Lessons for Substitute Teachers

The lessons in this section were designed with the substitute teacher in mind. Less science expertise is required to administer these lessons. However, the lessons are intended to teach valuable science concepts within a 40-minute (or so) period, and they are intended to be interesting and fun for students.

The lessons are organized by grade level and number so that middle schools can have a way of tracking which lessons substitute teachers should use, and which ones have already been used with a particular class. You and your department may decide to divide the lessons up differently, however, based on the subject matter that you teach at different grade levels at your school. Also, you may of course decide to use these lessons yourself rather than saving them for substitute teachers.

A Deadly Killer Lurks Among Us, (Grade 6, Lesson 1), L7–L8

This in an exercise that shows students how a written presentation and a biased presentation of the facts can bias the conclusions they draw. Give students the first page to work on. After they have completed the reading and the first set of questions, give them the second page of questions. If the copy is double-sided, ask that they complete the first side before turning it over. After the class completes the exercise, have them discuss their results.

Answer Key:

1. Answers will vary. Sample: Yes, it sounds dangerous.
2. Facts: The company uses Dihydrogen monoxide; Dihydrogen monoxide killed four people; Dihydrogen monoxide is found in acid rain and in pre-cancerous tumors. Sample inferences or conclusions: The company is polluting the river; dihydrogen monoxide is bad for the environment; the dihydrogen monoxide from the company is getting into our food and water; dihydrogen monoxide will make you sick or cause cancer.
3. Answers will vary, yes or no
4. Answers will vary. Sample: I would feel very sad and scared.
5. Answers will vary, yes or no
6. Answers will vary. Sample: I would not be surprised to learn that, since people are mostly water.
7. Answers will vary. Sample: My answers would change because I don’t think water is a dangerous chemical.
8. Answers will vary. Sample: I incorrectly concluded that dihydrogen monoxide was very deadly. This conclusion was probably based on the alarming language used by the writer, and the fact that important information was left out.
9. Answers will vary. Sample: The author presented the facts in the most alarming way possible. The language he used implied things that were very misleading. He did this to convince people to do what he wanted.
How Fast Are Your Reflexes? (Grade 6, Lesson 2), L9–L10
Students perform an experiment to test factors that affect their reflex reaction time by trying to catch a falling paper strip. Students first do the experiment themselves, then have a partner release the strip.

Answer Key: 2, 3. Answers will vary. Most students will probably find that they get larger numbers when someone else drops it or when using their non-dominant hand. 4. Students should suggest using a histogram. Encourage students to find a way to present all the data on one histogram. For example, they could add the data for left and right together to present the total, but shade the amount that represents the left hand a different color.

Design a Way to Water Crops, (Grade 6, Lesson 3), L11–L12
Students work in groups to design a system to move water from a river to a crop field. Students sketch a picture of their final designs. If time remains, designs can be presented to the class.

Answer Key: Answers will vary, but adaptations should build on the original design.

Presenting Graphical Data, (Grade 6, Lesson 4), L13–L14
Students explore how the presentation of data affects the way people view it by comparing graphs of the same data set on different scales. If there is time after students have completed the activity, start a classroom discussion about how data can be manipulated to mislead.

Answer Key:

Part One:
1. Most students will probably suggest Pond B. Very observant students may notice the actual data is the same.
2. Opinion should be supported with detail.
3. Pond A—1000, Pond B—1000
4. Pond A—600, Pond B—600
5. Difference is only in scale.
6. Pond B—looks like a more dramatic decrease

Part Two:
1. Difference between brands. Scale should be picked to show a large visible gap between A and B.
2. Disinfectant is effective. Scale should be picked to show both lines near the top of the graph.
Do Words Affect How We See Things? (Grade 7, Lesson 1), L15–L16
Students perform an experiment to see how written words can interfere with processing other information. If possible, provide enough stop watches for each pair of students, or one for every four students. The teacher should make a large version of the results table so that the class can combine their data into a larger sample. If there is time, students should discuss the results of both experiments as a class.

Answer Key: Students should decide if there is evidence of a delay in both their chosen experiment and in the experiment they did not choose. Results will vary. Students are likely to find that the position words cause a greater delay than the number words.

Estimating the Unknown, (Grade 7, Lesson 2), L17–L18
Students are guided through making reasonable assumptions to arrive at reasonable estimates of various values.

Answer Key: Accept any reasonable reasoning and estimates. There are no “right answers” to these, just reasonable answers.

How high is the homework pile? Assuming an average of one page per school day and approximately 180 days of school, reasonable estimates should be in the 2 centimeter range.

How many days would it take to walk 1000 miles? Assuming a person could walk about 8 hours each day at a pace of about 3 miles per hour, it would take about 42 days.

