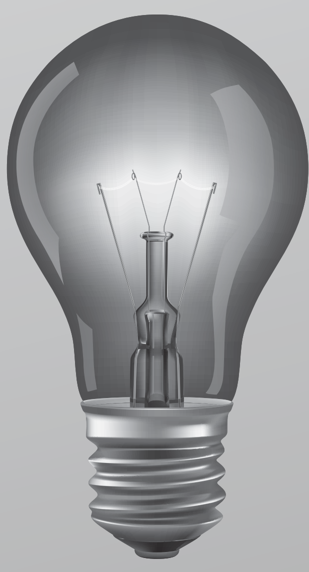
Learning and Teaching Scientific Inquiry: Research and Applications

Solutions Manual



Chapter 2: The Role of Models in Science

2.2 Scientific Inquiry Is Model-Making

Applying the Concept of a Model

1. A map of the United States is a human creation. There are multiple maps that you can make to represent the United States, and there is not one single map that can represent all structures and formations of the United States. It is useful for helping you understand entities such as the shape of the United States, the shape and location of individual states, and various rivers and mountain ranges.
2. Physical models: Mannequins in clothing stores show what clothing items would look like when worn. In restaurants, there are pictures of foods, or even plastic models of meals to show you the food you may order. On computer desktops, there are trash cans or recycling bin images that represent where you can put files in order to delete them. Abstract model: blueprints for a building
3. All scientific models must be able to explain and predict natural phenomena.
4. No model is absolutely correct. Some models are closer to reality than others, but by definition, a model is never completely correct or incorrect; it just represents something else. A model, by definition, should help us understand and predict natural phenomena.
5. A fashion model is not a good example of a scientific model because fashion models do not represent typical people. A scientific model represents reality as close as possible; so, for a fashion model to be like a science model, typical people would be employed as fashion models, not those who currently work as models. The meaning of the word *model* in *fashion models* is not the same meaning as the word when used in science.
6. Questions regarding models of the solar system:
    a. For the geocentric (Earth-centered) model, draw a solar system where the Earth is the center of the system and the Sun, planets, and stars circle around the Earth. For the heliocentric (Sun-centered) model, draw a solar system where the Sun is at the center and the planets and stars circle around the Sun.
    b. In both cases, the models are helpful in understanding what the solar system looks like and how the planets are positioned and move in space. However, both models have limitations. Both represent the solar system as two-dimensional, when, in fact, it is three-dimensional. The models also do not explain why the planets are moving in space.
    c. The heliocentric model is not better than the geocentric model even though it is more correct, because the heliocentric model is more complex and harder to understand. Sometimes it is easier to use a geocentric model in order to understand certain phenomena, such as the Sun rising and setting.

However, if you were planning on flying to the Moon, then the heliocentric model would be the better of the two models to use. A model is not judged by how accurate it is; it is judged by how useful it is.

7. This model could be useful to explain how lightbulbs work. However, just as with any model, it has some limitations. The "Dark Sucker" model does not explain how light reflects off mirrors or why we can see the Moon when it is in a dark sky. Scientists have more useful models for how lightbulbs work, which account for these limitations. This model could be useful, but it not the one that is used because of its limitations.

Chapter 3: Scientific Models and Conceptual Change

3.3 Fostering Changes in Students' Models

Practicing Generating Alternative Scientific Explanations

Explanations may vary, but some are provided here.

1. Putting fluoride in the water actually does not prevent tooth decay. People's changes in diet have caused tooth decay to decrease. Better brushing and flossing habits or more frequent visits to the dentist cause tooth decay rates to decline.
2. Early on, the weak plates would tend to break more quickly, so the ones that you would still own would be the stronger plates. Because these would be the only plates remaining, fewer plates would break as time goes on. People would learn to be more careful, because they would not want to break their plates. So, fewer plates would break as time goes on.
3. The more education the parents received, the more they are motivated to help their children do well in school. The more education the parents received, the better they are able to help their children do well in school. The more education the parents received, the more likely they are to have a good job and be able to send their children to good schools.
4. Humans have a circadian clock in their brain that tells them what time to wake up. People wake up constantly in the morning, check the clock, and fall back asleep. They then wake up when it is time to get up without remembering that they had been checking the clock.
5. Arthritis tends to vary in severity in most people. She may be in a period of time when her arthritis is not as severe. She truly believes that the magnets are working, so she has convinced herself that the magnets are helping her arthritis.
6. There are a lot more people in the water now than in the past, so shark attacks are more common, because there are more people to attack. Sharks do not have as much

fish to eat as they used to, so they are trying harder to find things to eat and attacking more people.

The following alternative hypotheses are not the only ones that can be given for each scenario.

7. If people are already obese, then they probably do not like to exercise, and instead they like to sit around watching television. Television does not cause obesity; obesity causes people to want to sit around.
8. Pepper is supported by the surface tension of the water.
9. Acetylsalicylic acid (aspirin) is not harmful unless you take too much. It is helpful if you do not take it too often.
10. People who develop Alzheimer's disease have the disease already working in their bodies. Therefore, practicing language skills will not help in preventing the disease.

The following explanations are not the only ones that can be given for each observation.

11. Fish eggs get stuck to the bottoms of water birds' feet. Then the eggs are deposited as the birds fly from lake to lake. Also, turtles could drag aquatic plants behind them as they travel from lake the lake, introducing the plant to another lake.
12. Lice do not like to feed on sick people. If you are sick, the illness harms or kills the lice, so they tend to accumulate on healthy people.
13. In a cup of vegetable oil, an ice cube sinks to the bottom. As the water melts from the ice cube, it also sinks to the bottom, because water is denser than vegetable oil. The ice cube is now surrounded by the cold melted water, which causes it to melt more slowly. In a cup of water, the melted water from the ice cube sinks to the bottom, because cold water is denser than warm water. Therefore, an ice cube in a cup of water is surrounded by warmer water, which causes it to melt faster.
14. Water and rubbing alcohol are made of molecules that are different sizes. The rubbing alcohol molecules are smaller than the water molecules and could fit in the spaces between the water molecules. The molecules can fit together more tightly, therefore causing 50 ml of water and 50 ml of rubbing alcohol to equal 97 ml.

3.4 Criteria for Good Scientific Explanations

Checking Your Understanding of Criteria for Good Scientific Explanations

1. If a scientific explanation does not have the words *why* and *how*, then the underlying scientific model cannot be tested, and the explanation is worthless.
2. The scientific explanation must stem from scientific models and must be in agreement with the model.
3. Both explanations state the same claim but in different words.

Chapter 4: Evaluating Variables, Explanations, and Models

4.2 Scientific Tests and Investigations Must Be Fair

Practicing for Identifying Whether Scientific Tests and Investigations Are Fair

1. This test is unfair. There are many other variables that should be considered, such as
    - diet and food intake,
    - differences in genetics,
    - predisposition to cavities, and
    - controlled frequency and method of brushing.

    To make this test fair, you will need to randomly select a lot of people, divide them, and test over a period longer than one year.
2. This test is fair because you are testing what you wanted to test. The point is not to see who is more likely to eat the most hot dogs; the point is to see who can eat more. So, this is fair provided that neither person is feeling ill, just ate dinner, etc.
3. If the students really wanted to see who the better speller was, they should both take the same test. It could be a second-grade test, a sixth-grade test, or any other test, but the test would have to be the same. Otherwise you are just testing who is the better speller for the age group, not who is the better speller overall.
4. This is a fair test because you are testing what you are intending to test, even if the outcome could be predicted. It would be an unfair test if one of them was frightened before the test or had to exercise immediately prior to the test.
5. The sample is limited to elderly people who have already arrived at the mall and may have done so using public transportation. This sample does not necessarily include persons who are "stuck" at home because of the unavailability of public transportation. This situation could be addressed by polling people in their home (e.g., phone polls). If possible, it would be helpful to compare the usage rates of the elderly using public transportation before and after cuts are made.
6. This test is unfair because the same washing machine should be used, the shirts should be soiled similarly, and the time between soiling the shirts and washing the shirts should be the same. To make this test fair, increase the sample size and control the variables above.
7. This test is unfair because the climates, soils, and average amount of rainfall in Minnesota and Texas are very different. To make this a fair test, the class should vary only the amount of sunlight the plants receive. This means that the test would need to be done in one location in order to control all other variables.
8. This test is unfair since children will have been engaging in various levels of activity while on recess break. Some will have been running, which would cause a high pulse rate, and others will have been doing more leisurely activities that do not affect the

pulse rate as much. A better method would be to check the pulse rates of the children after they have all done a similar activity, such as reading a book.

9. This test is unfair because robins and blue jays may not like the same food. The food that was put into the bird feeder may be more attractive to one kind of bird, which will skew the results. Also, if either type of bird is territorial, the results will be further skewed.
10. This test is unfair because the class is comparing two different plant species. To make this a fair test, the students must compare the growth of only one plant species. They cannot vary both the fertilizer and the type of plant. However, to truly test the effect of fertilizer on plant growth, students must do many replicates for many different seed types. Otherwise, they will only be testing the effect of fertilizer on the growth of the seed type being used.

    Thus, a good solution would be to instruct each group of students to plant several sets of plants. A set would consist of two pots containing the same plant type, one with fertilizer and one without. At the end of the growing period, compile all data from the classroom so that several plant types can be compared in order to draw a fair conclusion.
11. This test is unfair for a few reasons. Here are some things to consider to make it fair:
    - Sugar is not the only thing being dissolved in the gum as it is being chewed. For instance, flavoring is likely water-soluble. Perhaps one could assume that flavoring would be similar for the same brand. Hence, if one compared sugared and sugarless gum from the same kind of gum, then this problem would be addressed to a degree.
    - After chewing the gum, the gum will be wet with saliva, which could cause the weights after chewing to be in error by being "high" because they are wet. A way to address this would be to chew the gum for a short time—say, 10 seconds—take it out and then weigh it. This would be the mass before chewing, but would reflect the added weight of the saliva. Then the gum could be chewed for 10 minutes and reweighed. Hopefully, the wetness in both weights is fairly comparable.
12. The most important factors to consider are the following: Before the test, check that each soil type has the same degree of dryness. Each soil type should be compacted an equal amount in the coffee filters. Each soil sample should be given the same amount of time for water to soak. The same amount of soil should be used for each test so that the water has the same distance to travel through the soil into the pie pan. The water also must have the same opportunity to drain through all cans, so the number and size of the holes in the cans should all be the same.
13. The problem with this test is that although the test asks what type of soil is best for growing plants, only bean seeds are tested. Therefore, the results of this test would indicate which type of soil is best for growing bean plants, not just plants in general. Either the question or the method must be revised to produce a fair test.

