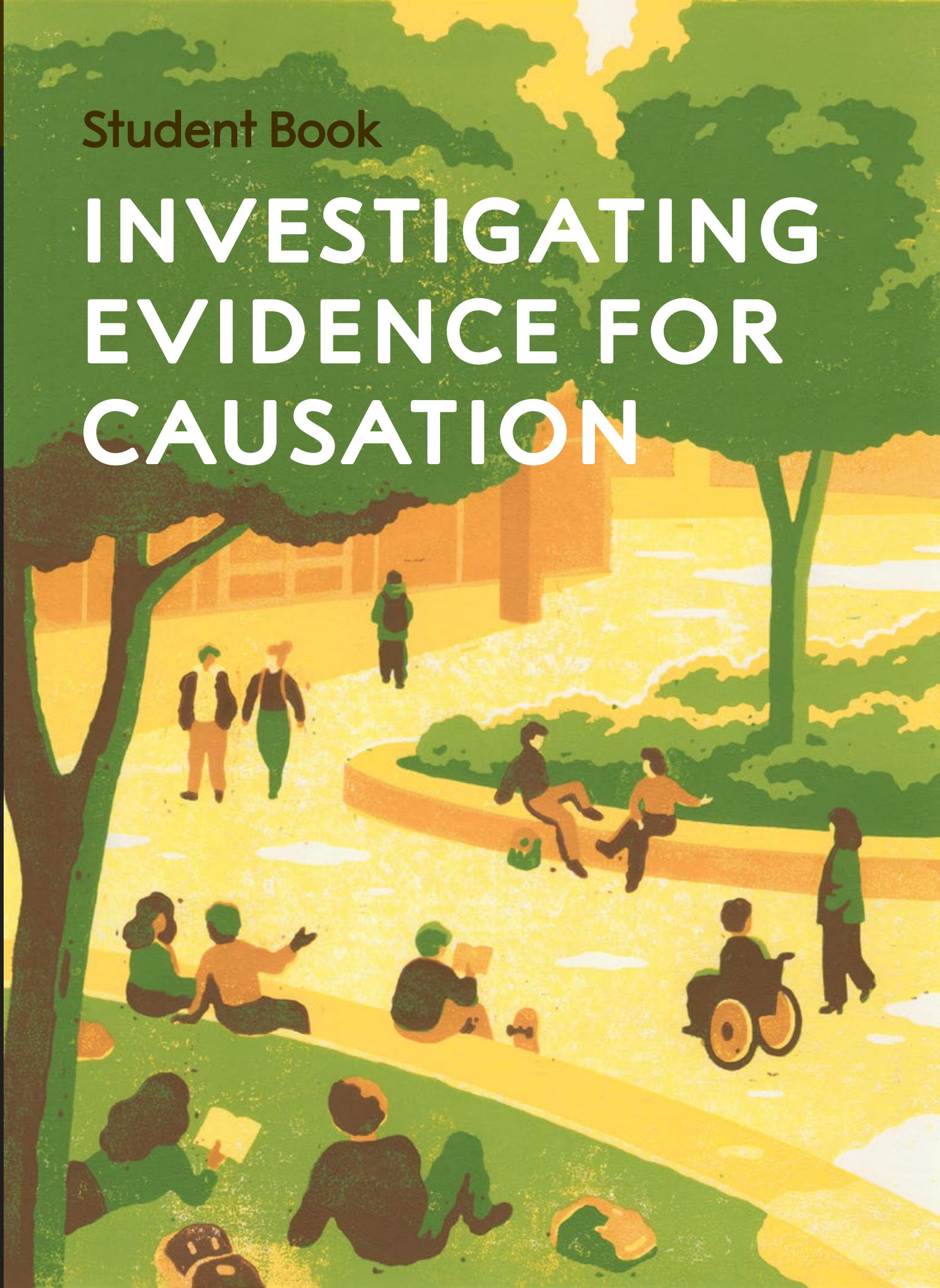
UNIT 4

v 1.0

SCIENTIFIC THINKING FOR ALL : A TOOLKIT

Student Book

INVESTIGATING EVIDENCE FOR CAUSATION



This book is part of the *Scientific Thinking for All: A Toolkit* curriculum that is a high school adaptation of the University of California, Berkeley, "Big Ideas" course titled Sense and Sensibility and Science https://sensibility.berkeley.edu/. It was developed by professors Saul Perlmutter, John Campbell, and Robert MacCoun and represents a collaboration among physics, philosophy, and psychology. *Scientific Thinking for All: A Toolkit* was developed by curriculum developers and researchers at The Lawrence Hall of Science, University of California. The initiative is a cooperation between Nobel Prize Outreach (NPO) and Saul Perlmutter. This work is supported by a consortium of funders including Kenneth C. Griffin, the William and Flora Hewlett Foundation, the John D. and Catherine T. MacArthur Foundation, the Gordon and Betty Moore Foundation, and The Rockefeller Foundation.

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Scientific Thinking
For All : A Toolkit

UNIT 4
Investigating
Evidence
for Causation
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STUDENT BOOK

THE LAWRENCE HALL OF SCIENCE
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DEAR STUDENT,

Have you ever read a news article and wondered if the information it contained was true? Or had a friend make a claim and wondered if they were right? This curriculum will equip you with ideas and techniques from science that can be applied to everyday life. Your conceptual toolkit will include strategies to help you evaluate information, reflect on your thinking, and make more informed decisions. You will use these tools to ask questions, brainstorm ideas, interpret data, manage trade-offs, and develop solutions.