Emptying a bathtub: Assuming about 35 gallons in a bathtub, a 16-ounce paper cup, and a cup transfer rate of 10 seconds each, it would take about 45 minutes.

Grains of sand in a teaspoon: Assuming grains average about half a millimeter in length, that a teaspoon is about 5 mL, and that about 20% of any volume of sand is actually air, there are approximately 32,000 grains of sand in a teaspoon.

Water in a lifetime: Assuming 6 to 8 ounce glasses a day and a life span of 80 years, you’d drink about 11,000 gallons of water.

Questions that may help students who are struggling with the additional questions:

• Emptying the bathtub: How much water does a paper cup hold? Can you compare the bathtub to larger containers like pails? How long does it take you to empty one cup of water from the tub?
• Grains of sand: How large is a grain of sand? What would its volume be if it were a cube? What volume is a teaspoon? What percentage of the sand do you think is air?
• Water in a lifetime: How much water do you drink in a day? What is the average life span of a person? How many days is the average life span?
Fractal Patterns, (Grade 7, Lesson 3), L19–L20

Introduces students to the concept of fractals, and has them draw several easy fractals. If time remains, students should try to design their own fractal rules and draw the results.

Answer Key:
1. \( \frac{3}{4} \) is unshaded.
2. \( \frac{9}{16} \) is unshaded
3. \( \frac{27}{64} \) is unshaded
4. The unshaded area is found by multiplying \( \frac{3}{4} \) by itself as many times as there are steps. (For step \( n \), the fraction of area unshaded is \( \left( \frac{3}{4} \right)^n \))

Design a Craft to Explore Europa, (Grade 7, Lesson 4), L21–L22

Students work in groups to design part of a craft to explore Jupiter’s moon Europa. Students then present their technological solutions to the class. Students are also asked to consider the moral implications of exploring a place that may contain new life. As a class, have students discuss the implications of their mission and vote on whether or not to send the craft.

Answer Key: 6,7: Answers will vary, but opinions should be supported with detail.

Xeno’s Paradox, (Grade 8, Lesson 1), L23–L24

Introduces students to the idea that an infinite number of steps can have a finite result, as well as having them analyze a familiar concept (speed) in a new way. Students should work in pairs and discuss their answers. If time permits, have students discuss their results as a class.

Answer Key:
1. Answers will vary. At first sight, Xeno’s reasoning makes sense.
2. Possible answers: Achilles and the turtle run at constant speeds, distance and time can be divided up indefinitely
3. Achilles has moved 10 m.
4. The lines should end up very tightly clustered just before the 20 m mark. Number of lines will be limited by pencil thickness and student patience.
5. 1; 1.5 s \((1\frac{1}{2})\); 1.75 s \((1\frac{3}{4}+14)\); 7th: 1.984375 s \((1\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{32}+\frac{1}{64})\); 8th: 1.9921875 s \((1\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+\frac{1}{32}+\frac{1}{64}+\frac{1}{128})\)
6. The number gets closer and closer to 2 s. It would take him 2 seconds.
7. Answers will vary. Students should realize that adding up an infinite number of terms does not always result in an infinite number, and relate this to Xeno’s paradox in some way.
Interpreting Graphs, (Grade 8, Lesson 2), L25–L26

Students plot data about an experiment and draw conclusions about the limitations of some physical laws. The final graph should look like this:

![Graph](image)

1. Students could describe the formula in several different ways. Verbally: “Every time you double the mass, you double the stretch” or “Every time you add 50 g, the spring stretches another 6 mm.” As a formula: \( \text{stretch} = \text{mass} \times 0.12 \)

2. 60 mm

3. Prediction was off. The actual stretch was greater.

4. The string is stretching more and not returning to its original length. This may be because the force of the large mass on the spring is making it stretch permanently.

5. Between 50 to 300 grams, because after that, the spring will be stretched permanently and the scale will not be accurate.

Which Letters Can Come Next? (Grade 8, Lesson 3), L27–L28

This exercises gives students practice forming and testing hypotheses as they model scientific processes. Rules for different letter sequences are given, and students are stepped through the process with leading questions. At the end, the teacher presents the following sequence of letters: \( z \ Y \ K \ H \). The teacher should write this sequence on the board using only straight lines. When the students reach question 10, they will suggest letters that can follow in the sequence. Any letter that can be written using only straight lines can be in the sequence. Letters with curves and loops cannot. The teacher should write any acceptable letters down as part of the sequence. After most of the class has tried to find a letter, discuss what students think the rule is.
Answer Key:
1. Answers vary.
4. Answers will vary, but should be consistent with selected hypothesis (or new one if original was 3)
5. Yes if chosen letter had different number of loops than x, no if same number of loops.
6. Answer depends on chosen hypothesis.
7. Answers will vary.
8. Answers should be consistent with stated hypothesis.
9. Answer should be consistent with stated hypothesis.
10. Answer will depend on how well hypothesis holds up to testing.