4.3 Important Variables

Practice With Identifying Important Variables

1. Questions regarding model cars and ramps:
   a. The most important variables are aerodynamics of the car, mass of the car, and size of wheels.
   b. The most important variables are the angle of the ramp, the material of the ramp (smoothness), and the length of the ramp.
2. The most important variables to consider are seed type, location (e.g., near lots of people or near predators), and size of feeder.
3. The five most important variables are the amount of sunlight (temperature), surface area of puddle, type of surface the puddle is on (e.g., blacktop will heat up faster than cement), air currents, and volume of puddle.
4. The most important variables are the voltage of battery, the thickness of wire, the amount of times the wire wraps around the nail, the length of nail, the thickness of nail, and the material of the nail. A few unimportant variables are the brand of battery, color of wire, and time of day.
5. Consider the size of the population, percent of population that drives cars, number of manufacturing companies in the city, etc.
6. A few important variables that determine the likelihood of rain are moisture level, atmospheric pressure, and temperature.
7. The variables that determine whether an object will float are the mass, volume, and surface area of the object touching the water.
8. A few variables that determine the likelihood of catching a fish are the population of fish in the body of water, availability of natural food source, type of lure used, noise around fishing area, and time spent fishing.
9. Some important variables are time spent in the sun, amount of exercise completed, amount and intensity of sunshine, amount and intensity of wind, outside temperature, and humidity.
10. Time spent in the sun, amount of exercise completed, the amount and intensity of sunshine, the amount and intensity of wind, and outside temperature are all important factors in how cold you feel.
11. Some factors to consider are the amount of rainfall, makeup of soil, steepness of hill, and the amount of exposed hill.
12. Speed of water (i.e., flow rate), size of silt particles, width of the river's mouth, and debris in the water (e.g., rocks or dead trees) all determine how much silt collects.
13. Light attracts beetles, as is determined from Tests 3 and 4 in which wetness and dryness are controlled, and the majority of the beetles head toward the light. Beetles prefer dryness as well, because if you compare Test 1 with Test 2, the only variable that changed is the location of the light. If beetles liked wet and dry the same, the distribution of beetles in Test 2 would not be even. Because fewer beetles are attracted

to the light when compared to Test 1, the only plausible explanation is that beetles do not like moisture.

14. Some important variables are the size of the hole in the balloon, the amount of air in the balloon (i.e., size of balloon), the weight of the metal strips, and the material making up the balloon.
15. The most important variables are the amount of air in the balloon and the amount of friction between the straw and the string.
16. A few important variables are the amount of sand and pebbles in the cup, how dirty the water is to begin with, what is in the water (tiny particles will not filter as easily as twigs and rocks), and the width of the holes in the cup. To make the water cleaner, use more sand and pebbles, put other materials in the cup (silt, soil, etc.), and filter multiple times.

4.4 Controlling Variables

Practice With Controlling Variables

1. Controlling variables in the classroom:
   a. How the slope of a ramp affects the distance a ball rolls:
      i. Must be controlled. Factors such as size, composition, and weight may affect how the ball rolls. The students are not testing these factors; they are only testing the slope of the ramp. Thus these important variables must be controlled.
      ii. Must be controlled. The composition of the ramp (e.g., felt, wood, etc.) will affect how the ball rolls. Since the students are not focusing on this variable, it must be controlled.
      iii. Must be varied. This is the independent variable that the students are testing.
      iv. Must be controlled. The point at which the ball is released will affect how far the ball rolls. Since the students are not focusing on this variable, it must be controlled.
      v. Not controlled. As long as the surface of the floor is of a homogenous composition and slope gradient, the ball must be allowed to roll as far as it can. This is the dependent variable that the students are testing. If the ball's rolling distance is limited, this will not be a very fair or thorough test.
   b. None of these (i–iv) need to be controlled. Because the question is whether a ball's rolling distance is affected by a ramp's slope angle, the ball and ramp composition for all the groups do not need to be controlled. As long as each group follows the rules in the solution to Problem 1. a. (above) and keeps the necessary important variables constant throughout the test, these variables do not need to be the same for the entire class.

2. This is an unfair test because the thickness of the materials is not controlled. The different thicknesses of materials (e.g., plastic wrap vs. a clip board) can make a big difference for this test. Thus it will be difficult to determine whether the results are due to the material type or the thickness of the material.
3. The first test is not truly testing whether the weight of the clay is an important variable, because these students are changing too many variables. The students are not testing clay, and they are changing the density of the object tested. This is an unfair test.

   The second test will prove that weight does not make a difference. These students controlled the weight but will discover that the clay will float when the shape is changed. This is a fair test.

   The third test will also show that weight does not matter because lumps of clay, no matter the weight, will sink—unless the students test pieces of clay so tiny that they are supported by the surface tension of the water. As long as students do not test tiny pieces of clay, this is also a fair test.
4. This test does not test one variable at a time. If the students want to test how weight affects the height of a ball's bounces, they should use balls of different weights but of the same circumference. If the students want to test to how the circumference affects the height of a ball's bounces, they should use balls of different circumferences but all of the same weight.
5. Important variables to consider are the type and size of tree, the number of leaves covered, the size of the bags, the amount of time that the trees are covered, and the amount of sunlight the trees receive.
6. Ensure that each sample is an equal amount (e.g., one gram samples) and that each sample has an equal contact area with the brown paper. To ensure equal contact area, the food may need to be mashed up and spread in an even layer over the paper.

4.5 Testing Variables by Observation

Practice for Testing Variables by Observation

The purpose of this section is to help students figure out how to carefully design tests. The solution to Problem 4 describes in detail a possible testing plan for the problem presented, and a reference is given for a detailed testing plan for Problem 9. The remainder of the solutions simply provides the important variables that students should find are relevant after careful and thorough testing. In general, while planning their tests, students should remember to always test the extremes, to control all variables except for the one being tested, and that if the results are close, to run the test again to ensure an accurate conclusion. Careful execution of the test according to these methods should lead to students' successfully isolating only the relevant variables.

1. Pulling the plant out of the dirt is out of place. Putting buckets over the top of the plant is redundant (it is the same as the plant not getting any Sun) and also out of place. Getting too dry is redundant (it is the same as the amount of water used). The plants' need for gravity is too hard to test.
2. Some of the important variables to consider are the shape of the boat, the density of the liquid, and the weight in the boat.
3. Some important variables to consider are the tightness of the band, the width of the band, and the length of band.
4. The most important variables are surface area of the effervescent tablet (crushed up) and temperature of water. To find these significant variables, students should first make a list of variables to be tested and rate them using a system such as the "ROUT" method. Students should follow all guidelines for fair testing presented in Section 4.6. For the variables being tested, students should remember to always test the extremes. For example, they should greatly vary the amount of water used (e.g., a small cup vs. a large bucket) and the temperature of the water (e.g., very warm vs. very cold) in order to produce the most obvious differences possible. Appropriate precautions must be taken to ensure that only one factor is being varied. Therefore, if ice is used to create very cold water, all ice cubes must be removed before the tablets are dissolved so that the tablet is submerged in pure water every time.

   It is interesting to note that in this test the amount of water may seem to be relevant, but the amount of water is actually irrelevant unless the amount of water is absurdly small. For example, the difference between using one bucket of water and using one glass of water is negligible, but the difference between using one glass of water and one drop of water is quite noticeable.

   It is also noteworthy that the number of tablets already dissolved in the water is not a relevant variable. After a certain amount of tests, it seems that the more tablets are dissolved, the slower the rate at which they dissolve. However, this slower rate is actually due to the fact that as each tablet dissolves, it slightly cools the temperature of the water. Therefore, if the rate is slowing, it is due not to the number of tablets or the concentration of the water, but instead to the temperature of the water. If students prematurely conclude that the number of tablets is a relevant variable, encourage them to touch the water. They will find that it is quite a bit colder than it was when they began the test. Students may believe that they are testing the number of tablets that are dissolved, but if they dissolve the tablets in quick succession, they are not holding the temperature of the water constant, and are thus testing more than one variable at a time.
5. The main variables to consider are the temperature of the water, the concentration of sugar in the water, and how or if the water is being stirred.
6. The main variables to consider are the temperature of the water, the concentration of salt in the water, and how or if the water is being stirred.

7. The main variable that will affect how much time the canister takes to fall is the height from which the canister is being dropped.
8. The most important variables are the shape of object and whether the object is hollow or solid.
9. The only variable that affects whether the cans will sink or float is the presence of sugar. A sugared drink will sink, while a sugar-free drink will float. Students should test variables such as brand, color, and caffeine levels. For a complete description of a possible testing method, see the solution to Problem 11 from Section 5.4.
10. Important variables are whether it is windy, how far apart the people are from each other, how loudly the subjects are speaking, and whether they are facing each other.
11. After careful testing, the students will find that the important variables are the type and size of plant, number of leaves covered, size of bags, amount of time that the plants are covered, and the amount of sunlight the plants receive.
12. The important variables are the voltage of the batteries, the type of lightbulb, and the type of circuit (e.g., series or parallel).
13. The most important variables are the steepness of the "hillside," the initial saturation level of the soil, the soil compactness, how hard the water falls, the height from which it falls, the type of soil (i.e., how porous it is), and the amount of debris (e.g., plant matter) in the soil.
14. The only important variable that will affect the speed of the wave is the medium—in this case determined by how tightly the Slinky is being stretched and the material of which the Slinky is made.
15. The most important variables are the temperature of the water and how much the solution is stirred.
16. The important variables to consider are how heavy the object is, how strong the magnet is, and, most important, whether the object is magnetic.
17. The most relevant variable in this test is how much water is in the bottle.