Scientific tools and techniques can lead to a better understanding of how the natural world works and provide approaches to solving the problems facing individuals, communities, and the environment. Each unit will provide you with additional conceptual tools for your toolkit, and you'll practice applying them to personal and societal issues such as human health, environmental pollution, and energy use. For example, you may consider questions such as: *How much sleep do I need? Is my community's drinking water safe?*

Science offers many useful strategies for learning about the world, including:

1. working together to share observations, questions, and ideas;
2. techniques for making sense of observations and data; and
3. the iteration of ideas by modifying them as new information becomes available.

Since it's difficult for anyone to catch their own mistakes, you'll collaborate with your classmates to share your thinking and learn from one another. It is our hope that this science toolkit will empower you to think more clearly about the things you care about, to provide you with strategies for addressing problems, and to help you achieve your personal goals.

Sincerely,

Scientific Thinking for All Program Team

TABLE OF CONTENTS


Investigating Evidence
for Causation

UNIT 4

INVESTIGATING EVIDENCE FOR CAUSATION

In this unit, you will explore concepts related to causal reasoning as you investigate scientific research on well-being. By investigating how different strategies impact a person's overall well-being, you will learn about cause-and-effect relationships. You will use causal reasoning by applying key questions that help identify causation and reveal alternative explanations. You will practice how to tell correlation from causation and how scientists design randomized controlled trials to gather evidence for causation. Considering these ideas will help you evaluate both everyday and scientific claims, enabling you to make a better-informed decision for yourself and your communities.

UNIT DRIVING QUESTION

How can scientific investigations provide evidence for cause-and-effect relationships, such as how different factors affect health and well-being?

CONCEPTUAL TOOLS

In this course, conceptual tools refer to scientific ideas and approaches that can be applied to real-world situations. Each conceptual tool is further explained in the activity in which it is introduced. The conceptual tools found in this unit are shown here and in each activity in which they appear.

Causal Reasoning

Indicators of Causation

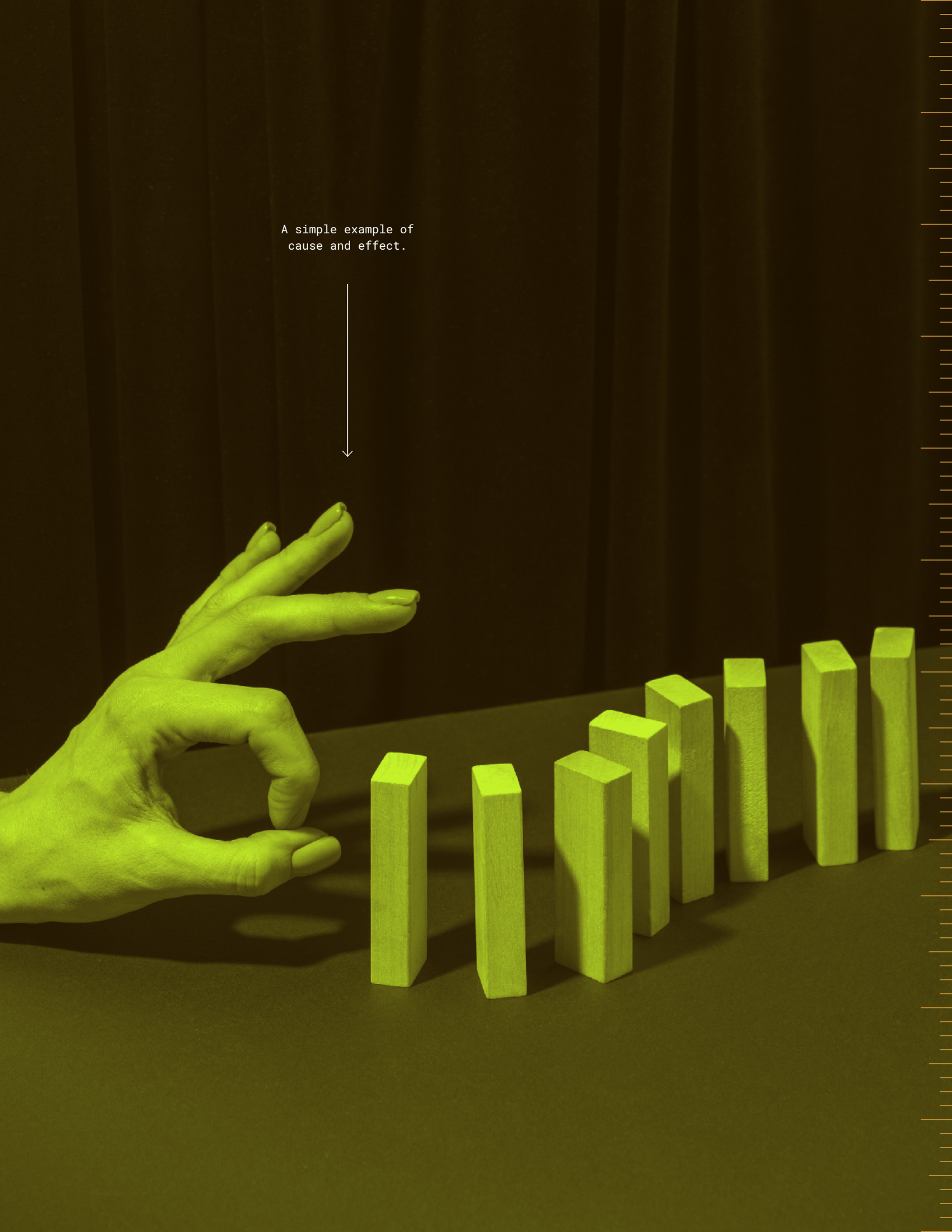
Correlation

Randomized Controlled Trials

ACTIVITY 1

Cause-and-Effect Claims

INVESTIGATION


A simple example of
cause and effect.