Did Mars Once Have Life? (Grade 8, Lesson 4), L29–L30

Some scientists discovered impressions in an Antarctic asteroid that look like fossilized bacteria. They make a case that these bacteria could have formed on Mars. Students consider evidence both for and against this claim, and draw their own conclusions. If time permits, the strength of the evidence and the likelihood of Mars having once had life can be discussed as a class. Students should be reminded that the scientists presenting the evidence agree that the evidence is not yet conclusive.

Answer Key:
1. Answers will vary, should be based on results of worksheet.
2. Answers will vary. Opinion should be supported by referring to facts or hypotheses presented on the worksheet.
3. Answers will vary. Some further information may include information about other possible Martian asteroids, more information on how ALH84001 was formed, or more information on other asteroids found on the same expedition.
A Deadly Killer Lurks Among Us!

Read the following editorial that appeared in the Nowheresville Gazette and then answer the questions that follow.

Citizens of Nowheresville, it has come to my attention that the Nowheresville Manufacturing Plant is releasing hydrogen hydroxide into our river and into our air. We must band together and insist the company stop using any of this deadly chemical. Hydrogen hydroxide can kill! Last year alone, four people died after accidentally breathing in excess quantities of hydrogen hydroxide while swimming in the river near the manufacturing plant. Our ground, our air, even the food we eat contains varying quantities of this chemical. Did you know that hydrogen hydroxide is a major component of acid rain? Did you know that it was found in pre-cancerous tumors? Ask yourselves—how much hydrogen hydroxide is present in your body right now? Please, help to stop this threat. Sign the petition to ban hydrogen hydroxide and keep your community safe.

1. After reading the editorial, would you sign the petition to ban hydrogen hydroxide? Why or why not?

2. What facts are presented by the editorial? What inferences and conclusions did you make while reading the article? On separate sheet of paper, make a chart that lists the facts in one column, and your inferences and conclusions in another.

3. Would you drink a glass of hydrogen hydroxide?

4. If a doctor told you that your brain is almost 70% hydrogen hydroxide, how would you react?
5. Would you drink a glass of water?_____________________________________________

6. If a doctor told you that your brain is almost 70% water, how would you react?

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

7. Hydrogen hydroxide is another name for water. How does knowing this fact change your answers to questions 1, 3 and 4? Why?

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

8. The facts the editorial presented were all true, assuming four people drowned in Nowheresville last year. Evaluate the inferences and conclusions you formed now that you have new information. How were your inferences and conclusions biased by the selection of facts and the way in which they were presented?

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

9. How did the author use science facts to mislead the readers? Why do you think he did this?

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________
OBSERVING

How Fast Are Your Reflexes?

How fast are your reflexes? Do the following experiment to find out.

1. Carefully cut out the reflex strip at the bottom of the page.

2. Hold the top of the reflex strip in your right hand if you are right-handed, and in your left hand if you are left-handed. The strip should be vertical.

3. Pinch the reflex strip with the thumb and forefinger of your other hand. Separate your thumb and forefinger, but keep them ready to pinch the paper.

4. Move the strip up so that the bottom edge of the strip is just above your thumb and forefinger.

5. Drop the strip and try to catch it by pinching your thumb and forefinger. Practice this a few times until you can catch it consistently.

6. Drop the strip five times, and record the number in the area where you catch it in the table below. You should record the number in the column for the hand that catches the strip. If you catch it between two numbers, write down the larger number.

7. Switch hands, and repeat the experiment.

8. Now have someone else hold and drop the strip while you catch it. Have them drop the strip five times for each hand. Record your results.

Table 1. Reflex Data by Trial

<table>
<thead>
<tr>
<th>Trial</th>
<th>I Drop the Strip</th>
<th>Someone Else Drops the Strip</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right Hand</td>
<td>Left Hand</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REFLEX STRIP:

| 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
ANALYZE

1. In the chart below, count the number of times you had a certain reflex value for each category. If you did not have a particular value, put 0 in that box.

Table 2. Reflex Data by Value

<table>
<thead>
<tr>
<th>Reflex Value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>I dropped strip</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Hand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Hand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Someone else dropped strip</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Hand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Hand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Which reflex value appeared the most when you dropped the strip? When someone else dropped the strip?

__________________________________________________________________________

__________________________________________________________________________

3. Is there a noticeable difference between your right and left hands when you dropped the strip? When someone else dropped the strip?

__________________________________________________________________________

__________________________________________________________________________

4. How would you represent the data in the table above as a graph? On a piece of graph paper, make the graph you feel best represents your data.

