Graphing Skills
Reading, Constructing and Analyzing Graphs

Unit Overview

OBJECTIVE
The purpose of this lesson is to provide the teacher with basic graphing skill lessons to be used throughout the science course of study. There are many different kinds of graphs and each has a fairly specific use. By teaching graphing at all grade levels students should be able to choose the best type of graph to represent their data. Students should also become familiar with how to analyze and interpret graphical information.

LEVEL
All

NATIONAL STANDARDS
UCP.1, UCP.2, G.2

CONNECTIONS TO AP
Each of the AP Science courses requires that students are able to read, construct and analyze graphs.

TIME FRAME
45 minutes

MATERIALS
- graph paper
- pencil
- data
- ruler

TEACHER NOTES
Graphing is a skill that should be introduced at each grade level and reinforced throughout the year. The analysis level of the graph will vary depending on the mathematical ability of your students. The lessons presented here may be used as stand alone lessons or may be combined as a general review of graphing skills.
Graphing is an essential tool in science. Graphs enable us to visually communicate information. The lessons that follow will focus on bar graphs and line graphs. Goals for this series of lessons on graphing include:

- Choosing an appropriate display for data (which type of graph to construct)
- Identifying data to be displayed on the x- and y-axes
- Scaling a graph properly
- Labeling a graph with axes labels, title, units and legend or key if necessary
- Including a line of best-fit or trend line
- Extrapolating and interpolating data points
- Understanding relevant relationships such as slope and area under the curve
Graphing Skills
Reading, Constructing and Analyzing Graphs

Bar Graphs and Histograms

OBJECTIVE
Students will become familiar with basic bar graphing skills to be used throughout their science course of study.

LEVEL
All

NATIONAL STANDARDS
UCP.1, UCP.2, G.2

CONNECTIONS TO AP
Each of the AP Science courses requires that students are able to read, construct and analyze graphs.

TIME FRAME
45 minutes

MATERIALS
(For each student working individually)

- 2 sheets of graph paper
- pencil
- data
- ruler

TEACHER NOTES
Graphing is a skill that should be introduced at each grade level and reinforced throughout the year. Before allowing students to begin this exercise, you should do the following:

- Often students confuse bar graphs and histograms because both graphs use bars and frequencies to display the data. A bar graph is used for categorical data and the histogram is used for quantitative data. Traditionally the bars in a bar graph have spaces between them and categories are provided along the base to identify each bar. Histogram bars have their bases on a numerical scale that is constructed like a portion of a number line. Unless there are gaps in the data, the bars in a histogram will not have spaces between them. The difference is a matter of type of scale on the horizontal axis and whether or not calculating the mean and median of the data makes sense.
• Encourage students to decide which sets of data belong on the $x$-axis and the $y$-axis. The key here is to place the independent variable on the $x$-axis and the dependent variable on the $y$-axis.

• Show the students how to properly scale a graph. The scale represents the range of frequency values shown on the graph. Visually show students how to properly accomplish this task by making an overhead transparency of a piece of the graph paper. Write down the range, count the squares on the graph paper and decide the scale by spacing appropriately. Emphasize the importance of using the entire length and width of the paper when creating the axes.

• Demonstrate proper labeling of a graph with a title, axes labels and units, and keys if necessary. Titles are usually given at the top of each graph and provide an overview of the information that is given in the graph. The axes labels should provide specific information as to what is represented. It is customary to label a graph in the format $y$ vs. $x$. For example if a graph is described as “Temperature vs. Time” then temperature should be on the $y$-axis and time should be on the $x$-axis. Depending on the level of your students you may wish to require this format.

• In analyzing a graph, show the students how to read and interpret the graph by using interpolation and extrapolation. Point out that it is difficult to identify specific interpolation (between) points on bar graphs but that rough comparisons are easy. Extrapolation (beyond) points is also difficult (if not impossible) to determine on bar graphs.

