CHAPTER 13

Analyzing Investigations

National and State Standards Connections

- Develop general abilities, such as . . . identifying and controlling variables. (NSES 5–8)
- Select and use various types of reasoning and methods of proof. (NCTM Pre-K–2)
- Identify the single independent, the dependent and the controlled variables in an investigation. (California Content Standards, Grade 5)

Purpose

Before you can design your own investigations, you need to learn to recognize the parts of a typical investigation. What are the variables under study? What hypothesis is being tested? These and other questions can be answered by analyzing an investigation.

Objectives

After completing this chapter you should be able to:

1. Identify the independent and dependent variables and the constants in an experiment.
2. Identify the hypothesis being tested when supplied with a description of an investigation.

Controlled Experiments

You're hungry and want boiling water for spaghetti quickly. Should you put the salt in before the water boils or after? What effect does adding salt to water have on the time it takes the water to boil?

Suppose you wanted to test the hypothesis, *If the amount of salt added to water increases, then the time it takes to boil will also increase.* To test this idea, you could heat three pots of water. Add a small amount of salt to one pot and a larger amount to another. Heat the third pot with no salt added to serve as a standard of comparison, or control. You would need to keep several other factors the same, such as the amount of water in each pot and the kind of metal each pot was made of. Without keeping these and others factors the same, you would not be sure if the results were the result of differing amounts of salt or some other variable that was not kept the same throughout the experiment.

In an experiment we want to be able to say that the independent variable and only the independent variable affects the dependent variable. We must make sure that all other variables that could affect the results are prevented as much as possible from having an effect.

The term ***variable*** describes factors that change or could possibly change in an experiment. A variable that might affect an experiment but is kept from doing so is called a ***constant.*** Constants are all those factors that are kept the same so they are prevented from affecting the outcome of the experiment. Some people refer to an experiment with explicit constants as a ***controlled experiment.***

Activity 13.1

Holding Factors Constant

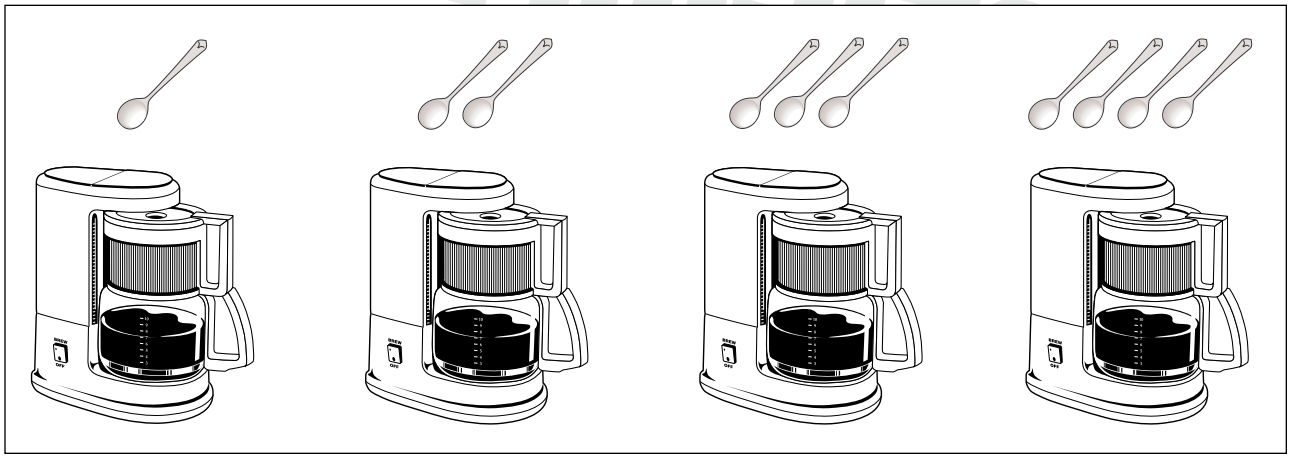
What factors were kept the same in this experiment on the effect of amount of coffee on the color of coffee produced?

Six cups of tap water were placed in each of four identical coffee makers. Then 1 scoop of Brand X coffee was added to the first coffee maker, 2 scoops to the second, 3 to the third, and 4 to the fourth coffee maker. The coffee maker ran through its full cycle each time.

BIG Ideas in Science 13.1

Holding Factors Constant

- A factor that might affect the outcome of an experiment but is kept from doing so is a *constant.*
- The data resulting from a scientific investigation may not be accurate if some conditions are not kept the same.