4.6 Testing Variables by Collecting Data

Practice Problems for Testing Variables by Collecting Data

1. Factors that affect how quickly hot water cools off:
    a. In this test, the color did not seem to have an effect on the data. However, the presence of a lid did have an effect.
    b. If the student ran a test with a painted can with a lid, the data would likely follow the same trend as that of the test with a lid and without paint (signified by the diamonds on the Figure 4.14 [p. 75]). This is because the lid is a significant variable and paint is not.
2. After carefully testing, students will find that the length of the string matters a lot and angle of release matters only a little bit. Weight is not a relevant variable. If students find that varying the weight of the bob changes the period, they may have actually

changed the length, either because the greater weight is longer than the smaller weight or because the greater weight stretched the string.

3. Assuming that the marble is simply released and not pushed, the height of the starting point of marble, the mass of marble, the mass of the cup, and the amount of friction between the cup and the ramp all affect how far the cup will travel.
4. The variables that could be tested are the total amount of weight on the meterstick, the distance between fulcrum and the first cup, and the distance between fulcrum and the second cup. The only way to fairly answer this problem is to move the cups along the meterstick and to keep the fulcrum stationary, not to move the fulcrum.
5. The variables that affect how far the ruler bends are the amount of weight hanging from the ruler and the distance between the table and the end of the ruler.

   For the pasta test, the variable that must be added to the list above is the thickness of the pasta. This means that if students are varying the main ingredient of the pasta (e.g., rice, whole wheat, white, corn), they must ensure that they are keeping the thickness of the pasta constant. While the main ingredient makes a small difference, the larger consideration should be the thickness of the pasta.
6. The most important variables that will affect how quickly the water's temperature increases are the amount of water in the container, the distance between the light source and the water, the intensity of the light source, the depth and surface area of the water, and possibly the color of the container.
7. The variables that have the greatest effect on the distance that the water will squirt are the amount of water in the bottle and the height of the hole above the floor.
8. The important variables to consider are how heavy the object is, how strong the magnet is, and, most important, whether the object is magnetic.
9. Some of the variables that affect pulse rate are recent physical activity and recently being frightened.
10. The important variables include how much weight you are pulling and the smoothness of the surface.
11. The important variables include how much weight you are pulling, the smoothness of the surface, and the steepness of the incline.

Chapter 5: Designing Scientific Tests and Investigations

5.2 Strategies for Testing Models and Explanations

Practice Problems for Testing Models and Explanations

1. Statements about why it is hotter in the summer than the winter:
   a. Supports the idea
   b. Goes against the idea

   c. Is not relevant to the idea
   d. Goes against the idea
2. His test provided evidence that supported his model. By putting a hole in the bottle, the student allowed the air to escape so the balloon could expand.
3. To test the given explanation, dig numerous wells at different depths and check to see if the water gets cleaner and purer the further down it travels. If water does get purer and cleaner, then this explanation is supported.
4. Water moving through a plant:
   a. This test is consistent with the model. Water travels up the xylem, causing the leaves to turn the same color as the water.
   b. Tests for the teacher's model of water transport:
      i. This is not a good test, because vertical slits would not affect the xylem. The water can still go up and down the tubes. If the petals become colored, this test would show that xylem do indeed run vertically up the stem.
      ii. This would be a good test, because the horizontal slits would not allow water to flow up to the leaves. Therefore, the leaves would not change color.
5. Choice (d) is the best test, because to evaluate a hypothesis, data must be collected on a comparison group as well (in this case, people with nonblond hair).
6. Choice (c) is the best method, because it is the only method that would have an effect on the air pressure inside the bottle. To test an explanation concerning air pressure, students must find a way to vary the air pressure or else their tests will not be relevant to the topic.
7. Choice (c) is the best method. Choice (a) is not a good test, because the subjects are already bald, and there is no control group. Choice (b) is not a good test because there is no control group. Choice (d) is not a good test, because it is unfair to compare men who are balding with men who are not.
8. To test choice (a), change the amount of liquid in each of the glasses and compare the results. Be sure to use extremes (i.e., very little liquid and a lot of liquid).

   To test choice (b), put liquids with very different densities (e.g., corn syrup and isopropyl alcohol) in the glasses and compare the results.

   To test choice (c), tap the glass with various-size objects and compare the results. Again, utilize extremes (i.e., very small objects and very large objects) to produce the most noticeable differences.

   Remember to keep all other variables constant except for the one being tested. After completing these tests, it will become clear that the pitch depends of the amount of liquid in the glass.
9. The student should expect to find the exposed apple half shriveled and the contained apple half not shriveled. The contained apple half will not lose any moisture, because the air in the plastic bag is already saturated due to the presence of the wet paper

towel. If the student repeated the test without the wet paper towel, he would likely find water droplets on the inside of the bag.

10. Choice (a) and choice (b) are not fair tests, because in each case you do not know if the roots are found in the other areas. For example, if you only dig up plants in dry, sandy soil and examine the roots, you do not know if you could potentially find those root systems in the moist, rich soil. Choices (a) and (b) are not complete tests.

    Choice (c) is the best option, because both soil types are being examined.

11. Balancing your body:
    a. If the center of gravity appears to be over the balls of the feet, this test supports the explanation.
    b. This test can be used to support the explanation, because most will fall over since the center of gravity is not directly over the part of the body that is supporting weight.
12. Soap bubble set up on a wand:
    a. To test the effects of wind, compare the small bubble, open air and the small bubble, dry beaker or the large bubble, open air and the large bubble, dry beaker. The size of the bubble examined is irrelevant—as long as it is controlled—since this is not the variable that is being tested.
    b. Compare the small bubble, dry beaker and the small bubble, wet beaker or the large bubble, dry beaker and the large bubble, wet beaker. The size of the bubble examined is irrelevant—as long as it is controlled—since this is not the variable that is being tested.

5.3 Putting Testing Strategies Into Practice

Practice Problems on Strategies for Testing Models and Explanations

There are many ways to test the following practice problems. The following solutions mention a few possible ways to test the explanation or model presented.

1. The key to testing the explanation is to make one change in the test while keeping all other steps the exactly the same so that only one variable changes at a time.

    One way to test this explanation is to not put the bottle in the freezer but execute the rest of the test in the same way. This test causes a much smaller temperature change than that of the original test. The small change may or may not be enough to cause the same effect as the original method. If the dime does bounce up and down, then the effect is not due to temperature and the resultant expansion; the given explanation is not a good one. However, if the dime does bounce, then the bouncing is most likely due to the dramatic temperature change and the expansion of the air.

    Another option is to not put your hands around the sides of the bottle. Again, this will produce a much smaller and slower temperature change. (See above.)

A third way to test this explanation is to position the dime so that it does not completely seal the bottle. If the explanation is correct, the dime should not bounce up and down at all, because the air that is expanding will escape from the hole at the top of the bottle.

Students should discover that the dime does not bounce in any of the modified tests. Thus, much support is found for the given explanation.

2. If the water coming out of the spout is obstructed by air coming out of the spout at the same time, then a straw that reaches from the air pocket at the top of the upside-down bottle to the mouth of the bottle will allow air to escape while the water flows out the mouth. Construct such a straw and observe the flow of the water. If properly constructed, the water will not "glug" out but flow in a steady stream. Thus, the test provides strong evidence that supports the explanation. Other methods of allowing air to escape, such as making a large hole in the bottom of the bottle before flipping it, will also support the explanation.
3. To test this model, change the shape and size of the hanger and compare the results to see if the pitch and tone changes. If the pitch and tone do change, then this is a good model.
4. To test this model, students should carefully rub the faces of two thin refrigerator magnets together. If the student moves the magnets slowly enough and pays careful attention to the behavior of the magnets, the student will find that the magnets seem to catch every so often. This "skip" is due to the poles. The magnets will slow down at a field of attraction and skip over a field of repulsion.
5. If the floating finger is a product of confusion from both eyes, then using only one eye at a time should eliminate the floating finger. Therefore, close one eye and observe whether the floating finger still appears. Note that the hypothesis has not been proved, but it has not been disproved either.
6. Place a magnet near a compass and observe how the magnet affects the compass. Compare the interaction of the compass and the bar magnet to the interaction of two bar magnets. The behavior of the two bar magnets should be very similar to the behavior of a compass and bar magnet, thus providing support for using the model of a bar magnet to explain how a compass works.
7. To test this, obtain a container of soapy water and a container of pure water. Using an eyedropper, place one drop of each liquid on a sheet of wax paper. Repeat several times until you have enough drops of each to make a fair conclusion. If soapy water is consistently more spread out into smaller droplets, then soapy water has less surface tension than the water, which should collect in larger drops. The small drops of soapy water compared to the large drops of water provide support for the explanation. Make sure the liquids are dropped from the same height to make the test fair.

5.4 Testing Competing Explanations and Models

Practice Problems on Testing Competing Explanations and Models

1. To test explanation (b), fill a can with water and ice. Then color the water with food coloring. Observe whether the drops on the outside of the can match the color of the water on the inside of the can. If water from inside the can leaks onto the outside of the can and causes the drops to form, then the water on the outside of the can will also be colored. However, since the water on the outside of the can is not colored, then the water probably did not leak from inside the can.

   To test explanation (a), fill a can with cold water and ice and then place the can in a container filled with carbon dioxide obtained from a large reaction of vinegar with baking soda. If water vapor from the air condenses on the can, then there should be no water droplets on this can, because the "air" is just carbon dioxide and does not contain water vapor. If water does not appear on the outside of the can, then explanation (a) may be true.
2. To test explanation (a), use an amount of water that weighs less than the amount of oil used. Pour the oil into the water, and observe if the water remains on the bottom of the cup. After some initial turbulence, the results should be the same as before, regardless of the change in amounts.

   To test explanation (b), pour the water on top of the oil, and observe the results. The water should eventually settle under the oil.

   For explanation (c), measure the same volume of oil and water, and record the masses of both. The mass of the water should be higher than that of the oil. Therefore, water is denser than oil and thus will always settle under the oil on the bottom of the cup.