• As students work on this activity monitor them closely to ensure that they have correct labels and scales on the graphs they are constructing.
SAMPLE DATA
Student graphs should look similar to the samples found below.

PART I: SIMPLE BAR GRAPH

Leading Causes of Death Worldwide

<table>
<thead>
<tr>
<th>Cause</th>
<th>Million of deaths per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular disease</td>
<td>18</td>
</tr>
<tr>
<td>Cancer</td>
<td>10</td>
</tr>
<tr>
<td>Infectious diseases</td>
<td>4</td>
</tr>
<tr>
<td>Accidents and trauma</td>
<td>8</td>
</tr>
<tr>
<td>Respiratory disease</td>
<td>6</td>
</tr>
<tr>
<td>Diabetes</td>
<td>4</td>
</tr>
<tr>
<td>Digestive and nutritional</td>
<td>2</td>
</tr>
<tr>
<td>Dearth</td>
<td>1</td>
</tr>
</tbody>
</table>

PART II: HISTOGRAM

Life Expectancies in the US

<table>
<thead>
<tr>
<th>Remaining Years Expected</th>
<th>Current Age Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>0</td>
<td>80</td>
</tr>
</tbody>
</table>
POSSIBLE ANSWERS TO THE CONCLUSION QUESTIONS

PART I: SIMPLE BAR GRAPH

1. How many deaths occur due to accidents and trauma each year?
   - 5.1 million deaths

2. Can you predict the number of deaths that are the result of cancers and tumors for the next ten years? Explain.
   - No. This type of extrapolation is a weakness of bar graphs.

PART II: HISTOGRAM

1. Make a prediction about the remaining years of life that would be expected for someone in the current age category of 91-100.
   - Some students will attempt to find a mathematical trend in the data by looking at how the years change over each interval. Students should answer between 0 and 2 years if using this type of pattern.

2. Is the answer to question 1 an accurate number? Why or why not? Justify your answer.
   - No, the answer in 1 is not an accurate number.
   - This is very difficult to predict from a graph of this type.

3. What type of data is easily represented by a bar graph?
   - Data that compares amounts or frequency of occurrence.

4. What is the importance of scaling?
   - Scaling is important for making accurate comparisons.

5. Distinguish between the dependent and the independent variable for each of the graphs that were constructed. On which axis should the independent variable be placed?

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Independent Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Bar Graph</td>
<td>Millions of deaths per year</td>
</tr>
<tr>
<td>Histogram</td>
<td>Remaining years expected</td>
</tr>
</tbody>
</table>

- The x-axis is usually used for the independent variable.
Graphing Skills
Reading, Constructing and Analyzing Graphs

Line Graphs

OBJECTIVE
Students will become familiar with the basic skills used in making line graphs. Line graphs will be used throughout their science course of study.

LEVEL
All

NATIONAL STANDARDS
UCP.1, UCP.2, G.2

CONNECTIONS TO AP
Each of the AP Science courses requires that students are able to read, construct and analyze graphs.

TIME FRAME
45 minutes

MATERIALS
(For each student working individually)

- 3 sheets of graph paper
- data
- pencil
- ruler

TEACHER NOTES
Graphing is a skill that should be introduced at each grade level and reinforced throughout the year. In this exercise students will construct line graphs using paper and pencil. Line graphs will be constructed and analyzed more than any of the other type of graph throughout the science course of study. You need to make sure all students are comfortable with this activity.