1. State the factors that were held constant and describe how they were kept the same.

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

2. *What factors are held constant in the following experiment?*

   A herd of Angora goats is divided into two groups. Both groups are housed in the same building, fed at the same time each day, and given the same amount of water. One group gets Brand X feed and the other Brand Y.

   _____ _____

   _____ _____

   _____ _____

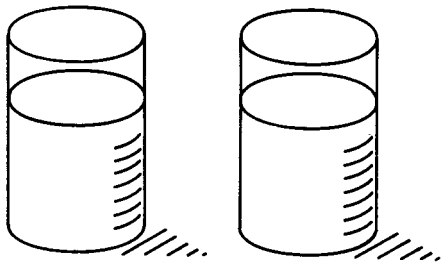
3. What additional factors did you assume were kept the same in the previous experiment, even though they were not specifically mentioned in the description?

   _____ _____

   _____ _____

   _____ _____

4. From this drawing alone, what factors would you infer were kept the same in this experiment setup?



   _____

   _____

   _____

   _____

5. Consider an experiment to test the prediction that the more light plants receive, the taller the plants will grow. Amount of light, the independent variable, changes because you purposely changed the light. The other variable, height of the plants, is your dependent variable and it changes in response to how you changed the independent variable. All other factors must be kept the same. Among the constants in this experiment are:

   - All the plants are the *same* size
   - The *same* soil in each pot
   - Water at the *same* time each day
   - Given the *same* amount of water
   - Kept in the *same* place

   Suppose two groups of plants were used. One group of plants would receive more light than the other group of plants. All other potential variables would be kept the same for each group of plants. They would become the constants for this experiment.

   By keeping all other factors the same, the experiment is a fair test of how amount of light affects the height of plants.

   Suppose in this experiment one group of plants was grown at 16 °C.

   At what temperature would you grow the other group of plants? ____

6. What factors should be held constant to test the following hypothesis?

   If the amount of salt added to ice is increased, then the temperature of the mixture will decrease.

   _____ _____

   _____ _____

   _____ _____

Go to page 264 to check your answers for Activity 13.1.

Hypotheses

Scientists are interested in explaining events. To do so they conduct investigations to determine how independent variables affect dependent variables. In order to plan what investigation should be conducted a statement called a hypothesis is made. Before you conduct an experiment, you should try to predict what is going to happen. You need to think about how changing your independent variable will affect your dependent variable. This type of prediction about the effect an independent variable will have on a dependent variable is called a **hypothesis.**

Activity 13.2

Constructing Well-Stated Hypotheses

1. What two variables are included in a hypothesis?

   _____

   _____

   _____

   A hypothesis can be written in several ways. One typical way is in the form of ***"If . . . , then . . ."*** sentences.

BIG Ideas in Science 13.2

Constructing Well-Stated Hypotheses

- A *hypothesis* is a prediction about the possible effect an independent variable will have on a dependent variable.
- A hypothesis points the way toward the design of an experiment to test it.

If the amount of salt added to ice *(independent variable)* is increased *(describe how you change it)*, ***then*** the temperature of the mixture *(dependent variable)* will decrease *(describe the effect)*.

Another way is in the form of ***"As . . . , the . . ."*** sentences, such as

As the amount of salt added to ice *(independent variable)* is increased *(describe how you change it)*, ***the*** temperature of the mixture *(dependent variable)* will decrease *(describe the effect)*.

The same hypothesis could also be written in other formats as well:

- The greater the amount of salt added to ice, the lower the temperature of the mixture.
- Increased amounts of salt added to ice causes lower temperatures of the mixture.

Initially, young students benefit from some structure, so you might find it useful to give them a format for writing hypotheses to get them started. Note that this format is similar to the formats for titles suggested in Chapter 12.

As . . . , the . . . format:

As the _____ _____ ,
(independent variable) *(describe how you change it)*

the _____ *will* _____.
(dependent variable) *(describe the effect)*

2. A hypothesis attempts to predict an outcome. *Which of the following predicts an outcome?*

   ❍ 1. As more salt is dissolved in water, the water will become cloudy.
   ❍ 2. The earth's crust contains 90 elements.
   ❍ 3. Magnetism and gravity are not the same.
   ❍ 4. If the length of a vibrating string is increased, the sound will become louder.

Young students often think of a prediction as a guess, even a *wild* guess. Some teachers introduce the term *educated guess* to help students understand that predictions are based on previous related knowledge and/or experience and are therefore not wild, random guesses. However, many students find it difficult to see the distinction among guesses of any type. You may find it more useful to ask students to write their hypothesis and then add an additional statement that explains *why* they predicted the way they did. Here are a few examples of what students might write:

a. As the temperature of a cold-blooded animal's environment increases, the temperature of its body also increases. (Cold-blooded animals can not sweat to cool themselves, or maybe because they have no fur or fat to insulate their bodies.)

b. A change in weather causes a change in mood. (My grandmother who has arthritis complains more on rainy days.)