   All of the tests provide support for explanation (c).
3. To test explanation (a), stand on a chair with arms at sides, noting the height of the fingertips from the ground. Then, step off the chair and extend hands above the head so that they are at the same height as the fingertips when you were standing on the chair. If the height of hands determines how much blood flows to the veins, then there should be no difference in vein swelling, because the hands were at the same height. However, the veins should eventually develop noticeably different appearances. Therefore, explanation (a) should be rejected.

   For another test of explanation (a), have one person support a second person's arm above his or her head so that the muscles do not need to support the arm. The other arm may hang down. With this test, there should be no significant difference between the arm above the head and an arm hanging by the second person's side. The lack of difference supports explanation (b).
4. To test model (a), hook up the battery, bulb, and wires as described, and observe this arrangement. It should not cause the bulb to light. This is not a very good model.

To test models (b), (c), and (d), hook up two lightbulbs in series and observe that each lightbulb is lit with the same brightness. Model (b) does not allow you to predict which lightbulb might light, and model (c) predicts that the first bulb will be brighter than the other. Because both bulbs have the same brightness, models (b) and (c) are not good models.

Due to the evidence against models (a), (b), and (c) and the equal brightness of the bulbs in series, model (d) seems to be the best option presented.

5. To test model (a), push the pepper beneath the surface of the water, and see if it comes back to the top of the water. If it does return to the top, it would seem that this is a better model.

   To test model (b), drop a few drops of liquid soap into the water. The soap reduces the surface tension of the water. If the pepper still floats on the top of the water, then this model would not be very good. If the pepper remains on the top of the water, then this is the better model.

6. To test explanation (a), add a little liquid soap to the water, and turn the cup upside down with the lid in place. If the lid stays on, then this is not a good explanation, because we changed the surface tension of the liquid.

   To test explanation (b), fill the cup completely full of water, and turn the cup upside down with the lid in place. If the lid stays on, then this is not a very good explanation, because there is no air in the container to form suction.

   To test explanation (c), find a way to equalize the interior and exterior pressures. This can easily be done by poking a hole in the bottom of the cup after it has been turned upside down. If the lid still stays on, then this is not a very good explanation, because the pressure is the same inside and outside the cup. However, the lid should fall off.

   With these tests, the most support is given to explanation (c). However, as always, each test should be performed multiple times to ensure a fair conclusion.

7. A radiometer spins due to infrared light. That fact makes it very hard for students to use tests done in the classroom to conclude why the radiometer spins. Presented below are two ways to test whether light or heat causes the device to spin. However, the correct explanation is not that simple; when light is used, there will invariably be a certain amount of heat as well. For that reason, this test works best as an exercise of problem solving skills.

   To test explanation (a), shine a fluorescent lightbulb on the radiometer and observe if the flags still spin. Fluorescent lightbulbs do not produce very much heat when lit, so if the flags still spin, it must be due to the light from the bulb, not the heat.

   To test explanation (b), use something that emits heat, such as a hair dryer, and observe if the flags on the radiometer still spin. If the flags spin due to the heat, then this is an adequate explanation.

8. To test explanation (a), blow into a plastic bag, capturing the carbon dioxide from your breath, and place it over the candle to see if the flame goes out. The flame does

not immediately go out. It is important that students take note of the wording of this explanation. It is true that the flame will eventually go out, because it will burn up all of the oxygen in the bag. However, there is not enough carbon dioxide in a person's breath to put out the flame. Taken to an extreme, carbon dioxide (acquired by collecting the gas from a vinegar and baking soda reaction) will extinguish the flame.

To test explanation (b), place a fan (an extreme source of wind) by the candle to see if the wind causes the candle to go out. The fan is an extreme approximation of a person's breath. If the flame does go out, then this is a good explanation.

9. To test explanation (a), use a stove-top burner and place the unlit candle underneath the coils. The candle does not re-ignite despite the close proximity of a heat source. Therefore, explanation (a) can be rejected.

   To test explanation (b), substitute a match for the each candle. When the match is substituted for the lit candle, the unlit (i.e., bottom) candle will relight. The bottom candle contains wax; thus, vaporized wax is moving up toward the match's flame. This supports explanation (b). When the match is substituted for the unlit (i.e., bottom) candle, the match does not re-ignite. The match does not contain wax, thus no vaporized wax is moving up to the flame. The fact that the unlit match does not re-ignite also supports explanation (b).

   To test explanation (c), gently blow on the candle shortly after it is extinguished. The candle does not re-ignite. Therefore, explanation (c) can be rejected.

10. To test explanation (a), do put not salt into the water, but instead simply change the water level in the beaker. If the pitch does not change, then pitch is not affected by water level, and explanation (a) is not supported by the evidence. Remember to test extremes: Compare the pitch that results from a small amount of water with the pitch that results from a large amount of water.

    To test explanation (b), fill beakers with liquids of different densities (e.g., 100 ml of corn syrup in one beaker, 100 ml of water in another beaker, 100 ml of isopropyl alcohol in another beaker). If pitch does not change, then pitch is not affected by density, and explanation (b) is not supported by the evidence.

    However, students should find that pitch changes with varied density and constant fluid level but remains the same when density is held constant and water level is varied.

11. To test explanation (a), vary the color of the soft drink and control the sugar and caffeine content. For example, take a dark-colored soft drink with no sugar and no caffeine, such as diet, caffeine-free root beer, and a clear soft drink without sugar and without caffeine, such as a diet, caffeine-free lemon-lime soft drink, and place both in a tub of water. If the can of dark-colored soft drink floats, then explanation (a) is incorrect.

    To test explanation (b), obtain a variety of soft drinks with sugar and without sugar. Be sure to control for caffeine and color (e.g., gather only caffeinated dark-colored drinks or only caffeine-free light-colored drinks). If any soft drink with sugar floats, or any soft drink without sugar sinks, then this explanation is incorrect.

To test explanation (c), obtain a variety of soft drinks with caffeine and a variety without caffeine. Be sure to control for sugar and color (e.g., gather only regular light-colored drinks or only diet dark-colored drinks). If any soft drink with caffeine floats, or any soft drink without caffeine sinks, then this explanation is incorrect.

The data from these tests provide the most support for explanation (b).

12. Place seeds with different orientations in a bag with a damp (but not soaking) paper towel. Place staples snugly on either side of the seeds to ensure that the seeds do not shift and change orientation throughout the test. Hang bag until roots start to grow. Observe the direction in which the roots grow. If all roots grow downward, the evidence supports model (a). If roots grow in different directions based on their orientation, then the evidence supports model (b).

    To confirm your conclusion, use the following test: Once the roots have grown, rotate the bag. The roots should grow in a direction different from their previous direction to reflect the "new" down.

13. Place plants underneath a box with a hole poked in the side for light to shine through. After a few days, observe the direction in which the stems of the plants grow. If the stems grow toward the light, then model (b) seems to be an adequate model. If the stems are growing upward, then model (a) seems to be an adequate model.

    To confirm your conclusion, use the following test: Turn the box so that the light is shining from a different side. After a few days, the stems should be growing toward the new light source.

14. To test explanation (a), replace wires with flexible objects that are not metal, such as a shoestring or a rope. If the bulb lights, then the evidence supports explanation (b) and goes against explanation (a). However, if the bulb does not light, then the evidence supports explanation (a) and goes against explanation (b).

15. To test explanation (a), fill two cups with room temperature water, and stir one of them. If the cup that was stirred does not decrease in temperature, then, given the evidence, this explanation is not plausible.

    To test explanation (b), fill two cups with room temperature water, and put a large amount of salt into one cup. Stir both cups equally so that the test is fair. The plain stirred water should not decrease in temperature while the temperature of the salt water should decrease. This provides evidence for explanation (b).

16. To test explanation (a), light a match and blow it out. Collect the smoke from the match inside of the beaker. Place the beaker over the candle, and observe that the water level inside the beaker does not rise. This evidence does not support explanation (a).

    For explanation (b), complete the test a second time, and carefully observe when the water goes into the beaker. If water is rising the entire time the candle is lit, then explanation (b) is a good one, because oxygen is being used up continuously as the candle burns. However, if the water level only rises once the candle goes out, then explanation (c) is more plausible.

For a more dramatic and much more noticeable change in water level, use multiple candles instead of only one. Many candles will provide more heat without changing the amount of oxygen, thus the water level will rise much more once the candle goes out.

Chapter 6: Problem Solving

6.2 Using Manipulatives and Visualization Aids

Practice Problems Using Manipulatives and Visualization Aids

1. Clock problems:
    a. A stopped analog clock will show the correct time twice in a 24-hour period. To figure this out, look at a stopped clock at exactly noon (where the big and small hand are overlapping and pointing toward the 12), then think about how many times in a 24-hour period a digital clock reads 12:00. Because there is noon and midnight, a stopped clock shows the correct time twice.
    b. A clock that is running backward will show the correct time four times in a 24-hour period. The best way to show this is to represent both the correct time and the backward time simultaneously. This can be done using two arms representing both hour hands of a clock.
    c. The most common incorrect answer is 23 times. However, the minute hand and the hour hand intersect on a normal analog clock 22 times in a 24-hour period. This problem is best handled with an analog watch. Physically move the hands forward in time, starting at 12:00. The hands intersect approximately every hour and 5.5 minutes following 12:00. You could simply count the 22 intersections, or use a calculation: Since 1 hour and 5.5 minutes is 65.5 minutes, you could calculate the amount of minutes in a 24-hour period and divide by 65.5 to get 21.98—approximately 22.

$$24 \text{ hrs.} \times 60 \text{ mins.} = 1{,}440 \text{ mins.}$$

$$1{,}440 \div 65.5 = 21.98$$

2. The most common wrong answer is $10. This is often reached by not using manipulatives.

    Imagine the farmer starting with either $0 or $70 (either amount will work). Each transaction gives a net gain of $10. So, after two trades, the farmer gets $20 more than when he started.

$$-60 + 70 = 10$$

$$10 + (-80) = -70$$

$$-70 + 90 = \$20$$

3. Word problems:
    a. For these problems, call the origin "side 1" and the destination "side 2."

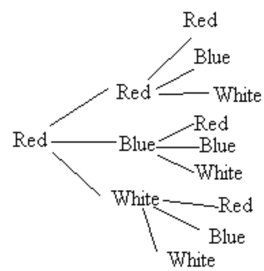
    Remember that the farmer can take items both ways or go back by himself.