Upon completion of the graphing exercise, analysis of the graph follows. Students should understand basic paper/pencil construction methods of graphing before proceeding to the Foundation Lessons which use Microsoft Excel® and Graphical Analysis®. Before allowing students to begin this exercise, you should have students make a practice graph at their desks while you make one at the overhead or chalkboard. In your example discuss the following points:

- Ask students if they can identify the x- and y-axes. Label these on your sample.
- Ask students about the terms independent and dependent variable. Do they know where to place each on their graph? Below the x-axis write the label “independent” and beside the y-axis write the label “dependent.” Remind the students that each of the variables should have some type of unit associated with them. Write the word “unit” in parentheses after the word “independent” and “dependent” variable on your example.
• Ask students to identify the last missing component of the graph (Title). Write the term “title” at the top of the graph. Point out that it is common to title a graph using the dependent variable (y-axis) vs. the independent variable (x-axis) format. Encourage students to give descriptive titles to their graph and not just re-name the axes. The graphs that the students construct should have informative titles. Titles should tell exactly what information the author is trying to represent with the graph. The title should be concise, clear and complete.

• Using any set of generic data points, illustrate to students how to determine the range for each variable and how to determine the scale for each axis. Point out that graph paper must always be used to construct a graph. Each square along an axis must represent the same increment. Encourage students to use as much space as available to construct their graph. Label each axis on the graph with the proper numbers according to the data given.

• Illustrate how to plot points on the graph. Emphasize that each point represents both an x and a y component. Remind students that the plotting of points in science is the same as plotting an ordered pair in the math class [in math the points are always given as (x,y)]. Encourage the use of pencil to plot the data set.

• Discuss with students the importance of using a graph to understand relationships. In the science classroom graphs are not generally connect-the-dot graphs. It is common practice to draw the best smooth curve or the line of best-fit that relates the data. Illustrate how this is done with the data previously plotted. If more than one set of data is to be displayed on any one graph, remind students that a legend or key will be necessary to identify each line.

• Point out to students that as their mathematical and scientific skills increase, the usefulness and meaning of their graphs will also increase.

• Illustrate the following analysis techniques:
  o Interpolation of data — find a value that lies on the smooth curve or line between two actual data points.
  o Extrapolation of data — find a value that lies on the smooth curve or line beyond the actual plotted points. Data can be extrapolated both on the front and back end of the line/curve.
  o Linear regression of data — If the plotted relationship generates a straight line, have students write the equation for the straight line in slope-intercept form (y = mx + b). To calculate the slope of the line use the equation:
    \[ \text{slope} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1} \]
    ▪ The y-intercept (b) can be found by extending the line of best-fit backwards until it crosses the y-axis.
SAMPLE DATA
Sample Data Set 1: The following set of data was collected while experimenting with position and time of a miniature motorized car traveling on a straight track.
Sample Data Set 2: The following set of data was collected during an experiment to find the density for an unknown metal.
Sample Data Set 3: The following set of data was collected during an experiment studying the effect of light intensity on rate of photosynthesis.
POSSIBLE ANSWERS TO THE CONCLUSION QUESTIONS

Sample Data Set 1:

1. What is the independent variable for this graph? Explain.
   
   • Time is the independent variable. It is the property that is controlled by the experimenter. It is plotted on the x-axis.

2. Determine the position of the car after 2.5 minutes.
   
   • About 7.5 to 8.0 meters. Arriving at this answer requires that the student use knowledge of interpolation.

3. If the experiment were carried out for 30 minutes, what would be the position of the car?
   
   • About 90 meters. Arriving at this answer requires that the student use knowledge of extrapolation.

4. Calculate the slope of the line drawn. What does the slope of this line represent? Explain.
   
   \[
   \text{slope} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}
   \]
   
   • Students may choose any set of points to solve. Answers may vary slightly. Possible solution might be:
   \[
   \text{slope} = \frac{\Delta y}{\Delta x} = \frac{30 \text{ m} - 15 \text{ m}}{10 \text{ min} - 5 \text{ min}} = \frac{15 \text{ m}}{5 \text{ min}} = 3 \text{ m/min}
   \]
   
   • The slope represents the speed of the miniature car — distance per time.