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
APPLYING

Design a Way to Water Crops

Suppose you are an early settler in a western town. The town has no electrical plant or running water. You are a farmer. The soil in your area is very dry, and will need extra water if your crops are to grow. There is a river that runs near the town. Can you develop a system for watering your crops?

With a group of three or four other students, discuss your problem and try to design a system for watering your crops. Use the following steps to guide you.

1. Clearly identify the problem. What do you need to design? What must it do? What resources do you have?

2. Brainstorm ideas. Start by writing all ideas down, even if they sound silly.

3. As a team, decide and list which ideas you want to develop further. Focus the rest of your discussion on those ideas.
4. Sketch a picture of your final design.

5. You have successfully designed and constructed the irrigation system for your farm. A neighboring farmer is struggling with his own crops. He comes to beg you for help. Could your system be adapted to supply enough water for both farms? How would you adapt it?
EXAMINING BIAS

Presenting Graphical Data

The two graphs below show how the fish population has changed in two ponds over the period of forty years. Refer to the graphs as you answer the questions.

1. Take a quick look at the two graphs. Which pond had a larger decrease in the fish population? How can you tell? ______________________________________________

2. If someone told you that Pond A and Pond B were the same pond, would you believe them? Why or why not? ________________________________________________

3. How many fish were in Pond A in 1970? _____________________________
   How many fish were in Pond B in 1970? _____________________________

4. How many fish were in Pond A in 2000? _____________________________
   How many fish were in Pond B in 2000? _____________________________

5. What is the real difference between graph A and graph B? Explain how the two different graphs present the same data.
   ____________________________________________________________________
   ____________________________________________________________________

6. You are writing a newspaper story about how pollution kills fish in ponds. Which graph would you use to accompany your article? Why?
   ____________________________________________________________________
   ____________________________________________________________________
The way data is presented can bias the way people think about the data. Graph A and Graph B on the previous page actually presented the same data, but did not give the same impression to someone looking at them. Consider the following scenario, then create two different graphs with the same data used by groups with two different goals.

Suppose there are two disinfectants that claim to kill bacteria. Scientists perform a clinical trial using both disinfectants, and publish the following results:

<table>
<thead>
<tr>
<th></th>
<th>Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Brand A (percentage killed)</td>
<td>65</td>
</tr>
<tr>
<td>Brand B (percentage killed)</td>
<td>62</td>
</tr>
</tbody>
</table>

1. You are an advertising agent for Brand A. You want to convince your viewers that Brand A is better than Brand B. Design a graph using the above data that you can use in your advertisements.

What do you want your graph to emphasize?

What scale could you pick that will give you the emphasis you want?

2. You are a news reporter doing a report on how food poisoning occurs when bacteria is spread throughout home kitchens. Design a graph using the above data that will encourage your readers to use any kind of disinfectant to help prevent food poisoning cases.

What do you want your graph to emphasize?

What scale could you pick that will give you the emphasis you want?
OBSERVING

Do Words Affect How We See Things?

In a certain experiment, people were given words written in different colors, and asked to say what color the word was written in. However, the words themselves were color words. In the first part of the experiment, the colors and the color words matched. In the second half of the experiment, the color words were different colors. The word *red* might be green, or blue, instead of red. It would take most people noticeably longer to list the colors of the words in the second half of the experiment. This delay in identifying the color when the word and color are different is called the Stroop effect.

The following two experiments are variations on the Stroop effect experiment. With a partner, select one of the experiments. Try it on five different classmates, and compare your results with other groups that picked the same experiment.

EXPERIMENT ONE: WORDS AND NUMBERS

1. Take two sheets of paper. On each, draw a box that is divided into 16 squares. One paper will be your first set of words, and the other will be your second set of words.

2. Each set of 16 squares should contain one, two, three, or four copies of the word *one*, *two*, *three*, or *four*. In the first set, the number of words should match the word used. In the second set, the number of words should be different from the word used. For example, some of your squares might look like this:

<table>
<thead>
<tr>
<th>First Set</th>
<th>Second Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>one</td>
<td>two</td>
</tr>
<tr>
<td>three</td>
<td>three</td>
</tr>
<tr>
<td>three</td>
<td>four</td>
</tr>
<tr>
<td></td>
<td>two</td>
</tr>
</tbody>
</table>

3. Show a classmate the first set of words. Have the person tell you as fast as possible how many words are in each square. The person showing the papers should mark down how many boxes the reader gets wrong on the first try. The other partner should time how long it takes the person to finish the task, using the second hand on the classroom clock or a stopwatch.

4. Repeat the experiment with the second set of words.

5. Record this data in the table on the next page.

6. When you have recorded data for five people, copy your results into the main table on the board.
EXPERIMENT TWO: WORDS AND POSITIONS

1. Take two sheets of paper. On each, draw a box that is divided into 16 squares. One paper will be your first set of words, and the other will be your second set of words.