    The farmer first takes the chicken across the river to side 2. The farmer then returns to side 1 and then takes the grain across to side 2. The chicken and the grain are on the same side of the river (side 2). These two cannot be left alone. So, the farmer must take the chicken back across the river to side 1 so that the chicken does not eat the grain. The farmer drops off the chicken and picks up the dog and brings him to side 2. Now the dog and the grain are on side 2. Finally, the farmer goes back to side 1 alone to pick up the chicken and complete the task.
    b. Remember that one boy can ride in the boat by himself.

    First, two boys cross the river to side 2, and one boy returns to side 1. Then one man crosses the river to side 2, and the other boy returns to side 1. Then two boys cross the river to side 2, and one boy returns to side 1. The second man crosses to side 2, and the boy returns to side 1. Finally, the two boys cross the river to side 2.
    c. Remember that more than one cannibal or explorer can be sent across the river.

    One cannibal and one explorer cross the river to side 2. The explorer returns to side 1 and sends two cannibals to side 2. One cannibal goes back to side 1 and two explorers cross to side 2. Now, one cannibal and one explorer cross the river to side 1. Then two explorers cross to side 2. One cannibal crosses to side 1, picks up another cannibal, and returns to side 2. Finally, one cannibal returns to side 1 again to pick up the last cannibal and cross to side 2.
4. Gumball machine problems:
    a. The first inclination is to think of a probability formula to help you calculate the answer. However, this problem can be solved simply by using manipulatives. If you wanted to be assured of getting at least one pair of colored gumballs, you need to spend four pennies. With the best luck, your first two pennies would get two of the same colored gumballs, but you cannot rely on luck. If you had the worst luck, the first three pennies you spend would all purchase each colored gumball (red, white, and blue). If you had each of the colors, your next gumball must pair with one of them.
    b. The chances of getting three of the same colored gumball are one in nine. The color of your first gumball does not matter. Instead, what matters is that the second and third gumball matches up with the color of the first gumball. For example, a red gumball comes out of the machine. The chart below shows the possible outcomes after receiving the red gumball first. There are nine distinct outcomes after receiving the red gumball first. Only

one outcome results in all three gumballs being the same color. This process can also be done for blue and white gumballs. In each case, only one of the nine possibilities results in three gumballs of the same color. Adding all of the outcomes together gives you 3 outcomes of the possible 27 ($\frac{3}{27}$) that give you three gumballs of the same color. This fraction can be reduced to one in nine ($\frac{1}{9}$).



5. Since compound DC is not radioactive, both atoms D and C must not be radioactive. All of the other compounds are radioactive and also contain either D or C. Therefore, the atoms A, B, and E must be radioactive.
6. There are approximately 300 chipmunks in the park. Since the biologist found that the marked chipmunks, when caught again, represented 9 out of 63 (or $\frac{1}{7}$) of the chipmunks, then she can probably assume that the 43 originally caught chipmunks represent approximately $\frac{1}{7}$ of the total chipmunks. So, simply multiply.

$$43 \times 7 = 301 \text{ chipmunks}$$

7. Method 1: Fill up the 5 L bucket and pour 5 L of water into the 7 L bucket. Then fill up the 5 L bucket to the top once more. Use that 5 L bucket to fill up the 7 L bucket. This will leave you with 3 L left in the 5 L bucket. Empty the 7 L bucket. Pour the 3 L into your 7 L bucket. Fill 5 L bucket again and pour what you can into the 7 L bucket. This will leave 1 L in the 5 L bucket. Empty the 7 L bucket, pour the 1 L from the 5 L bucket, and then fill and pour in 5 more liters for a total of 6 L.

   Method 2: Fill the 7 L bucket and pour water out to fill up 5 L bucket. This leaves 2 L in the 7 L bucket. Empty the 5 L bucket. Then pour the remaining 2 L into the 5 L bucket. Then fill the 7 L bucket once more and fill the 5 L bucket again with the water in the 7 L bucket. This leaves 4 L in the 7 L bucket since there were already 2 L in the 5 L bucket. Get rid of the water in the 5 L bucket once more, and pour the 4 L from the 7 L bucket into the 5 L bucket. Fill the 7 L one more time and pour enough water to fill the 5 L bucket. This leaves 6 L in the 7 L bucket.

6.3 Working Outside the Box

Practice Problems for Working Outside the Box

1. Think of ways in which you could decrease the height of the truck. There are multiple solutions to this problem. One possible method is to slightly deflate the tires of the truck. Another way is to add additional weight to the truck in order for it to ride lower to the ground. Other ideas may also produce the required outcome.
2. One way to solve this problem is to remove one lug nut from each tire so that each tire has three lug nuts.
3. Dropping a book and paper:
    a. Find a way to increase the surface area of the book. One way to do this would be to open the book and tuck the edge of the pages into the binding of the book. Then, point the pages of the book downward. Decrease the surface area of the paper by crumpling it into a ball. Release the two objects at the same time, and the paper should fall faster.
    b. Release the closed book and a crumpled piece of paper at the same time.
4. The most common error for this problem is to calculate the distance the superbug travels for each leg of the trip. It is much easier to calculate in terms of total time and maximum speed traveled. Since the trains will each travel 50 miles in one hour, they will collide in one hour. The superbug travels at 75 miles per hour. Therefore, he will be able to travel 75 miles no matter which direction he flies or how many times he turns around.
5. The key to completing this puzzle is to understand that you can draw your lines outside of the box. This is the literal "think outside of the box" problem. The problem cannot be solved unless you move past the dots with some of your lines.
6. Weight of film canisters:
    a. The key is to split the nine canisters into groups of three and not weigh every canister. Split the canisters into three groups of three, and compare two groups of three to figure out which group contains the light canister. If the balance tilts toward one set of three, you know the light canister is in that set. If the balance shows no difference between those sets of three canisters, the light canister must be in the set of three not on the balance. Using the set of three that contains the light canister, put only one canister on each side of the balance. If the balance is tipping, the light canister is presently on the scale. If the balance is not tipping, the canister not on the balance is the light canister.
    b. Use the method as described above but start by making three groups of nine. Repeat the procedure with three groups of three followed by three individual canisters.
7. In a partially filled glass, the water forms a meniscus (i.e., the water is slightly higher around the sides than in the center). A floating object will always move toward the

highest point of the water. So, fill a glass of water slowly to the point where it cannot hold any more water. Notice that the surface of the water is shaped like a mound. This can be compared to placing droplets of water on the surface of a penny. Carefully place the Ping-Pong ball or cork in the center of the water. It will once again sit at the highest point of the water, but now the highest point is in the center of the container.

8. Perhaps the most straightforward way to make the lump of clay float is to mold the lump into the shape of a boat. This will increase the surface area of the clay that touches the water.
9. Objects float based on the relationship between their densities and the density of the liquid. An object that is denser than the liquid will sink, and an object that is less dense than the liquid will float.

   There are multiple ways to solve this problem. One method is to increase the density of the water by dissolving salt in the water. Eventually, the density of the water will exceed the density of the golf ball, and the golf ball will float on the water's surface.
10. With a sheet of aluminum foil in your hand, immerse the foil and your hand into the water. Crumple the foil beneath the water's surface. The crumpled foil now filled with water (not air) will sink.

6.4 Patterns and Similarities

Practice Problems for Detecting Patterns and Sequences

1. This sequence represents numbers (i.e., **O**ne, **T**wo, **T**hree, **F**our, **F**ive, **S**ix, **S**even, etc.). Thus, the next three letters are **E**, **N**, **T** (i.e., **E**ight, **N**ine, **T**en).
2. The key to solving this problem is to avoid moving similar tokens next to each other. If tokens of the same color are placed next to each other, they will be locked, and no further moves can be made. Thus, the solution is to move one set of tokens until you reach the point that, by moving one more, the other set of tokens will be permanently blocked. Just before that point is reached, the other set of tokens should be moved until a similar point is reached.
3. The pattern you will likely find when working on this problem is that a decrease in angle between adjacent mirrors will increase the number of images seen.
4. As the pencil example illustrates, as weight is added below the balance point, it becomes easier to balance an object. Find a way to increase the weight below the balance point using the clay.
5. From a hanging roll, using your thumb and forefinger, pull very quickly at a perpendicular angle.
6. Determining density:
   a. Place the ice cube in each individual liquid and observe the results. The denser substance will be at the bottom.
   b. Salt water is denser than pure water. One method to demonstrate this is to put colored pure water into an empty baby food jar. Cover the jar with

aluminum foil, and seal it with a rubber band. Then put some salt water into a bigger container, and place the baby food jar on its side on the bottom of the bigger container. Poke two holes in the foil; one near the bottom and one near the top so that the pure water can flow out of the jar. Pure water should rise to the top of the bigger container, showing that pure water is less dense than salt water.

   c. Following the same procedure as 6. b., use food coloring to color one of the milks to see which is denser.

7. Placing a gas in a liquid:
   a. To avoid wetting the paper towel, invert the cup so that the bottom of the cup is facing the ceiling. Keeping the cup in this position, slowly submerge the cup into a tub of water. Pull the cup out of the water without altering the cup's position.
   b. Fill a container with water and obtain two cups. Submerge one of the cups in the container of water (make sure this cup is filled with water). Then invert the second cup before placing it in the container of water so that air is trapped inside. Now, slowly tip the cup filled with air and catch the escaping air with the other cup.
   c. Fill a container with vinegar, and obtain a piece of chalk and a cup. Submerge the cup into the container of vinegar (make sure this cup is filled with vinegar). Place the chalk into the vinegar and capture the resulting carbon dioxide gas in the cup.