5. Write the equation for the line and substitute the value determined for the slope.
   
   • \[y = mx + b\]
   
   position (m) = (3 m/min) (time) + 0
Sample Data Set 2:

6. What values were considered when creating the scale for each axis in this experiment?

- Mass: the range of the numbers was from 2.00 to 24.00 grams. The scale was chosen so that each line represents 5 grams. (student answers may vary as chosen scales may vary)
- Volume: the range was from 0.18 to 2.11 cm³. The scale was chosen so that each mark represented 0.50 cm³.

7. What does a data point on this graph actually represent?

- Each data point represents a mass and a volume measurement. The relationship between the two is the density which is the slope of the best-fit line.

8. What volume would a 20.00 gram sample of this substance occupy?

- About 1.75 cm³. Arriving at this answer requires that the student use knowledge of interpolation.

9. Calculate the density of the substance. (HINT: calculate the slope of the line.)

\[
\text{slope} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}
\]

- Students may choose any set of points to solve. Answers may vary slightly. Possible solution:

\[
\text{slope} = \frac{\Delta y}{\Delta x} = \frac{15 \text{ g} - 5 \text{ g}}{1.44 \text{ cm}^3 - .44 \text{ cm}^3} = \frac{10}{1.00} = 10.0 \text{ g/cm}^3
\]

- The slope represents density — mass per unit volume.

10. Write the equation for the line and substitute the value determined for the slope.

\[
y = m \cdot x + b
\]

mass (g) = (10.0 g/cm³) (volume(cm³)) + 0

11. Use the equation to find the mass when the volume is 5.00 cm³.

\[
y = m \cdot x + b
\]

mass (g) = (10.0 g/cm³) (5.00 cm³) + 0

mass (g) = 50.0 grams
Sample Data Set 3:

12. Does this graph represent a linear relationship? Why or why not?

- This graph is not a linear relationship. The slope of the line changes with time.

13. Identify the dependent variable in this graph. Explain.

- The dependent variable is the percent transmittance. Time is the independent variable, the one that the experimenter has control over. At each time interval, the transmittance is measured.

14. If the experiment were continued for 30 minutes, what trend in percent transmittance could be expected?

- The graph begins to level somewhat between 10 and 15 minutes. It seems logical that the percent transmittance would soon level off or begin to fall.

15. Calculate the slope of the line at 5 minutes. What does this represent?

- A tangent line must be drawn at 5 minutes.
- \[
\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta y}{\Delta x} = \frac{60\% - 50\%}{7\text{ min} - 3.7\text{ min}} = \frac{10}{3.3} = 3.03\% / \text{ min}
\]
- The slope represents the instantaneous rate. Notice that the slope of the line is different at 10 minutes.
Bar graphs are very common types of graphs. They are found in almost all science books, magazines, and newspapers. They can be useful tools in scientific study by allowing us to visually compare amounts or frequency of occurrences between different data sets. Bar graphs can be used to show how something changes over time or to compare items with one another. When reading or constructing this type of graph you should pay close attention to the title, the label on the axes, the unit or scale of the axes and the bars.

In a simple bar graph the specific group or experimental subject is assigned the $x$-axis (horizontal). The $y$-axis (vertical) is known as the frequency axis. In general, the $x$-axis will be divided into categories while the $y$-axis is designated for the frequency of occurrences. Histograms are very similar to simple bar graphs with one exception — the bar represents a range of values rather than one single value and the intervals must all be of equal magnitude. Study the sample graphs below before completing this exercise.

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**Simple Bar Graph**

![Simple Bar Graph](image1)

**Histogram**

![Histogram](image2)

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*Figure 1* *Figure 2*
PURPOSE
In this exercise you will create simple bar graphs, and histograms. You will be expected to properly label each of your graphs and analyze each one by making statements about trends in the data.

