created by John Tukey of Princeton (he also created the stem-and-leaf plot). A box plot is a scaled display in which the data are divided into four equal parts and are used to show the spread of the data relative to the median and the quartiles.

Why:

Looking at the mean and standard deviation is one method of measuring the center and spread of a data set. However, these statistics can be more difficult to calculate and interpret. Using the median to measure the center and the quartiles to show spread is a simpler, more easily visualized method. Also the median and quartiles are not as easily affected by extreme values, as are the mean and standard deviation.

How:

1. Rank the raw data in numerical order from least to greatest.
2. Divide the data into two equal halves at the **median** (the middle value). If the median is a data point, do not include it into either group.
3. Find the median of the lower half. This value is the first or lower quartile (Q_1). This is equivalent to the 25^{th} percentile.
4. Find the median of the higher half. This value is the third or upper quartile (Q_3). It is equivalent to the 75^{th} percentile.
5. Use a number line scaled in an appropriate equal intervals.
6. Draw short vertical lines at the values for the lower and upper quartile. Complete the "box" with horizontal lines joining the vertical lines. This represents 50% of the data. Mark the median as a vertical line inside the box. The "whiskers" are drawn as horizontal segments extended from the middle of the sides of the box to the minimum and maximum values.



Interquartile range (IQR): The interquartile range is the difference between the upper and lower quartile. ($Q_3 – Q_1$) This gives the spread of the middle 50% of the data. A rule of thumb is that 0.75 times the IQR is a good approximation of the standard deviation of the data set.

Outlier: An outlier is an extreme value that is not typical of the data. These are values lying more than 1.5 times the interquartile range away from the nearer quartile. Outliers should be represented by open circles and the whiskers should be drawn to the next closer value within the acceptable range.

Caution: It is important that students understand that a smaller side of the "box" or a shorter "whisker" does not mean that there are fewer values represented by that the values are grouped closer together, in other words, they have a smaller spread.

Additional uses:

- Parallel box plots are a useful way of comparing groups of data. For example, compare the data from different lab groups or different trials of an experiment. Or compare the data collected from an experiment conducted at different times when a variable is changed, such as time of the day.
- Provide a box plot under a histogram to give more information quickly.
- Box plots can be oriented horizontally or vertically.

Addendum #2

Laboratory Notebook	**Name:**	
	Date:	**Hour:**