2. Each set of 16 squares should contain the word left, right, top, or bottom. In the first set, the position of the word should match the word. For example, the word left should be on the left side of the box. In the second set, the word should be in a different position. For example, some of your boxes might look like this:

<table>
<thead>
<tr>
<th>First Set</th>
<th>Second Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>left</td>
<td>right</td>
</tr>
<tr>
<td>bottom</td>
<td>top</td>
</tr>
</tbody>
</table>

3. Show a classmate the first set of words. Have the person tell you as fast as possible where the word is located (top, bottom, left, or right) in each square. The person showing the papers should mark down how many boxes the reader gets wrong on the first try. The other partner should time how long it takes the person to finish the task, using the second hand on the classroom clock or a stopwatch.

4. Repeat the experiment with the second set of words.

5. Record this data in the table on the next page.

6. When you have recorded data for five people, copy your results into the main table on the board.

Table 1. Words and ____________

<table>
<thead>
<tr>
<th>Card 1</th>
<th>Card 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Time (s)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Analyze Does the experiment you chose show evidence of the Stroop effect? Does the experiment you did not choose show evidence of the Stroop effect? Explain.
ESTIMATING

Estimating the Unknown

How many middle-school students are there in Chicago?

At first glance, this may seem like an impossible question to answer. However, you can estimate the answer if you make some reasonable assumptions. This type of question is often called a Fermi question, after the physicist Enrico Fermi. Fermi would often ask his students questions like the one above.

The ability to make rough estimates is a valuable skill to scientists. By doing quick estimates, a scientist can narrow the range of possibilities and focus on the most reasonable hypotheses. So how can you estimate the number of middle-school students there are in Chicago?

Read the following steps. If you disagree with any of the estimated numbers, try following the steps using your own numbers.

1. How many people are in Chicago?

   Chicago is a very large city, and its population is probably several million people. Let’s estimate the population is about 3,000,000.

2. How many students are there in Chicago?

   If we assume that the ages of people are evenly distributed, we can estimate the number of students. Students spend about 12 years in school, from about the ages of 6 to 18. The average person lives to be about 80 years old. So we would expect that 12 out of 80 people in Chicago would be in school. If we take \( \frac{12}{80} \) times 3,000,000, we get 450,000 students in Chicago.

3. How many students are in each grade?

   Now we assume that the students are evenly distributed in grades 1 through 12. So the number of students in each grade is 450,000 divided by 12, or 37,500 students.

4. How many middle school students are in Chicago?

   Middle school typically ranges from grade 6 to grade 8. Since there are 37,500 students per grade, we can multiply that number by 3 to get 112,500 middle school students.

We estimate that there are 112,500 middle school students in Chicago.

This is a rough estimate. How close is it? That would be hard to check, but not impossible. For example, in 2002, Chicago public schools reported an enrollment of 437,618 students. Our estimate for step 2 was within 3 percent of that number.
Try to estimate the answers to the following question. Use the questions given in each step as a guide.

1. If you made a pile of all the science homework you do this year, how high would the pile be?
   a. How many pages of homework do you do in a week?
   b. How many school weeks are in a year?
   c. How many pages of science homework do you do a year?
   d. About how high is a 100-page notebook?
   e. How high would your science homework pile be?

2. How many days would it take you to walk 1000 miles?
   a. How long does it take you to walk one mile?
   b. How many hours a day could you realistically walk? Make sure you leave yourself time to eat, sleep, and rest.
   c. How far would you get during a one-day period?
   d. How many days would it take you to walk 1000 miles?

3. On a separate piece of paper, answer one of the following questions three questions, or ask and answer your own.
   a. How long would it take to empty a bathtub with a paper cup?
   b. How many grains of sand would a teaspoon of sand contain?
   c. How much water will you drink in your lifetime?
MODELING

Fractal Patterns

If you look at a fern, it has a certain shape. If you look at one of the large fronds of the fern, it will have a shape similar to the shape of the whole fern. If you look at one of the smaller fronds on the large frond, it too will have a shape similar to the large frond and also to the whole fern. Ferns are a natural example of a type of shape called a fractal. A fractal is a shape where smaller pieces of the shape look very similar to the whole shape. No matter how small a piece you look at, you can see the shape of the whole object. Fractal shapes are found everywhere in nature. For example, you can find fractals in ferns, in clouds, and even in cell structures found in your body. Follow the directions to draw a simple fractal.