3. Which of these is stated as a hypothesis?

   ❍ 1. If cloud cover serves as an insulator, then the surface temperature of the earth should get colder on cloudless nights.
   ❍ 2. Green leaves manufacture food, stems transfer food, and roots store the food.

4. Which of these are hypotheses?

   ❍ 1. The colder the temperature, the slower plants grow.
   ❍ 2. The deeper one dives, the greater the pressure.
   ❍ 3. Algae are living organisms.

5. Now you try to write a hypothesis. Write a statement that predicts the outcome if the *amount of light* is one variable and the other is *plant growth.*

   _____

   _____

   _____

You now have had some practice in identifying variables and hypotheses when given partial descriptions of investigations. Next you will analyze the entire investigation and identify the variables involved and the hypothesis being tested.

6. Carlos was interested in determining the effect the number of seeds planted in a particular space will have on the growth of the plants. He planted the same type of radish seeds 1 cm deep in identical cups using the same kind of potting mix. In the first cup he planted 5 seeds, in the second 10 seeds, in the third 15 seeds, and in the fourth cup he planted 20 seeds. Each cup received the same amount of water twice a week. He measured the length of the leaves at the end of 3 weeks.

   What factors were kept the same (the constants)?

   _____

   _____

   What variable was manipulated (the independent variable)? _____

   Which variable was expected to respond (the dependent variable)? _____

   What was the hypothesis being tested? _____

   _____

   _____

7. Here is a description of another experiment:

   Is there a relationship between the amount of training received and the length of time a learned behavior persists in insects? Select a number of sowbugs (pill bugs or 'rollie-pollies') which always turn right when entering the intersection of a T-shaped maze. Using the tendency of sowbugs to avoid light, it is possible to train them to turn left by shining a strong-light from the right as they enter the intersection. Subject an insect to 1, 5, 10, 15, or 20 training sessions. Test each insect once an hour by running it through the T-maze.

   What were some of the constants?

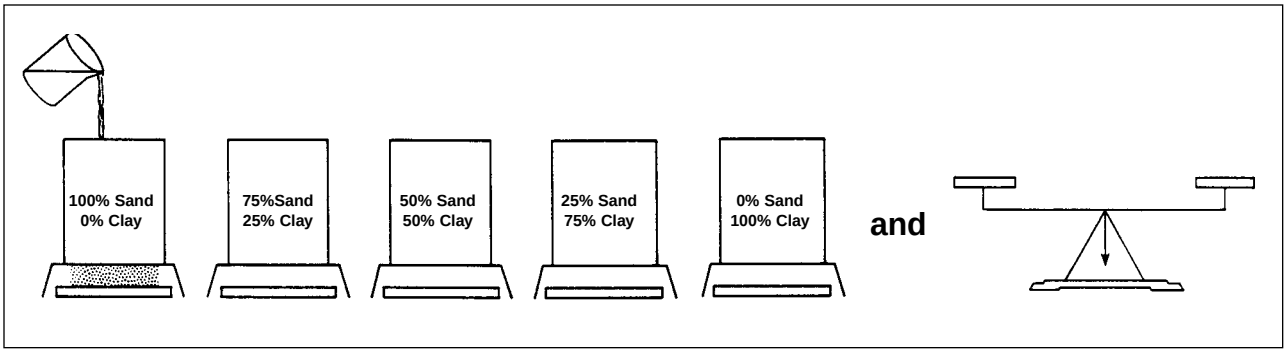
   _____ _____

   _____ _____

   What was the independent variable? _____

   Which was the dependent variable? _____

8. Suppose you read that farmers in Florida, where the soil is sandy, had to irrigate their crops frequently, but that farmers in Virginia, where the soil often has a high clay content, had to irrigate their crops less frequently even in the heat of summer. You wonder, "Will different kinds of soil hold different amounts of water?" The drawings below indicate the kinds of materials available to you. Think about how you might conduct an experiment to answer your question.



What would be your independent variable? _____

Which would be your dependent variable? _____

What would be some constants in your experiment? _____

_____

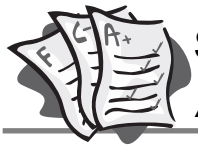
What hypothesis would you test? _____

_____

Go to page 265 to check your answers for Activity 13.2.

You now have had some practice in analyzing investigations, looking at the variables involved, and identifying the hypothesis being tested. In the next chapters you will begin the task of designing your own investigation.