6.5 Working Backward

Practice Problems for Working Backward

1. The amount of bacteria on the casserole doubles every hour, so the casserole would be half covered one hour before it is fully covered. Therefore, at 11 hours, the casserole was half covered.
2. Problems with 10 coins:
   a. For the first player to always win, he or she must force the number of coins to a multiple of three (e.g., if four coins remain, the first player must take one to leave three). If the other player has three coins to choose from and chooses one, then the first player can take the last two coins. If the second player chooses two, then the first player can take the last coin. Therefore, if you, as the first player, force the other player to choose from three coins, you will win. The same principle applies for six, nine, and so on. So, for the first person to always win, he or she must take one coin on his or her first turn to leave nine coins from which the opponent can choose.
   b. See the solution to Problem 2. a. (above), except the opposite rules will apply.

3. Air is made of tiny particles that move around and collide with each other to create pressure. Initially, the air inside the jar and the air outside of the jar exert the same pressure. If you can decrease the pressure inside the jar, then the pressure outside of the jar will be relatively larger and will push the egg inside of the jar. When the paper is burned, the air inside the jar is heated, and the pressure is increased. Some of the air will push itself out of the jar, but when the fire is extinguished air cannot re-enter the jar because the egg makes an airtight seal. When the air cools down after the fire is extinguished, the pressure inside the jar decreases relative to the pressure outside of the jar and the egg is consequently pushed inside the jar in order for the pressures to equalize because the air that escaped must re-enter the jar.

   To get the egg to escape from the jar, you must make an airtight seal with the egg and either (1) increase the pressure of the air inside the jar or (2) decrease the pressure of the air outside the jar. Heating the jar directly on a hot plate would destroy the jar, but it is possible to pour hot water on the jar when it is turned upside down (it must be upside down so that the egg creates an airtight seal). Heating the jar increases the temperature of the air inside the jar and would therefore increase the pressure of the air inside the jar, pushing the egg out.

   If this does not work, it may be necessary to bring the upside-down warm jar outside into cooler weather, where the outside air pressure is even lower. This would create a larger difference in pressure and would most definitely push the egg out.

6.6 Estimations and Approximations

Practice Problems for Estimations and Approximations

1. Begin by estimating the number of people in the city: approximately 10 million.

   Then estimate the number of people per household and how many households own pianos: There are 3 people per household, and 1 in 10 households own a piano.

   So if there are 3.3 million households, 330,000 of them have pianos.

$$3{,}300{,}000 \text{ households} \times \frac{1}{10} = 330{,}000 \text{ households with pianos}$$

   However, we must add in a couple thousand pianos for churches, schools, etc.

$$330{,}000 \text{ pianos} + 5{,}000 \text{ pianos} = 335{,}000 \text{ pianos}$$

   Thus, we have a count of 335,000 pianos. Assume these pianos are tuned once per year. A piano tuner tunes approximately 10 pianos per week. There are 50 workweeks per year, so a tuner will tune approximately 500 pianos per year.

$$10 \text{ pianos per week} \times 50 \text{ workweeks per year} = 500 \text{ pianos per year}$$

So we can divide the number of pianos by number of tunings per tuner, which yields an estimate of 670 piano tuners in New York City.

335,000 pianos ÷ 500 tunings per tuner = 670 piano tuners

2. Here is one method of estimation for a college campus:

Estimate the number of students in your school: 4,000 students.

Estimate the number of slices of pizza or entire pizzas each student eats per week: 0.5 entire pizza per week.

Estimate the number of weeks in a semester: 20 weeks.

Estimate the number of entire pizzas that would fit in one square meter (1 m^2). Small pizzas are 12 in. in diameter, mediums are 14 in., and larges are 16 in. Draw a pizza and 1 m^2 on the board, and ask students to estimate how many pizzas would fit into a single square meter: seven pizzas.

Then perform some calculations in order to reach your estimate:

4,000 students × 0.5 pizza per week for every student × 20 weeks per semester = 40,000 pizzas consumed per semester

40,000 pizzas per semester ÷ 7 pizzas per m^2 = 5,700 m^2 of pizza per semester

3. Assuming your head is a sphere, measure the circumference of your head in centimeters and divide by 2π to find the radius. Then, take the radius and calculate the surface area of your head using the formula $4\pi r^2 = A$. Once you have the area, you can assume that your head is half-covered by hair and thus divide the total area by two. Measure a 1 cm × 1 cm area, and count the hairs in that area. Multiply the total hair-covered area by the number of hairs in the 1 cm × 1 cm area to arrive at your answer.
4. Fold a piece of aluminum foil as many times as needed so that its thickness is measureable. Determine how many layers of foil you have measured, and divide the total thickness by the number of layers to find the thickness of a single layer.
5. This solution is similar to that of Problem 4. Stack dollar bills of any denomination until you reach a measurable thickness. Divide that thickness by the number of bills in the stack. Once you have determined the thickness of a single bill, multiply it by ten million to determine the height of a stack of $100 bills that would total one billion dollars.

   This problem can also be solved using sheets of paper, but be aware that a bill is slightly thicker than a standard sheet of paper.
6. The surface area of a sphere is equal to $4\pi r^2$ and the radius of the Earth is 4,000 miles. There are somewhere between 6 and 7 billion people on the Earth. Looking at a globe, one can see that only approximately one-quarter is land. So, the area of the Earth is equal to the following:

$$4 \times 3.14\ (4{,}000\text{ miles})^2 = 200{,}960{,}000\text{ sq. mi.}$$

But only one-quarter is land, the area of land surface is the following:

200,960,000 sq. mi. ÷ 4 = 50,240,000 sq. mi.

Finally, this value must be divided by the number of people in the world: 6 billion. The result will be the following:

50,240,000 sq. mi. ÷ 6,000,000,000 people = 0.008 sq. mi. per person

So each person will receive about one-tenth of a square mile.

7. The best way to solve this problem is to take a large shelf of books and knock all the books off the shelves to the floor below the shelf. Time how long it takes a person to replace all the books in order at a regular pace. Once the books have been reshelved, count the number of books that were reshelved during that time period. The time that it would take to reshelve 2 million books can then be extrapolated from these measurements.
8. First, figure out how old Lincoln would be if he were alive today (he was born in 1809). Estimate the number of breaths an average person takes per minute. Since there are 60 minutes in 1 hour, 24 hours in 1 day, and 365 days in 1 year, perform the following calculation to determine how many minutes are in a year:

   60 mins. × 24 hrs.× 365 days = 525,600 mins.

   Then multiply the number of minutes in a year by the number of breaths an average person takes per minute. Finally, multiply this product by Lincoln's age.
9. Estimate the height from the floor to the ceiling in one room, then multiply this distance by the number of floors in the building.

   A more accurate method would be to consider not just the room height but also the story height. If the room is approximately 8 feet high, then a story in the building is approximately 10 feet high. If the room is 10 feet high, then a story in the building is approximately 15 feet high. The number of stories in a building is usually the same as the number of floors in a building. To find the height of the building, multiply the number of floors in the building by the appropriate story height.
10. A person walking at a good pace can cover 1 mile in 15 minutes, or 4 miles in 1 hour. The distance from the Earth to the Moon is about 250,000 miles. If the person walks 4 miles per hour, it will take about 62,500 hours to walk to the Moon.

    250,000 mi. ÷ 4 mph = 62,500 hrs.
11. Using the formula

    volume = area × height

    First, make all the units the same:

    $5 \text{ ml} = 5 \text{ cm}^3$

$$4{,}000\ m^2 = 40{,}000{,}000\ cm^2$$

Next, divide the volume by the area to get the height (or size) of the oil droplet (round up to 50,000,000 for an easier calculation):

$$5 \div 50{,}000{,}000 = 10^{-7}\ cm \text{ or } 100\ nm$$

12. If the average American consumes one cup of milk per day and the U.S. population is approximately 300,000,000 people, then approximately 300,000,000 cups of milk are consumed each day. Therefore, if one cow produces 90 cups of milk per day, and Americans consume 300,000,000 cups of milk per day, approximately 3.3 million cows are required to meet the demand:

$$300{,}000{,}000 \text{ cups} \div 90 \text{ cups per cow} = 3{,}333{,}333.33 \text{ cows}$$

13. Method 1: Find the mass of the radish seeds by subtracting the mass of the empty jar from the mass of the jar filled with the radish seeds. Then, measure the mass of a known number of seeds (e.g., 50 seeds) and divide that mass by the number of seeds to approximate the mass of a single seed (e.g., 5 grams ÷ 50 seeds = 0.1 grams per seed). Finally, divide the mass of all the seeds by the approximate mass of a single seed to estimate the total number of seeds in the jar.

    Method 2: Use the following formula:

$$\text{base} \times \text{height} = \text{volume}$$

    So, count how many radish seeds it takes to just cover the bottom circle of the jar, which is the base. Then, count how many radish seeds in a row it takes to make a line from the base to the lid, which is the height of the jar. Multiply these numbers together.
14. Considering the large amount of inherent uncertainty in such a test, the traveler can conclude that the numbers are nearly the same. To obtain more accurate results, the traveler could count for longer periods of time to get a larger sample size.
15. Have someone stand a long distance away (about the length of two football fields) and clap. You will see the motion of the clap before you hear the sound.
16. Hold a meterstick by the end and stand so that the mirror touches the other end of the meterstick. You know that your fingers are exactly 1 meter away from the mirror, and the image's fingers are exactly 1 meter away from the mirror as well. Therefore, the image in the mirror is always the same distance as the real object from the mirror.
17. This is best estimated by paying attention to how often you swallow every few minutes, and also estimating how much saliva you add to a bite of food. The average person produces about 2 quarts of saliva in one day.