1 : CAUSE-AND-EFFECT CLAIMS

GUIDING QUESTION

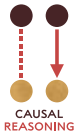
Why is it important to identify possible cause-and-effect relationships?

INTRODUCTION

One of Yale University's most popular courses is a class for teenagers on happiness. Psychology professor Laurie Santos developed the free online course to help high school students improve their overall well-being. Well-being is a combination of a person's mental, physical, emotional, and social health, both short-term and long-term. A person's well-being is related to someone's mood, health, attitudes, and relationships with others. By studying potential causes of unhappiness, researchers like Dr. Santos hope to discover and share useful strategies for improving people's well-being.

Throughout this unit, you will use causal reasoning to evaluate strategies to improve well-being. Causal reasoning is the use of observation and logic to identify cause-and-effect relationships. Causal reasoning is a powerful tool that helps evaluate problems and potential solutions for individuals and communities. In this activity, you will begin to use causal reasoning to evaluate possible strategies for increasing well-being.

CONCEPTUAL TOOLS



If you need to review the concept of scientific variables, you will find a Science Review at the end of this activity.

MATERIALS LIST

FOR EACH STUDENT

- STUDENT SHEET 1.1 "Evaluating Salas High School Forum Posts"

Dr. Laurie Santos teaches research-backed methods for increasing well-being to high school and college students.

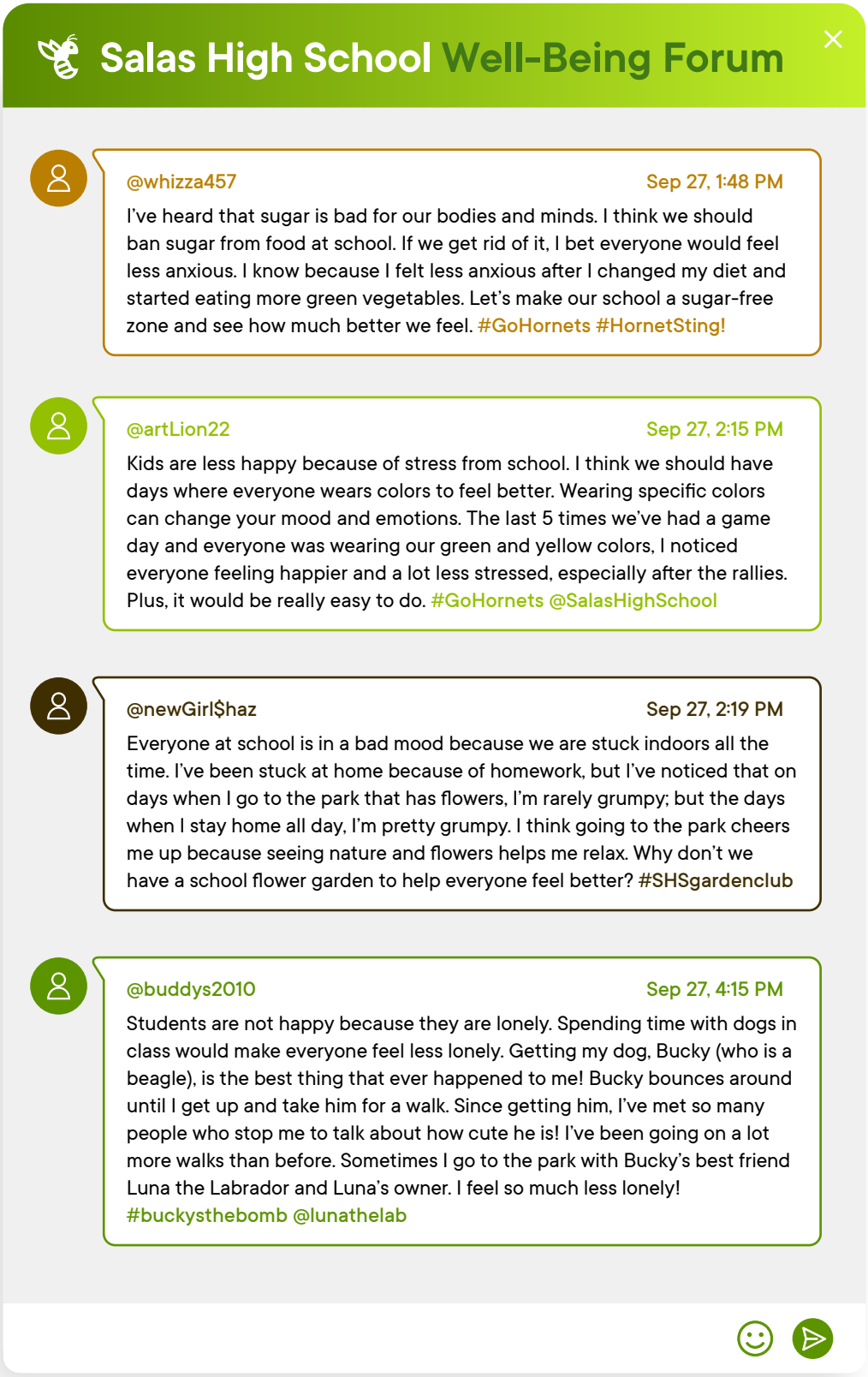
PROCEDURE

1 As a class, read the following fictional scenario:

> *The staff at Salas High School wants to improve the well-being of their student population. They hope to identify strategies that students can use to better cope with every-day stress in order to improve their well-being. The school created a Well-Being Task Force made up of students with the goal of recommending a well-being strategy for Salas High School. The recommendation depends on:*
>
> 1 *strong evidence that the strategy will increase teenage well-being.*
>
> 2 *a practical way to implement the strategy at Salas High School.*
>
> *The task force has begun by collecting suggestions from students and staff for schoolwide strategies to improve well-being.*