MATERIALS
- 2 sheets of graph paper
- data
- pencils
- ruler

PROCEDURE
PART I: SIMPLE BAR GRAPH

1. Obtain one piece of graph paper and a pencil.

2. Study the data table below.

<table>
<thead>
<tr>
<th>Leading Causes Of Death Worldwide</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause</td>
<td>Deaths Per Year (millions)</td>
</tr>
<tr>
<td>Cardiovascular disease</td>
<td>16.9</td>
</tr>
<tr>
<td>Cancers and tumors</td>
<td>7.2</td>
</tr>
<tr>
<td>Infectious diseases (includes AIDS, malaria, etc.)</td>
<td>13.5</td>
</tr>
<tr>
<td>Accidents and trauma</td>
<td>5.1</td>
</tr>
<tr>
<td>Respiratory disease</td>
<td>3.5</td>
</tr>
<tr>
<td>Digestive and nutritional</td>
<td>2.3</td>
</tr>
<tr>
<td>Diabetes</td>
<td>0.9</td>
</tr>
</tbody>
</table>

3. Choose the data to be graphed on the x-axis and the y-axis.

4. Survey the data and determine an appropriate scale for each axis. Be sure to utilize as much of the graph paper as possible to display your data. Use your pencil to lightly mark the scale of your x- and y-axes. Have your teacher check your scale before proceeding any further. When making a bar graph, the individual bars should be constructed with the same width. You should determine the width of your bars.

5. When your teacher approves, construct your simple bar graph. Be sure to label each axis with units and give your graph a title.
PART II: HISTOGRAM

1. Study the following data and follow the same graphing procedure. This data should be graphed as a histogram. It is important that histograms have the same interval and width for each bar. For example, each bar might represent 10 years in the data table below.

<table>
<thead>
<tr>
<th>Current Age</th>
<th>Remaining Years Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>72.6</td>
</tr>
<tr>
<td>11-20</td>
<td>59.5</td>
</tr>
<tr>
<td>21-30</td>
<td>50.1</td>
</tr>
<tr>
<td>31-40</td>
<td>40.7</td>
</tr>
<tr>
<td>41-50</td>
<td>31.7</td>
</tr>
<tr>
<td>51-60</td>
<td>23.2</td>
</tr>
<tr>
<td>61-70</td>
<td>15.8</td>
</tr>
<tr>
<td>71-80</td>
<td>9.7</td>
</tr>
<tr>
<td>81-90</td>
<td>4.5</td>
</tr>
</tbody>
</table>
CONCLUSION QUESTIONS
Using the graphs that you constructed, answer the following questions.

PART I: SIMPLE BAR GRAPH
1. How many deaths occur due to accidents and trauma each year?

2. Can you predict the number of deaths that are the result of cancers and tumors for the next ten years? Explain.

PART II: HISTOGRAM
1. Make a prediction about the remaining years of life that would be expected for someone in the current age category of 91-100.

2. Is the answer to question 1 an accurate number? Why or why not? Justify your answer.

3. What type of data is easily represented by a bar graph?

4. What is the importance of scaling?

5. Distinguish between the dependent and the independent variable for each of the graphs that were constructed. On which axis should the independent variable be placed?

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Independent Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Bar Graph</td>
<td></td>
</tr>
<tr>
<td>Histogram</td>
<td></td>
</tr>
</tbody>
</table>
Graphing Skills
Reading, Constructing and Analyzing Graphs

Line Graphs

There are all kinds of charts and graphs used in the science classroom. Graphs are useful tools in science because trends in data are easy to visualize when represented graphically. A line graph is beneficial in the classroom for many different types of data, and is probably the most widely used scientific graph. Line graphs can be used to show how something changes over time or the relationship between two quantities. They can also be readily used to interpolate (predict between measured points on the graph) and extrapolate (predict beyond the measured points along the same slope) data points that were not actually measured. Analysis of these graphs provides very valuable information.

PURPOSE
In this activity you will learn the basic procedure for constructing and analyzing line graphs.