STEP 1:
• On a separate piece of blank paper, draw a large equilateral triangle.
• Mark the half-way points on each side.
• Connect the points to form the central triangle.
• Shade in the central triangle. The shaded area is not considered part of your shape.
• Your shape, the basic shape of the fractal, should look like this:

Now you will alter the shape so that each of the three triangles in the basic shape is formed by the basic shape as well.

STEP 2:
• Mark the half-way points for each edge of the white triangles.
• Connect the points for each white triangle to form a central triangle.
• Shade in the central triangle.
• Your shape should now look like this:
**Step 3:** Once again divide all the white triangles into smaller triangles, and fill in the central triangles.

**Step 4:** Continue dividing and filling in triangles until the white triangles are too small to divide any farther.

You have just drawn a fractal called the Sierpinski Triangle. Answer the following questions about the Sierpinski Triangle:

1. For the basic shape, as shown in Step 1, what fraction of the area is unshaded? How can you tell?

2. After Step 2, what fraction of the area is unshaded?

3. After Step 3, what fraction of the area is unshaded?

4. What is the mathematical relationship between the answers to questions 1, 2, and 3? Describe how you would find the unshaded area after any given number of steps.

Another fractal you can draw is called the Koch Snowflake. Start with an equilateral triangle (a). Shade it in (b). Divide each edge into thirds and draw an equilateral triangle on the middle third of each edge (c). Shade those in (d). Keep dividing each edge into thirds and adding an equilateral triangle. The first four steps are show below. Why is it called a snowflake?

a.  
   b.  
   c.  
   d.  

Try to come up with a rule to draw your own fractal pattern, and then draw the fractal.
APPLYING

Design a Craft to Explore Europa

Suppose you are part of a team of scientists that are designing a spacecraft to explore Europa, one of Jupiter’s moons. The ultimate goal of the explorer is to search for life that may exist in the oceans thought to be beneath the ice that covers the surface of Europa. The class will divide up into four teams. Each team will work one of the following problems, and present their solution to the class.

LANDING
Your mission is to design a method of landing that does not break the ice on the surface. The most important task is to make sure the explorer lands without being damaged when it touches down on solid ice. Do you have a back-up plan if the explorer encounters a large crack in the ice?

EXPLORING AND BREAKING THE ICE LAYER
Your mission is to develop tools that can explore the ice. Your colleagues feel that the ice itself may contain life, so your machines must probe the ice carefully. The thickness of the ice layer isn’t known. If the ice is very thick, you will also need to design a tool that could get the explorer through a thick layer of ice and into the Europan ocean below.

MANEUVERING IN THE OCEAN
Your mission is to develop the explorer for moving in the ocean. The explorer must be able to move from place to place in the ocean. You also have to take into account how deep you want the explorer to go, and how currents might affect your explorer.

COLLECTING OCEAN DATA
Your mission is to develop tools that will search for life in the ocean of Europa. Consider how you might detect microscopic life, such as bacteria, as well as how you might detect larger life-forms that might exist.

Once you have chosen your project, develop your ideas as team. Use the following steps to guide you.

1. Clearly identify the problem. What do you need to design? What must it do?
2. Brainstorm ideas. Start by writing all ideas down, even if they sound silly.
3. As a team, decide which ideas you want to develop further. Focus the rest of your discussion on those ideas.
4. Decide how you want to present the ideas to the class.
5. Present your ideas.
Now that you built your explorer to send to Europa, you must decide if you will actually send it. A group of scientists has just contacted your group asking you not to launch the spacecraft. They argue that if there is actually life on Europa, sending spacecraft from Earth could cause serious damage to the Europan environment and possibly even cause mass extinction. Your team plans to take a vote on whether or not to proceed with the mission after hearing their concerns.

6. How would you vote? Why would you vote that way?

7. What are some consequences that would result if the team votes the same way you would vote?

As a class, take a vote on whether or not to proceed with the mission. Discuss the consequences that may result from your decision.
There is a story about a race between the Greek warrior Achilles and a turtle. Achilles could run ten times faster than the turtle, so he offered the turtle a head start. Xeno, an ancient Greek philosopher, argued that if a runner had a head start in a race, the other runner should never be able to catch up. According to Xeno, the turtle should win the race.

Suppose the turtle started ten meters ahead. In the time it took Achilles to run the extra ten meters, the turtle had moved one meter ahead. In the time it took Achilles to run that one extra meter, the turtle had moved one-tenth of a meter ahead. No matter how small the distance between Achilles and the turtle, the turtle would move ahead in the time it took Achilles to run that same distance. Therefore, the turtle would always be ahead, and would win the race.

And yet, in a real race, the faster Achilles would easily pass the turtle to win the race. Where is the problem in Xeno’s reasoning?

Pair up with another student to discuss and answer the following questions.