6.9 Problems Encountered by Science Teachers

1. If a small slit is cut low in the straw, the students will be able to blow through the straw, but fluid will not be able to travel up through the straw. When the students inhale, they will draw in air instead of fluid.
2. No answer necessary (creating an electrical fuse)
3. The reaction can be done within the balloon itself. Remember that CO_2 is denser than air, so some air may be released from the top of the balloon to insure that only CO_2 remains in the balloon.
4. Wrap a thermometer in a rag that has been wet with room-temperature water. To show more extreme results, place the thermometer in front of fan. The fan will cause quicker evaporation, which will further cool the rag.
5. See Problem 4 above.
6. Mercury would be 2 ft. away from the Sun. Its diameter would be 0.042 in. (0.1 cm) and could be represented by a grain of sand.
   Venus would be 3.7 ft. away from the Sun. Its diameter would be 0.1 in. (0.26 cm) and could be represented by an apple seed.
   Earth would be 5.1 ft. away from the Sun. Its diameter would be 0.11 in. (0.28 cm) and could be represented by an apple seed.
   Mars would be 7.7 ft. away from the Sun. Its diameter would be 0.06 in. (0.15 cm) and could be represented by a radish seed.
   Jupiter would be 26.4 ft. away from the Sun. Its diameter would be 1.2 in. (3 cm) and could be represented by a large marble.
   Saturn would be 48 ft. away from the Sun. Its diameter would be 1.02 in. (2.6 cm) and could be represented by a large marble.
   Uranus would be 97 ft. away from the Sun. Its diameter would be 0.4 in. (1.1 cm) and could be represented by a small marble.
   Neptune would be 152 ft. away from the Sun. Its diameter would be 0.42 in. (1 cm) and could be represented by a small marble.
   Pluto would be 200 ft. away from the Sun. Its diameter would be 0.02 in. (0.05 cm) and could be represented by a grain of sand.
7. Lung capacity can easily be measured through water displacement. Assemble a large tub of water, a graduated cylinder, and a hose. Completely fill the graduated cylinder with water before inverting it in the tub. Place the hose near the top of the cylinder and ask students to blow into the hose. The air will force the water out of the cylinder. The amount of air can easily be measured. An alternative method would be simply blowing into a balloon and measuring the resultant volume of the balloon.
8. Ask students to close their eyes and cover one ear. The instructor should move around the room making a loud repeatable noise, such as clapping. Ask students to indicate the source of the sound. Repeat the activity when students have both ears uncovered.

9. When a disk magnet is rolled down a smooth surface, the magnet will curve slightly in reaction to the magnetic pull of the poles. Theoretically, if the magnet is rolled directly toward the north or south pole, the magnet will roll in a completely straight line without deviating in either direction.

Chapter 7: Integrating Content and Scientific Inquiry in Your Lessons

7.1 Introducing the Learning Cycle

Testing Your Understanding of the Learning Cycle

1. The main instructional goal of the exploration phase is to create a concrete experience that illustrates the scientific concept being taught.
2. It is very difficult for students to think abstractly about new ideas. Beginning with a concrete experience allows for students to observe the new idea and refer back to their experiences when the new idea is unpacked in the concept-development phase.
3. If the explorations are too open-ended, students may not make conclusions that are in line with correct science concepts, because they rely too much on prior knowledge rather than confronting the evidence from the activities. Exploration phases that are too open-ended place too much confidence in students' abilities to piece together science content and a concrete experience. This type of exploration does not provide the critical scaffolding that students need from teachers to properly understand the content.
4. Teachers could ask students to describe their thoughts to group members, draw pictures about their observations, write down their group's ideas, design and fill in a data table to record what they observe, or complete some other assignment that requires them to think about the data as they observe it.
5. The main instructional goal of the concept-development phases is to link exploration phase observations and thoughts to scientific content. The teacher provides necessary scaffolding by asking questions so that students think through the concept.
6. During the concept-development stage, the teacher must help students develop an accurate understanding. A teacher should not simply tell the students what they need to know, but rather the teacher should help students along by asking questions about what they just experienced in the exploration phase, while also providing essential scaffolding information. The teacher should provide a summary of the concept in order to confirm students' developing understanding.
7. Vocabulary is abstract. Students need a concrete experience first in order to link the science content vocabulary with something they have already observed. This prior concrete experience allows students to better recall the vocabulary.
8. The teacher should not immediately correct the student but should ask the student how he or she arrived at that conclusion. The teacher can also ask the student to

confirm an observation made during the exploration phase or to compare his or her observations with those of other groups. Sometimes the data from the exploration phase will contradict the student's initial observation, and the student will rethink his or her position. Retesting can also sometimes be effective.

9. The instructional goals of the application phases are twofold. First, the concept being taught is put into long-term memory through straightforward practice. Second, the application phase allows for students to use the concept in a novel situation. Practice in a new context shows the students that the concept under study is true in multiple settings, not just in certain activities in the classroom. This also allows the concept to be placed into students' long-term memory.
10. The application phase must apply the concept introduced in the earlier stages of the learning cycle. The concept being taught must be rehearsed and applied in order to put the concept into the long-term memory of the student. Introducing a new topic in the application phase would prevent the concept under study from being placed into students' long-term memory.
11. The learning cycle should be used when teaching a scientific concept, not a skill. Therefore, the learning cycle could be used to teach the concept of how density determines the rising and sinking of liquids and gases. The learning cycle should not be utilized to teach how to draw Lewis dot structures in chemistry or how to use a triple beam balance.

7.2 The Learning Cycle Approach Versus Traditional Teaching: A Case Study

Applying Your Understanding of the Learning Cycle

1. The exploration phase is located in the Activity section of this lesson. Here students are working with concrete materials to experience the concept being taught.

   Concept development is located in the Class Discussion and Journaling sections. Here appropriate terms are introduced to the students as they unpack how these terms relate to the concept being studied.

   The application phase is located in the Extension section. Here students are practicing the terms introduced in the concept-development phase. The application phase presented in this learning cycle does not include the second part of the application phase, in which students should practice the concept in a novel situation.
2. The exploration phase occurs when the students are given materials to measure the boiling points of the various liquids and asked to answer appropriate questions.

   Concept development occurs when the results are discussed and the concept of physical properties is explained.

   The application phase occurs when students are tasked with investigating how other substances affect the boiling point of water. Also, the homework assignment allows for students to apply the concept in a new way.

3. Lesson 2 is more consistent with the learning cycle. Lesson 1 is too teacher-directed. Students are not experiencing the concept under study in a concrete way. Instead, the teacher is experiencing the concept in a concrete way. In lesson 1, the students are not doing the thinking; the teacher is doing the thinking.

   Lesson 2 is more student-centered. Here the students are experiencing the concept in a concrete way. The students are doing most of the thinking when they address the provided questions. Even during the concept-development phase (i.e., the discussion), the teacher asks questions in order to scaffold students' thinking as the teacher prepares to introduce the terms related to the concrete experience that students had prior in the lesson. During the application phase, the students are required to practice the concept by examining various circuits and indicating whether or not the light would turn on. This allows for students to commit the concept under study into long-term memory.
4. The phase missing in this lesson is concept development. After the students have gathered data on how the material rubbing on the surface affects the length of the elastic strap, proper terms should be introduced. Although this lesson covers the concept of friction, the term is never introduced. The teacher could hold a group discussion in which the students share their findings from Procedure: Part 1. The questions provided would be well used in a group discussion. The teacher needs to use the students' concrete experience to teach them the concept that is being studied. The concept can be summarized simply by reiterating the content objective: "The amount of friction between two objects rubbing together depends on the textures of the surfaces rubbing." The reinforcement of the content objective in the form of a summary does not happen in this lesson. At the end of the concept-development phase, the teacher should clearly summarize the main ideas of the scientific concept.
5. This lesson is missing the application phase. To put the new concept into long-term memory, the students must rehearse and apply the concept. The following is an example of a possible application phase: The students should repeat the test from the exploration phase but this time with objects of varying weights instead of 2 L bottles. The students should weigh the objects in their hands and predict which will make the elastic stretch the farthest before carrying out the test. Students can also consider the following scenario: A boy wishes to rearrange his room. He has a bed (probably quite heavy), a dresser (probably slightly heavy), and a bean bag chair (probably quite light). What will determine whether he can move the furniture himself or whether he needs help to do the rearranging? Students should predict which objects the boy can move by himself and for which objects he will need help.
6. The application phase is missing in this lesson. A teacher could add the following to make this lesson complete:
   a. Give students pictures of other shaped magnets. Predict where the pole would be located on the magnets. Test students' predictions by giving them the magnets and having the students determine where the poles actually are.

b. Drop a paper clip into a cup of water. Ask students to remove the paper clip from the water with a magnet without getting the magnet wet.

c. Present students with the following problem: "You are going boating with your family on Lake Michigan. As you and your family are getting in your boat, your dad pulls out the metal key, puts it in the keyhole, turns the key, and snaps it off! He pulls out half of the key with the other half stuck in the keyhole. How could you get the metal piece out of the keyhole?"

7. This lesson does not focus students' attention on what is important to note about sound and object vibration. There are no questions for the students to answer during this exploration phase to focus their learning.

8. Give students four different containers. Have students fill one container with rocks, another with sand, another with dirt, and the last container with water. Be sure each container is filled with the same amount of material. Put each container under a heating lamp and wait two minutes. After two minutes have passed, take the temperature of each substance by placing a thermometer just below the surface. Record the temperature in a data table. Repeat for a total of 20 minutes. Ask students questions about the rate at which temperature changes for each substance.

9. The application phase introduces a new concept. It does not rehearse and apply the concept being addressed in the lesson. A possible application activity is to give students three identical-looking pieces: two should be magnets and one should be a simple piece of metal. Ask the students to identify which of the three are magnets. They should observe the way the objects interact and will only be able to determine which are magnets by observing which ones repel. They will not be able to answer the question by observing attraction behaviors, since the metal will be attracted to the magnets. Or, students could be given a bar magnet and a compass and be asked to determine whether a compass needle is a magnet. Students should then be asked to explain how they came to their conclusion.

10. This application phase introduces a new concept. It does not rehearse or apply the concept under study, which is how the slope of an incline plane affects how much force is needed to pull an object up. Therefore, this is not an appropriate application phase. An effective application would be to challenge students to lift 2 L bottles filled with sand from the floor to a table or chair using only a single strand of cotton sewing thread. Students can also consider the following problem: A man wants to load two heavy push lawn mowers into the back of a truck. He has a short ramp, which would create a very steep plane, and a very long ramp, which would create a fairly shallow angle. Which configuration will require less effort to load the push mowers onto the truck?

The remaining questions (11–19) ask for learning cycle lesson plans. Rather than example lesson plans, what follows is a set of guidelines for creating effective learning cycle lesson plans. Most of these guidelines are taken directly from the text. In some cases, practice problems from other areas in the text would provide direction for exploration or application phases. When applicable, these problems and solutions are referenced.