2 In your group, brainstorm at least two well-being strategies that might be effective for students at the school. Discuss what type of information you would want to know about the strategies to decide if they would be successful in a school setting. Record your ideas in your science notebook.

3 Six members of the school have submitted suggestions on the Well-Being Task Force social media page. As a group, read the following posts:



4 A problem and its possible solutions can be evaluated by studying causation. Causation is when a change in one factor leads to a change in another. Often the changes are simple, such as an increase in the number of cats in a house (a cause) leading to a decrease in the number of mice (an effect). A cause is a factor that produces a change in another factor (the effect). An effect is a factor that is changed by another factor (the cause).

The relationship between a cause and its effect can be represented as variables X and Y. With your group, use Student Sheet 1.1, "Evaluating Salas High School Forum Posts," to help analyze each post. Use causal reasoning to identify the variable that represents the possible cause (X) and possible effect (Y) for both the problem and the proposed solution for each post. Record your ideas in the appropriate columns on the student sheet.

5 Choosing an effective strategy depends on identifying the cause of the problem and evaluating how well the strategy would work to solve the problem. After you have analyzed the proposed solutions suggested in the posts, discuss with your group which strategy you think would be *most effective* and which would be *least effective* in improving well-being. In your science notebook, record:

a ideas that support your choices, based on your own background knowledge.

b the kind of additional evidence you would want to gather.

Be ready to share your ideas with the rest of the class.

6 Based on the suggestions, the Well-Being Task Force has decided on four possible schoolwide well-being strategies to explore further. These are described in Figure 1.1.

FIGURE 1.1
Proposed Well-Being Strategies for Salas High School

Gratitude Writing

A way for students to express gratitude through writing such as keeping a journal, writing a letter to someone, sharing thank-you notes, or another form of written expression.

Pet Therapy

A way for students to interact with animals such as helping at an animal shelter, visiting with a therapy animal, or providing time to spend with a dog at school.

Green Spaces

A way for students to spend more time in natural places such as tending a school garden, regular visits to a park, adding more plants around campus, or another way to bring nature into their routine.

Quality Sleep

A way to help students get more and better sleep such as starting school later, teaching about healthy sleep habits, or some other way of helping students get better rest.

With your group, choose one of the four strategies (from Figure 1.1). In your science notebook, record:

a ideas that support your choice, based on your own background knowledge.

b the kind of additional evidence you would want to gather.

7 Share your ideas from Steps 5 and 6 with the class.

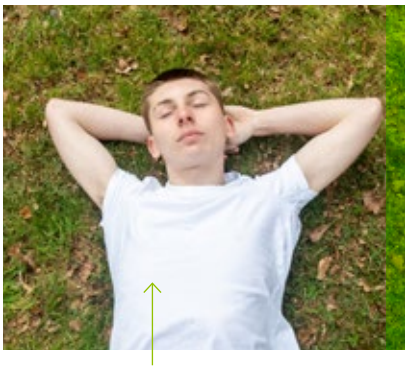
BUILD UNDERSTANDING

1. Choose one of the well-being strategies that your group brainstormed in Procedure Step 2. Use causal reasoning to:
   - **a** identify a well-being problem that you think this strategy addresses. Describe the possible cause(s) of that problem.
   - **b** evaluate how likely it is that the strategy would help to solve the problem. Explain your reasoning, using your own background knowledge, and describe what evidence you would want to gather to be more sure that the strategy would work.

The Build Understanding and Connections to Everyday Life items are intended to guide your understanding. Some of these items may be discussed with a partner, be part of a class discussion, or require an individual written response. Your teacher will guide you as to how these items will be used in your class.

CONNECTIONS TO EVERYDAY LIFE

2. Which of the following are examples of possible cause-and-effect relationships? For each, use your background knowledge to explain your answer.
   - **a** The sound of a fire engine siren and cars pulling to the side of the road.
   - **b** Doing my laundry on Thursday and spilling food on my shirt the next day.
   - **c** A cat sitting on a windowsill, and a bird flying past the window outside.
   - **d** Someone swallowing acetaminophen, and the pain in their sprained wrist going away a short time later.
3. What do you do in your own life that helps your well-being? Describe any evidence you have that it works.
4. Avery struggles to fall asleep at night and thinks their mattress is the problem. They go out and buy a new mattress, but they haven't considered whether staying awake and on their phone could be the cause instead. Explain how this situation shows the importance of investigating cause and effect.



Finding activities that support well-being can improve physical and mental health.

EXTENSION

Explore more well-being strategies and investigate one or two that interest you by using the resources your teacher provides.