Now take the Self-Assessment for Chapter 13.



Self-Assessment
Analyzing Investigations

Read the description of this investigation and then answer the questions below.

1. A study was conducted to determine how the number of paper clips picked up was related to the number of dry cells connected to the electromagnet. The magnet, connected to 1, 2, 3, 4 or 5 D cells, was placed on the top of a pile of 100 paper clips and lifted.

   a. Identify the constants in the above investigation.

   _____ _____

   _____ _____

   b. Identify the independent variable. _____

   c. Identify the dependent variable. _____

   d. State the hypothesis being tested. _____

   _____

2. Check those statements below that are stated as a hypothesis.

   ❍ a. Baking powder is used in biscuits.
   ❍ b. The brighter the color of an orange, the juicier the fruit.
   ❍ c. Brass contains copper and zinc.
   ❍ d. As the amount of antifreeze increases, the temperature at which the mixture freezes gets lower.

3. Check the statements that are hypotheses:

   ❍ a. As the amount of cabbage in a soup increases, the intensity of the odor also increases.
   ❍ b. Most apples are red, but some are yellow.
   ❍ c. The faster a river flows, the greater the erosion.
   ❍ d. Dental floss is waxed so that it slips easily between teeth.

4. Suppose you wished to test the hypothesis stated below. Which of the factors listed should be kept the same in the experiment? *Hypothesis: The warmer the water, the faster an aspirin will dissolve.*

   ❍ a. amount of water
   ❍ b. brand of aspirin
   ❍ c. temperature of water
   ❍ d. size of the tablet

5. Write a justification statement for the following hypothesis:

   Hypothesis: The thicker the coating of peanut butter, the slower a sandwich will be eaten.

   _____

   _____

Go to page 346 in Appendix B to evaluate your answers.

High Stakes Testing

A sample multiple-choice item from State and Standardized Exams.

A student wishes to test the hypothesis that adding antifreeze to water lowers the freezing point of the water. What would be the dependent (responding) variable?

F. Amount of water put into a container
G. Amount of antifreeze added to the water
H. Temperature at which the water/antifreeze mixture freezes ←
I. Type of thermometer used to measure the freezing point

Virginia: SOL Grade 8 Released Item.

Websites and Search Terms

For more information about topics in this Chapter, use search words or phrases such as:

constants
"holding factors constant"
"interpreting data"
"writing hypotheses"

to find Web sites such as:

http://www.sasked.gov.sk.ca/docs/elemsci/g4fslc12.html

A Model for Assessing Student Learning

Assessment Type: Open Response Question

Directions to the Student

Chris wants to find out which of two spot removers is better. First, he tried Spot-Remover A on T-shirts that had fruit stains and chocolate stains. Next, he tried Spot Remover B on jeans that had grass stains and rust stains. Then he compared the results.

a. What did Chris do wrong that would make it hard for him to decide which spot remover is better?
b. If you wanted to help Chris find out which spot remover is better, how would you design an experiment?

Open-Response[1]

_____

_____

_____

Points	Scoring Guide
4	Student recognizes kinds of material, stains, and spot removers as three variables to consider. Describes control of material and stain, while varying only spot remover. Clearly identifies a plan that will make comparison of the spot removers possible.
3	Student identifies both kinds of materials and stains as variables that must be held constant. May describe a design that eliminates variables, rather than ways of holding them constant. Misses some points of logic.
2	Students saw that Chris introduced variables in his design that were not held constant. One of those variables is identified, but a way of holding the variable constant may not be described, or it may be described incorrectly.
1	Student recognizes the problem of stain removal, but makes no comment on design. Does not recognize that variables have been introduced.
0	Blank
	Examples of Student Response* for Each Scoring Guide Level
4	a. He didn't try Spot remover A on the jeans and he didn't use spot remover B on the T-shirts. b. First I would have two T-shirts with fruit stains and chocolate stains on it. Then I would put stain remover A and stain remover B on it which ever got the stains out better would be the one he would use. I would have two pairs of jeans with grass and rust stains and I would put stain remover A on one of them and stain remover B on the other. What ever gets out the stains the best would be best.
3	a. He used two different kinds of clothing, and the clothing also had different kinds of stain on them. b. I would have the same kind of clothing and I would also have the same of stains on my clothing.
2	Chris used he spot removers on different stains. I would get spot remover a and spot remover b and use them on the same stains. The find my results.
1	I would do the same thing that he did but look a the close very carefully.
*Student errors have **not** been corrected.	

[1]Source: Grade 4, Science Question 2, KIRIS Common Open-response item. Kentucky Department of Education, KIRIS Division, 500 Metro Street, Frankfort, KY, 40601.