MATERIALS
- 3 sheets of graph paper
- data
- pencil
- ruler

PROCEDURE
1. Follow along with your teacher as a sample line graph is constructed. Label a blank piece of graph paper as your teacher explains the important components of a line graph.

2. When instructed, use the sample sets of data to construct line graphs. Place only one graph on each sheet of graph paper and use as much of the graph as possible to display your points. Do not connect the dots! Draw the best smooth curve or line of best-fit as your teacher demonstrated.

3. Following the steps below will help ensure that all components of the graph are correctly displayed.
   a. **Identify the variables.** Independent on the \( x \)-axis and dependent on the \( y \)-axis
   b. **Determine the range.** For each axis subtract the lowest value data point from the highest value data point.
   c. **Select the scale units.** Divide each axis uniformly into appropriate units using the maximum amount of space available. (Remember that the axes may be divided differently but each square along the same axis must represent the same interval.)
   d. **Number and label each axis.** Be sure to include units where appropriate as part of the axis label.
   e. **Plot the data points as ordered pairs.** \((x, y)\)
   f. **Draw the best straight line or best smooth curve.** For a straight line, use a straight edge to draw your line in such a way that equal numbers of points lie above and below the line.
   g. **Title the graph.** The title should clearly describe the information contained in the graph. It is common to mention the dependent variable (\( y \)-axis) first followed by the independent variable (\( x \)-axis).
4. After creating graphs for the 3 data sets below, use the graphs to answer the conclusion questions on your student answer page.

**Sample Data Set 1:** The following set of data was collected while experimenting with position and time of a miniature motorized car traveling on a straight track.

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Position (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>45</td>
</tr>
<tr>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>25</td>
<td>75</td>
</tr>
</tbody>
</table>

**Sample Data Set 2:** The following set of data was collected during an experiment to find the density for an unknown metal.

<table>
<thead>
<tr>
<th>Volume (cm³)</th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18</td>
<td>2.00</td>
</tr>
<tr>
<td>0.44</td>
<td>5.00</td>
</tr>
<tr>
<td>0.66</td>
<td>7.50</td>
</tr>
<tr>
<td>1.41</td>
<td>16.00</td>
</tr>
<tr>
<td>2.11</td>
<td>24.00</td>
</tr>
</tbody>
</table>

**Sample Data Set 3:** The following set of data was collected during an experiment studying the effect of light on the process of photosynthesis.

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Percent Transmittance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>32.5</td>
</tr>
<tr>
<td>5</td>
<td>54.3</td>
</tr>
<tr>
<td>10</td>
<td>63.5</td>
</tr>
<tr>
<td>15</td>
<td>65.0</td>
</tr>
</tbody>
</table>
Graphing Skills
Reading, Constructing and Analyzing Graphs

Line Graphs

DATA AND OBSERVATIONS
Staple your completed graphs behind this answer page.

CONCLUSION QUESTIONS
Using the graphs that you constructed, answer the following questions:

Sample Data Set 1:

1. What is the independent variable for this graph? Explain.

2. Determine the position of the car after 2.5 minutes.

3. If the experiment were carried out for 30 minutes, what would be the position of the car?

4. Calculate the slope of the line drawn. What does the slope of this line represent? Explain.

5. Write the equation for the line and substitute the value determined for the slope.
Sample Data Set 2:

6. What values were considered when creating the scale for each axis in this experiment?

7. What does a data point on this graph actually represent?

8. What volume would a 20.00 gram sample of this substance occupy?

9. Calculate the density of the substance. (HINT: calculate the slope of the line.)

10. Write the equation for the line and substitute the value determined for the slope.

11. Use the equation to find the mass when the volume is 5.00 cm³.
Sample Data Set 3:

12. Does this graph represent a linear relationship? Why or why not?

13. Identify the dependent variable in this graph. Explain.

14. If the experiment were continued for 30 minutes, what trend in percent transmittance could be expected?

15. Calculate the slope of the line at 5 minutes. What does this represent?