KEY SCIENTIFIC TERMS

causal reasoning
causation
cause
effect
well-being

SCIENCE REVIEW

SCIENTIFIC VARIABLES

Independent and Dependent Variables

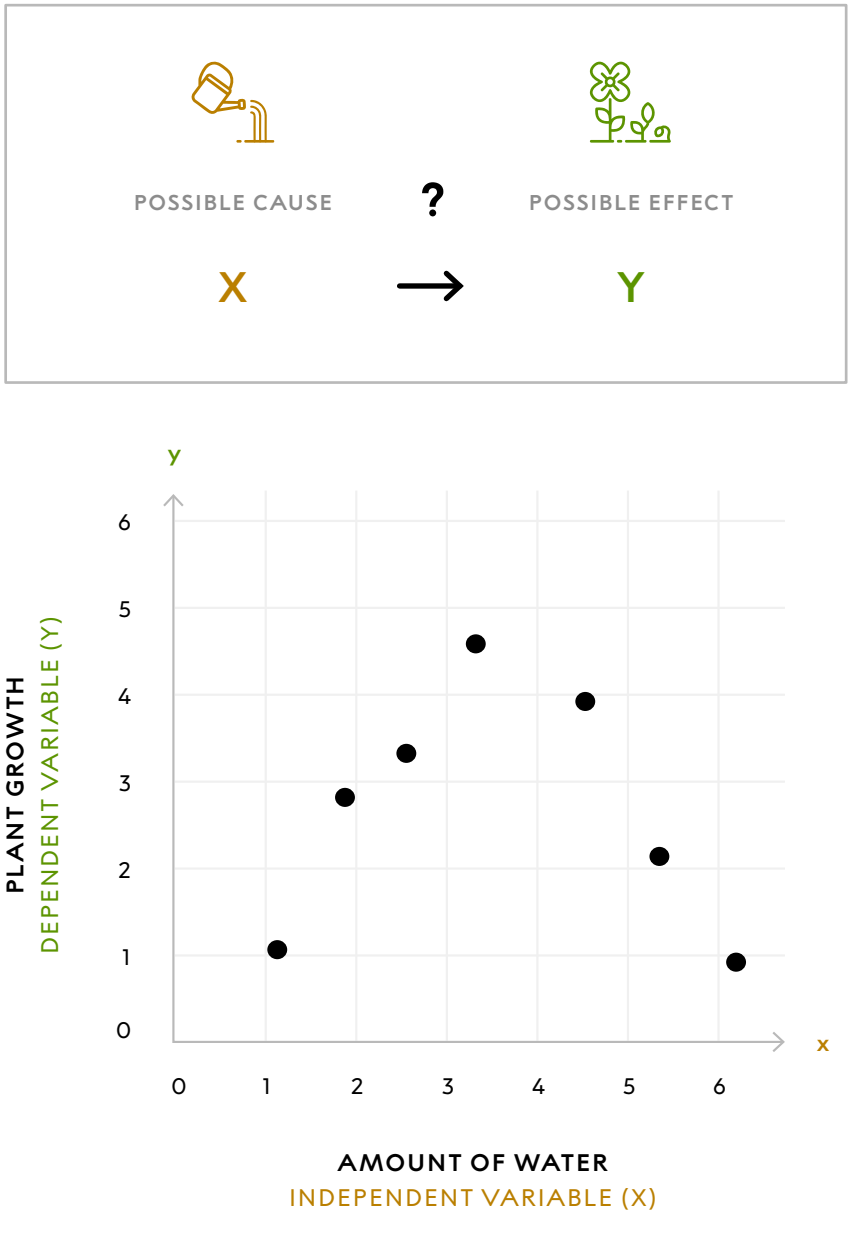
Although the terms *cause* and *effect* can be used in everyday situations, scientists consider both as variables when they study causation. A *variable* is a feature, factor, or result that can change or vary. The *independent variable* is the variable in an experiment that is manipulated (typically using a treatment) to test its effect on the dependent variable. The *dependent variable* is the variable in an experiment that is measured after the independent variable has been manipulated to see if it changes as a result of the manipulation.

In a research study, the independent variable is the possible cause, and the dependent variable is the possible effect being investigated. For example, if you want to know if the amount of water has an effect on the number of leaves on a plant, you could set up an experiment with three plants that are the same type and size and have other characteristics that are the same. Your independent variable is the amount of water—that's what you will adjust in the experiment—to create a difference between the group you are testing and the comparison group. Your dependent variable is the number of leaves on the plant. You can count the leaves and make comparisons between the plants to see if the number of leaves is affected by the amount of water.

Graphing Variables

One of the purposes of collecting data is to see a trend between the independent variable and the dependent variable. When displaying the data on a graph, scientists use a standard approach that plots the independent variable (X) on the x-axis and the dependent variable (Y) on the y-axis. This is shown in Figure 1.3.

FIGURE 1.3
Graphing Variables



ACTIVITY 2

Measuring Well-Being

LABORATORY

Some devices can measure a wide range of health metrics, such as heart rate and sleep patterns.

2 : MEASURING WELL-BEING

GUIDING QUESTION

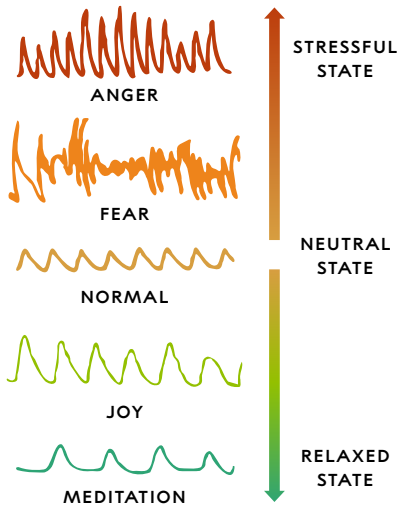
What are the challenges of studying well-being?