1. Discuss Xeno’s reasoning. In theory, does there appear to be anything wrong with his reasoning?

2. Write down any assumptions you think Xeno made about motion and speed. Which assumptions do you think are reasonable?
Suppose Achilles were only twice as fast as the turtle. As the diagram above shows, the turtle starts 10 meters ahead of Achilles. When Achilles reaches the 10-meter position, the turtle has moved ahead 5 more meters. These positions are shown by the dashed lines.

3. How far has the turtle moved when Achilles has run to the turtle’s second position (15 meters)? _________________________________ Draw lines to show the new positions.

4. Continue drawing lines showing the positions of Achilles and the turtle when Achilles reaches the turtle’s former position. What happens as you approach the 20-meter position?

5. Suppose Achilles runs 10 meters every second. How long would it take him to run to the first position? The second? The third? How long would it take Achilles to reach the seventh and eighth positions?

6. If you continue to add the time intervals as you did in question five, how long would it take Achilles to run the full 20 meters? (Hint: Will the time intervals add up forever, or do they reach a limit?)

7. Do you think the answer to question 6 is related to the apparent contradiction in Xeno’s paradox? Why or why not?
ANALYZING DATA

**Interpreting Graphs**

A group of students hung different masses from a spring and measured how much the spring stretched. They then removed the mass, and measured how much the spring had changed from its original length. They recorded their data in the following table.

**Table 1. Change in Spring**

<table>
<thead>
<tr>
<th>Stretch and Change in Length</th>
<th>Mass (g)</th>
<th>50</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>350</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount stretched - mass on (mm)</td>
<td></td>
<td>6</td>
<td>12</td>
<td>18</td>
<td>24</td>
<td>30</td>
<td>36</td>
<td>42</td>
</tr>
<tr>
<td>Change in length - mass off (mm)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Plot the data in the graph below. Use one color for the amount stretched, and another color for the change in length. With the same color pencils, draw lines connecting the data points. Fill in the key with the colors you have used to plot and draw the lines.

**Figure 1. Change in Spring**

**KEY**

- Amount stretched — mass on:
- Change in Length — mass off:
Answer the following questions based on your graph.

1. Write a mathematical formula that describes how to find the amount the spring will stretch when a certain mass is attached to the bottom of the spring.

2. What does your formula predict the amount of stretch will be if a 500 g mass is attached to the bottom of the spring? Mark this point on your graph.

The students continue the experiment, and make a table of their new data.

<table>
<thead>
<tr>
<th>Mass (g)</th>
<th>400</th>
<th>450</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount stretched — mass on (mm)</td>
<td>49</td>
<td>57.2</td>
<td>67.2</td>
</tr>
<tr>
<td>Change in length — mass off (mm)</td>
<td>1</td>
<td>2</td>
<td>3.5</td>
</tr>
</tbody>
</table>

3. Plot this new data. How did your prediction compare with the data? Over what range of masses can you use your formula?

4. What do you think is happening to the spring in the second part of the experiment? Why do you think this is happening?

5. If you were to make a spring scale using an identical spring, what range of masses would you recommend your scale be used for? Why?
FORMING HYPOTHESES

Which Letters Can Come Next?

Suppose you have a sequence of letters that follow a simple rule. For example, you might have the following string of letters:

\[ A \ b \ C \ d \ E \ f \]

By observing the sequence, you could form several hypotheses about the rule that is being used. Here are three sample hypotheses:

- Hypothesis 1: The letters must alternate between uppercase and lowercase.
- Hypothesis 2: The letters must be in alphabetical order.
- Hypothesis 3: The letters must follow the order of the alphabet, and also alternate between uppercase and lowercase.

Each hypothesis enables you to predict if another letter can be next in the sequence. Suppose you want to predict whether or not the letter \( D \) can be added to the end of the current sequence. Each hypothesis gives a specific prediction:

- Prediction based on Hypothesis 1: Yes, \( D \) is uppercase, so it can come next.
- Prediction based on Hypothesis 2: No, \( D \) cannot come next because the sequence would not be in alphabetical order.
- Prediction based on Hypothesis 3: No, \( D \) cannot come next because the sequence would not be in alphabetical order.

Now suppose the person who made the rule tells you that \( D \) can follow the sequence. This new data would rule out Hypotheses 2 and 3. Does this mean that Hypothesis 1 is the correct rule? Possibly. But you would have to continually test the predictions it makes against the observations. If the hypothesis held for a long period of time, you would be pretty certain you had figured out the rule. But you could never be absolutely sure (unless you were told what the rule was). In this way, the sequence game models the process scientists use when developing theories.

Consider the following letter sequence, and some hypotheses about the rule the sequence follows, then answer the questions.

\[ A \ B \ w \ D \ E \ g \]

- Hypothesis 1: Capital letters must be in alphabetical order.
- Hypothesis 2: Each letter must have a different number of closed loops than the letter before it.
- Hypothesis 3: A lowercase letter must follow two capital letters.