Guidelines for Creating Learning Cycle Lesson Plans

- There should be three distinct phases: the exploration phase, the content-development phase, and the application phase.
- The exploration phase should not be too open-ended. Students should be working toward the understanding of a clear content objective. This understanding will be developed more fully in the later sections of the lesson.
- Students should be on-task during the exploration phase. Students should not be allowed to just play with the materials, although a little bit of playing at the beginning of the lesson can be helpful. Students should be performing logical tests in order to discover something about the content.
- The instructor should have prepared questions that will focus the students' attention on what is important. The teacher can ask these questions during the exploration phase. During the content-development phase, student responses can be discussed as a whole group.
- Students should be talking as much as the teacher during the content-development phase. They should be developing an accurate understanding of the context through discussion of their findings and comparison with the findings of the rest of the class.
- The teacher should summarize and clarify the concept at some point during the concept-development phase. This can be as simple as restating the content objective.
- The application phase may have two parts: simple practice of the concept in a familiar context and practice of the concept in a novel context.
- The application phase should not introduce a new—or even related—concept. While the application activities can build on previous experience, ensure that students are practicing only the concept being studied in this lesson.

15. See Problem 12 in Section 5.4.
16. See Problem 13 in Section 5.4.
18. See Problems 4, 5, and 6 in Section 4.6.
19. See Problems 4, 5, and 6 in Section 4.6.

7.4 Integrating Problem Solving and Model Testing Into the Learning Cycle

Practice Problems: Implementing Problem Solving and Model Testing in the Learning Cycle

When writing the solutions to this section, please refer to the Guidelines for Creating Learning Cycle Lesson Plans provided in Section 7.2.

Chapter 8: Observations and Inferences

8.2: Observations and Inferences in the Classroom

Checking Your Understanding of Observations and Inferences

It is important to note that all observations include some inferences. This key provides the intended solution, but all of the following are in some way inferences.

1. Are these statements observations or inferences?
    a. Observation
    b. Inference (The material is wood.)
    c. Observation (Measurements are always observations.)
    d. Inference (The material is paper.)
    e. Inference (The markings are letters.)
    f. Observation
    g. Inference (The object is an apple.)
    h. Observation
    i. Inference (The material is metal.)
    j. Inference (The object is a penny.)
2. Are the statements observations, inferences, or neither?
    a. Inference
    b. Observation
    c. Inference
    d. Neither. This statement is a prediction.
3. Option (c) is not an observation. It is an inference that the dew is from the fog.
4. Is the statement an observation or an inference?
    a. Inference. It is trying to explain from where the condensation came.
    b. Inference. It is based on the appearance of the shells.
    c. Observation. It describes what the student would see when the candle burned.
    d. Inference. It is trying to explain the motivation of the students while also characterizing the students' actions as "rioting." An observation would be that the students were carrying signs, throwing rocks, yelling, etc.
    e. Inference. An observation would be that the students were carrying signs, throwing rocks, yelling, etc.
5. Have inferences been made instead of observations?
    a. The statements "the can cooled off so fast that it was crushed" and "some of the cold water went into the can" are both inferences. The first statement is an attempt to explain why something happened. It would be a better written observation to simply state that the can collapsed when it was placed

in the cool water. The second statement is also an attempted explanation of how the water got into the can. It would be a better written observation to state that water poured out of the can as it was lifted.

b. The statement "the water was attracted to the opposite charges on the comb" is an inference, or an attempt at explaining an observation. The observation is that the water bent away from the comb.
c. The inference is that "the plants were trying to find sunlight." All other statements in this section are observations.
d. The student made an inference that the substance coming out of the kettle is smoke. It would be a better written observation to simply call the substance "a substance."

6. Observations and inferences in activities:
   a. Observations: The ice cube is near the top of the container of water. The ice cube sank to the bottom of the container of isopropyl alcohol.
      Inferences: The ice cube is less dense than the water, so it floated. The ice cube is denser than the isopropyl alcohol, so it sank.
   b. Observation: The ground pepper is on the surface of the water.
      Inference: The ground pepper is floating on the surface.
   c. Observation: Bubbles rise to the surface of the water as it boils.
      Inference: Bubbles of oxygen rise to the surface of the water as it boils, because oxygen is less dense than water.
   d. Observation: The raisins move up and down as bubbles collect on the surface of the raisins.
      Inference: The bubbles on the surface of the raisins cause the raisins to float.
7. Do these activities develop observation skills, inference skills, or both?
   a. This activity is asking for both observations (i.e., what the students feel) and inferences (i.e., the students' guessing what is in the bag).
   b. This activity is asking for inferences.
   c. This activity is asking for inferences.

Chapter 9: Classification

9.2 Classification in Elementary and Middle School

Practice Problems

1. Two examples of serial classification are lining up students according to height and separating classes by age.
2. Corundum is very hard (see Mohs' scale in Table 9.1). It harder than most other materials except diamonds. Therefore, it scratches most other materials.

3. The pH scale is a serial classification, because it classifies substances on a scale from 0 to 14 according to acidity and basicity.
4. Merchandise is typically separated first according to gender: men's and women's clothing. Then the clothing is separated by age, type, brand, color, and finally size.
5. Considering groups:
    a. Things on a farm
    b. Animals (cow, sheep, chicken, farmer) and plants (corn and hay)
    c. Mammals (cow, sheep, farmer), birds (chicken), and plants (corn and hay)
    d. Two-legged mammals (farmer), four-legged mammals (cow, sheep), birds (chicken), and plants (corn and hay)
6. Money can be separated according to type (e.g., coin or bill), value (e.g., greater than $0.10 or less than $0.10), color, presence of ridges on the sides of coins, etc.
7. The periodic table is an excellent example of a classification scheme, because the elements are organized according to reactivity, mass, and electron configuration.
8. All shirts are items of clothing, but not all items of clothing are shirts. Similarly, all pants are items of clothing, but not all items of clothing are pants.
9. Young children have a simple definition of an "animal" that usually includes its being furry. They have not yet expanded their definition of an animal beyond that of a mammal.
10. The category, or class, of birds called crows are included in the class called black birds, but the class of birds called black birds are not included in the class called crows. Young children have a hard time understanding the concept of class inclusion, because they struggle when too many attributes are presented. They would focus on only the attribute of color and claim that since all crows are black birds, all black birds must then be crows.
11. Geologists have several methods of classification, because they have different reasons for needing to classify minerals. It is also true that just one method of classification would not fully describe each mineral.
12. Viruses do not neatly fit into biologists' definition for either living or nonliving things. So, viruses illustrate the ambiguities found in all classification systems.
13. See #14.
14. A platypus is commonly classified as a mammal. However, a platypus embodies characteristics of both birds (e.g., it lays eggs) and mammals (e.g., it is hairy). This is an example of the ambiguities found in all classification systems, because the platypus does not exactly fit into either category.
15. Biomes are classified according to what is useful for those doing the classifying. In some cases, only a few (say, six) distinctions are necessary, but in other cases more precision is needed.

Chapter 11: Measurement

Section 11.2 Implementing Measurement in Elementary and Middle School

Checking Your Understanding of Measurement

1. Estimating sizes:
    a. 2.5 meters
    b. 30 centimeters (for an adult male foot)
    c. 0.5 meters, 50 centimeters
    d. 6 grams
    e. 2 kilograms
    f. 3–4 liters, depending on the size of the box
2. 22°C
3. You would be quite cold without a jacket!
4. You would feel pretty warm.
5. It is difficult to measure the height of a plant accurately. The top of a plant can be defined as the top branch or the top leaf. The leaf can be stretched to its full height or left as is. The bottom of the plant is also hard to define since the ground is uneven and perhaps squishy. All things considered, the uncertainty would likely result in a margin of error of 2–3 centimeters, depending on the size of the bush.
6. It is hard to tell exactly how high the ball has bounced since it is only at the apex of its bounce for a tiny amount of time. Greater accuracy can be achieved through many repeated trials and by using a measuring device that is at least as tall as the bounce.
7. There are many possible methods for measuring reaction time. One such method involves only a ruler and a bit of calculations. For younger students, the teacher could do the calculations and display a results table. The first student will hold a ruler vertically in the air. The second student will hold out a hand as if to grasp the ruler between the thumb and fingers but will not actually touch the ruler. The zero mark on the ruler should align with the second student's fingers. Without warning, the first student should drop the ruler. The distance that the ruler dropped before being grabbed by the second student should be recorded. This should be repeated several times to find an average distance. The reaction time can be found with the following formula where *t* represents reaction time and *d* represents the average distance that the ruler fell:

$$t = \sqrt{(2d \div 9.81)}$$

This method would yield less uncertainty with more repetitions and with accurate measuring of the distance that the ruler fell. However, unless an entirely electronic method of measuring reaction times can be found, a certain amount of human error will enter into the process, and, in some sense, the test will measure the reaction times of both students combined.

Alternate method: Each student should have a stopwatch. The first student will say, "Go" when he starts the stopwatch. The second student will start his stopwatch when he hears the student say, "Go."

8. The result will be more accurate with a 10 ft. long tape measure, because there will be only the uncertainty of a single instrument. However, if a single 1 ft. long ruler is used, the uncertainty will be multiplied each time the ruler is moved, especially as the ruler will have to be moved several times to make the full measurement.
9. The mass of the clay should not change noticeably. The mass does not depend on the shape of the object.
10. Provided that there are no contained hollow sections, the volume of the clay should not change.
11. If the balls are approximately the same size, they should have approximately the same volume as well. Many people will predict that that metal ball will make the water level higher (i.e., have a greater volume), because the distinct concepts of mass, density, and volume are often confused.
12. There will be a certain amount of uncertainty (a couple centimeters) due to the fact that heights vary slightly throughout the course of the day and that people being measured may stand especially straight or may stretch out their arms. Although there will be natural exceptions to this generalization, with a large enough sample size, you find that most people are about the same width as they are tall.
13. Based on the method used to count the squirrels, the two numbers are about the same. A difference of 4 from 80 is a very small degree of variation between the two counts.