INTRODUCTION

Dr. Michael Otto likes to give simple advice on well-being: "Go out for a walk. You'll feel better." Dr. Otto is a professor in the Psychological and Brain Sciences department at Boston University. Based on years of research, he and his colleagues recommend exercise to improve well-being. While Dr. Otto's advice seems straightforward, his research is part of a larger effort to understand how well-being is influenced by both mental and physical factors.

To understand well-being, researchers investigate its effects on both the mind and the body. This includes everything from studying emotions to measuring physical changes. Emotional well-being can be measured by observing behavior or asking people questions about their moods and feelings. Some measurable physical signs that relate to well-being include changes in heart rate, breathing, and hormone levels. In this activity, you will test if exercise can improve well-being, and you will investigate the challenges of studying it.

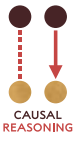
FIGURE 2.1
Breathing Patterns for Different Emotions



The graph shows the patterns and rates of breathing for different emotional states over 25 seconds. Each peak represents one breath.

If you need to review the concept of body systems related to exercise, you will find a Science Review at the end of this activity.

CONCEPTUAL TOOLS



MATERIALS LIST

FOR EACH PAIR OF STUDENTS

- TIMER
- CALCULATOR
- STUDENT SHEET 2.1 "Measuring Physical and Mental Responses to Exercise"

PROCEDURE

1 Read the following fictional scenario as a class.

> *Pedro is a student at Salas High School and would like to recommend exercise as a well-being strategy. However, he has doubts about whether it will have a measurable difference. Speaking to the Well-Being Task Force, he says, "I think it might be difficult to evaluate the well-being of students and learn if our recommended strategy actually has a positive impact. I am not even sure someone can reliably measure a student's feelings or well-being. I mean, people react differently to situations, and their emotions change all the time!"*
>
> *The Well-Being Task Force decides to explore Pedro's concerns further. They ask biology students at Salas High School to compare physical and mental measurements of well-being before and after exercise.*

2 You will be working in pairs to test if exercise causes a change in well-being by measuring heart rate, mood, and alertness levels. Decide which partner will take the exercise test and which partner will be the timer and record the data on a student sheet.

3 Discuss the following questions with your partner. Record your ideas in your science notebook.

   a Your class will be averaging the data from many students who are doing the experiment. How does this help to improve the accuracy of the results? Explain your answer.

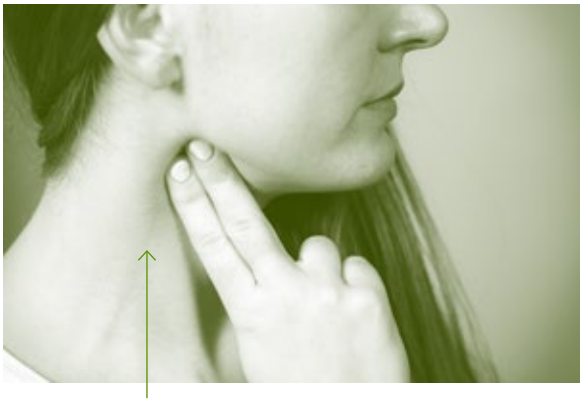
   b In your class data, do you think it will be more difficult to notice changes in heart rate, mood, or alertness? Explain your prediction.

4 Prepare to have your test partner measure their heart rate before exercising by having them sit comfortably.

5 Your test partner will measure their average heart rate while you record the data in the Before Exercise table on Student Sheet 2.1, "Measuring Physical and Mental Responses to Exercise."

- **a** Have your test partner use the first two fingers of one hand to locate their pulse at the base of their wrist or on the side of their neck.
- **b** Have your test partner count their heart beats for 30 seconds while you keep track of time.
- **c** Multiply the 30–second pulse by 2 to calculate your test partner's heart rate for 60 seconds. Record the data for Trial 1 in the Before Exercise table.
- **d** Repeat Steps 5a–5c two more times and record the data for Trials 2 and 3 in the Before Exercise table and calculate the total for all three trials.
- **e** Calculate your test partner's average beats per minute by dividing the total by 3 and recording it in the bottom row of the Before Exercise table. Then, record the average beats per minute in the "Before Exercise" row of the Data Table for Test Partner (at the top of the student sheet).

Locating the pulse on the wrist below the base of the thumb.



Locating the pulse on the side of the neck.

6 Have your test partner rate their alertness and mood on a scale of 0 to 10 (with 0 being the lowest and 10 being the highest). Record their ratings in the "Before Exercise" row in the Data Table for Test Partner on the student sheet.

7 Wait for your teacher's instructions. When you get the signal to do so, have your test partner exercise once for 3 minutes and then immediately repeat Steps 5a–5e for your test partner to measure their heart rate. Record all 3 trials and calculate the average beats per minute in the After Exercise table. Then, record the average beats per minute in the "After Exercise" row in the Data Table for Test Partner (at the top of the student sheet).

8 Repeat Step 6 to measure your test partner's alertness level and mood. Record their ratings in the "After Exercise" row in the Data Table for Test Partner.

9 Calculate your test partner's change in heart rate, alertness, and mood by subtracting the before measurement from the after measurement. Record the results in the "Change in Each Measure" row of the Data Table for Test Partner.

10 As a class, compile and calculate a class average for each variable before and after exercise:

- heart rate
- alertness
- mood

Review the data and graphs displayed by your teacher. Discuss any changes you noticed between the before exercise data and the after exercise data.