✔Self-Check

Activity 13.1

Holding Factors Constant

Activity found on page 256.

1. | **Constants** | **How they were kept the same** |
   |---|---|
   | amount of water | same amount—6 cups each time |
   | type of coffee maker | identical coffee makers were used |
   | kind of water | same kind—tap water |
   | type of coffee | same brand of coffee—brand X |

   You may have listed other constants besides these, such as the size of the scoop. Although the size of the scoop was not explicitly stated, we can hope that the same scoop was used each time. The independent variable in this experiment is the amount of coffee and the dependent variable is the resulting color of the coffee. Any differences in color that we observe we can attribute to the independent variable, amount of coffee, provided we kept all other factors constant.

2. | | |
   |---|---|
   | type of goat | feeding time |
   | type of housing | amount of water |

   If you listed constants other than these, you may have included other factors that need to be held constant but were *not explicitly* stated in the experiment description.

3. | | |
   |---|---|
   | number in each group | age of the animals |
   | temperature of housing | bedding characteristics |
   | amount of feed available | |

   You may have thought of others. This is all right if you believe that they could affect the dependent variable.

4. | | |
   |---|---|
   | amount of liquid | kind of liquid |
   | size of container | temperature of liquid |
   | shape of container | pressure on liquid surface |

   By this time you are probably saying, *How in the world do they expect me to get all of those? Besides, I thought of some others*. This is just the point. In any experiment there could be many potential variables; so many that it is often difficult to think of them all. A good way to help you identify these potential variables is to make a list of the materials and environmental conditions used in an experiment. Then, think of ways to vary each of the materials and conditions that might affect the outcome of the experiment.

5. 16 °C

6. *Several identical containers* were filled with the *same amount* of ice. Use the *same kind of salt* in each and measure the temperature with the *same kind of thermometer* in each.

   You may have thought of others. As long as you were attempting to keep everything in all setups the same except the amount of salt, it would be appropriate.

Activity 13.2

Constructing Well-Stated Hypotheses

Activity found on page 258.

1. Independent variable
   Dependent variable

2. #1 and #4 predict the effect one variable will have on another.

3. In #1 the effect of the independent variable (amount of cloud cover) on the dependent variable (surface temperature at night) is predicted. Therefore, #1 is a hypothesis. To justify their hypothesis, a student might add, "I read that clouds act as insulators."
   In #2, only factual information is given, and is therefore not a hypothesis.

4. 1, 2

   #3 is merely a statement of fact and is therefore not a hypothesis.

   #1 and #2 are hypotheses. As an additional step, students could have added the following to justify their hypotheses:

   #1 (I know that greenhouses are kept very warm.)

   #2 (The deeper you go, the more water there is pushing down on you.)

   One advantage to having students write a justification statement for their hypotheses is that it gives you, their teacher, some insight into their thinking. Their reasons may not always be correct, but you will at least know why they hypothesized as they did.

5. The greater the amount of light, the greater the amount of plant growth.

   or

   The less light the plant receives, the less the plant will grow.

   These are just some of the predictions that you could have written as you thought about what might happen to one variable as you purposely changed another. Information you know and your prior experiences both contribute to your ability to hypothesize about what will happen. If you test your hypothesis, you are testing your reasoning as well. When designing an experiment to test your hypothesis, you should use only one independent variable. You could, if you wanted, have more than one dependent variable because there are often multiple ways to measure the resulting effects. You would also want to be sure that all other potential variables are kept the same in your experiment. These factors become your constants.

6. Some factors that were kept the same are: kind of seed, planting depth, soil, environmental temperature, amount of water, kind of container, and amount of light received. Because the number of plants in a particular space was manipulated and the length of the leaves was expected to respond, the hypothesis probably was: *As the number of plants in an area increases, the length of the leaves will become shorter.* Or it could have predicted that the leaves would be longer. In stating a hypothesis, the decision as to what the effect will be can be based on past experience, related information, and even a hunch, but should never be a wild guess. Until data are gathered and interpreted, however, one prediction may be just as valid as another.

7. type of animal
   shape of maze
   strength of light source
   environmental temperature

   These are just some of the constants. You may have stated others.

   The independent variable was the amount of training, while the dependent variable was the length of time a learned behavior persisted.

8. The percent of sand and clay is the independent variable, while the mass of the retained water is the likely dependent variable. Factors that could vary, such as the amount of soil, volume of the containers, soil temperature, kind of sand, and kind of clay must be kept the same. The hypothesis most likely being tested is: *As the amount of clay in the soil increases, the amount of water retained by soil also increases.*