1. Which hypothesis do you want to test?

2. You are considering whether or not the letter \( x \) can come next in the sequence. What is your prediction, based on your chosen hypothesis?
3. You find out that the letter $x$ can come next. Does this fact support or rule out your hypothesis?

4. Write a letter you think can come after $x$ in the sequence.

5. The actual rule is that the letters must have a different number of closed loops than the last letter. Could your letter have actually come next?

6. If you did not know the rule, but did know if your letter could have come next or not, would your prediction have supported your hypothesis?

Consider the following sequence:

$z \ Y \ l \ K \ H$

7. Form a hypothesis about what the rule for the sequence is.

8. Based on your hypothesis, circle any of the following letters you predict can come next:

$C \ O \ o \ w \ W \ M \ N \ A \ a$

9. You are told the next letter in the sequence could be $F$. Does this fact support your hypothesis? __________________________________________________

10. As a class, suggest letters to your teacher that can come next. As the sequence grows, see if you can figure out what the rule is. Would you change your answer to question 5? __________________________________________________

11. Make up a simple rule, and write down a sequence of five letters that follow that rule. Ask a classmate to hypothesis about the rule and to predict if letters you select can be next in the sequence. See how long the sequence gets before your classmate’s predictions are accurate for four turns in a row. Does your classmate’s final hypothesis match your rule? Now switch places and form hypotheses and predictions about your classmate’s sequence. Did your final hypothesis match your classmate’s rule?
DRAWING CONCLUSIONS

Did Mars Once Have Life?

In 1984, a scientific expedition collected meteorites from Antarctica. One of these meteorites, labeled ALH84001, appeared to be from the planet Mars. The team studying this meteorite found some bacteria-like impressions that they thought might be fossils of Martian bacteria.

The evidence for the impressions being fossilized Martian bacteria was far from being conclusive. The scientists studying ALH84001 suggested that, while there were other possible explanations for what they saw, fossilized life was the most likely explanation.

On the next page are the arguments used to suggest the asteroid contained Martian fossils, as well as arguments for other explanations of the observations. Read through each side of the issue. After reading both sides, decide what you think about that particular issue, and record it in the blank column. After you have completed the table, answer the questions.

1. Did you agree more with the arguments for the impressions being Martian fossils, or did you agree more with the arguments against the impressions being Martian fossils?

2. Suppose a team of scientists your company to fund an expedition to Antarctica to search for more meteorites that may contain Martian fossils. It is your job to make a recommendation to the committee—should they fund this expedition? Write a brief paragraph that explains what recommendation you would make, and why.

3. Do you think there is strong evidence that Mars once had life? What other information would you like to have about ALH84001 that might help you decide?
### Arguments for Fossils

**Is ALH84001 from Mars?**
- We know the composition of the Martian atmosphere because of data from the Viking Lander. Gas bubbles found in ALH84001 have the same composition as the Martian atmosphere.

**Mars was once a volcanic planet, and ALH84001 was originally formed from a volcano.**

### Arguments Against Fossils

- It's almost certain that ALH84001 is not native to Earth. We cannot rule out, however, that it may be from an asteroid. It's possible an asteroid has a similar gas composition, although no asteroids like that have yet been found.

- Volcanoes are not unique to Mars, but exist or existed on Venus, Earth, and Io as well.

### What Do You Think?

#### Did ALH84001 ever contact liquid water on Mars?
- The carbonate globules found on the meteorite’s crust could have been deposited in the rock by liquid water. While Mars does not have liquid water now, it most likely had liquid water at the time the globules formed.

- There is no other evidence of water-deposited minerals like clay or rust found in the meteorite. Also, carbonate globules can grow without water at very high temperatures. Life almost certainly could not exist at such temperatures.

#### Does ALH84001 contain fossils of Martian bacteria?
- There are impressions in the meteorite’s carbonate that look like bacteria.

<table>
<thead>
<tr>
<th>structure found in ALH84001</th>
<th>bacteria fragment from Earth rock</th>
</tr>
</thead>
</table>

- Most bacteria found on Earth are a hundred times larger than the size of those in the meteorite. Also, there are inorganic ways of producing the same shapes.

- Preparing samples for an electron microscope can produce shapes similar to those seen in ALH849001.

- The other meteorites did not contain carbonate globules. Earth bacteria might not grow in meteorites without carbonate.

<table>
<thead>
<tr>
<th>The shapes do not appear when we prepare samples that do not contain the carbonate.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Other meteorites from Antarctica do not contain these shapes, so it is unlikely they are due to contamination by Earth bacteria.</th>
</tr>
</thead>
</table>