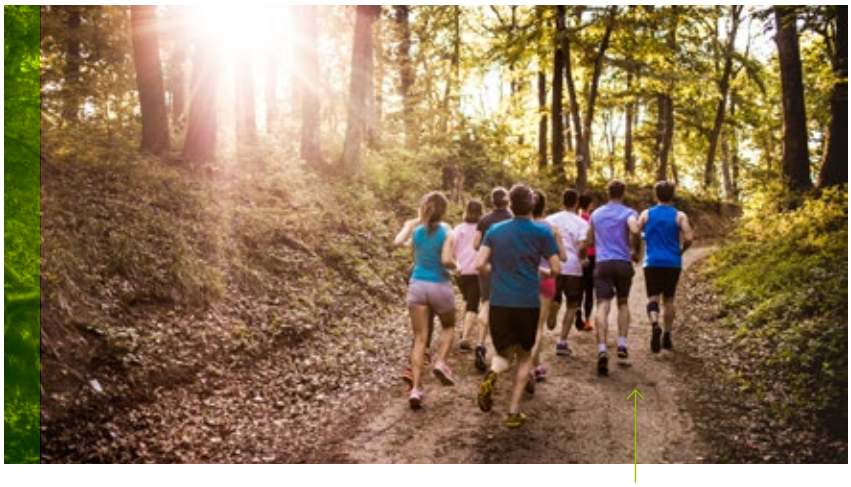
11 With your test partner, consider other reasons for what could have caused the average changes for the class. Instead of the exercise they just performed, identify other factors that might have affected your test partner's:

- heart rate
- alertness
- mood

Record your ideas in your science notebook and be ready to share them with the class.

12 An alternative explanation is another possible explanation for a result, such as an unnoticed variable or random chance. With your class, discuss which alternative explanations might have influenced your class results.

13 Using your work from Steps 10–12, how sure are you that exercise improves mood? Explain your reasoning, using data and your ideas for alternative explanations. Record your ideas in your science notebook.



Running is a popular activity that many people say improves their mood and well-being.

BUILD UNDERSTANDING

① In the class experiment, do you think it was exercise or some other factor(s) that affected your class results the most? Support your reasoning, using ideas from your class discussion.

CONNECTIONS TO EVERYDAY LIFE

② Imagine you have been having trouble sleeping for several weeks. A friend suggests going for a walk every night after dinner and recording how well you sleep each night to see if it helps.

- **a** Do you think having this kind of data would help you decide if the walks were improving your sleep?
- **b** What other data could you record that might offer alternative explanations for a change in well-being?

EXTENSION

In many well-being studies, researchers use subjective measurements, which means that people report their own feelings instead of using an outside measurement that is the same for everyone. Watch a video and do your own research to explore why scientists consider surveys of subjective well-being to be reliable tools for measuring mental well-being.

KEY SCIENTIFIC TERMS

alternative explanation

SCIENCE REVIEW

The Circulatory and Respiratory Systems

A body system is a group of organs and structures that work together to perform a specific function in the body. The circulatory system, also known as the cardiovascular system, is made up of the heart, blood vessels, and blood. The heart pumps blood through the blood vessels to deliver oxygen and nutrients to all parts of the body. The rhythmic pulsation that you feel in your wrist or neck is called a pulse, and it happens every time your heart beats. The number of heartbeats per minute is called your pulse rate or heart rate.

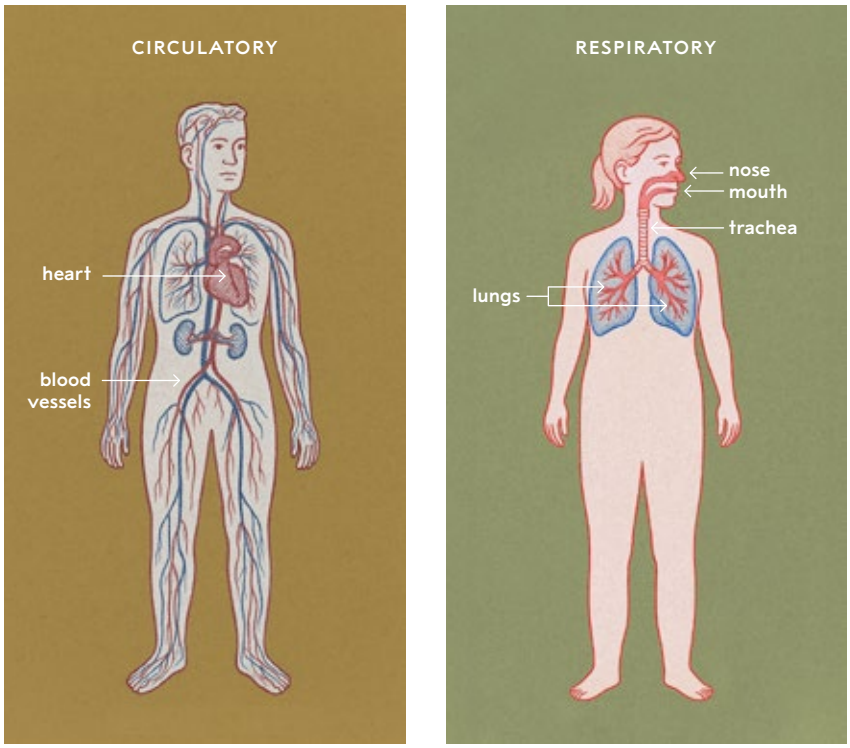


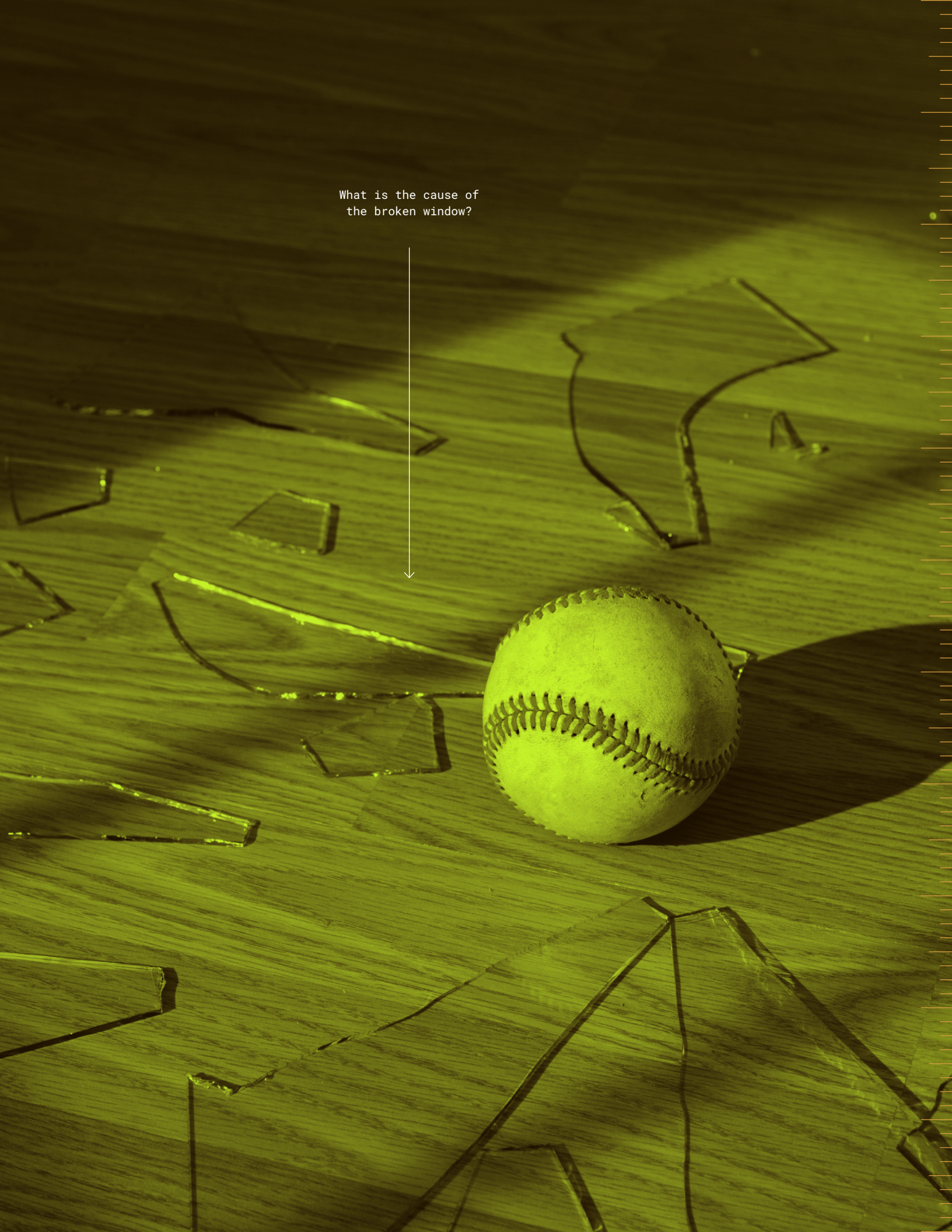
FIGURE 2.2
The Circulatory and Respiratory Systems

The respiratory system works alongside the circulatory system to provide oxygen to every cell in the body. It includes the lungs and the airways that lead to the lungs, such as the nose and mouth. When you breathe in, oxygen enters your lungs and moves into the blood. The heart then pumps this oxygen-rich blood to the rest of the body. Cells use this oxygen to break down food molecules, releasing the energy needed for movement, growth, and other functions.

ACTIVITY 3

Questioning Causation

INVESTIGATION


What is the cause of
the broken window?

3 : QUESTIONING CAUSATION

GUIDING QUESTION

How do people consider if one event caused another?

INTRODUCTION

People use causal reasoning every day when they ask why and how something occurred. Asking a series of questions is one way to examine potential evidence for or against a cause-and-effect relationship. Three helpful questions that focus on indicators of causation are:

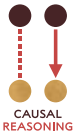
1. Do changes in the two variables tend to happen together?
2. Does the possible cause usually happen before the possible effect?
3. Is there a likely way the possible cause could lead to the possible effect?

As you explored in Activity 2, a fourth question can help evaluate a claim about causation:

4. Is another explanation for the result likely?

In this activity, you will explore how to use these questions in everyday thinking about well-being.

CONCEPTUAL TOOLS



MATERIALS LIST

FOR EACH GROUP OF FOUR STUDENTS

- STUDENT SHEET 3.1 "Causation Cartoons"
- STUDENT SHEET 3.2 "Reevaluating Salas High School Forum Posts"

What caused the paint to spill?

PROCEDURE

PART A: RECOGNIZING CHARACTERISTICS OF CAUSATION

1 Causal reasoning involves analyzing if, when, and how changes happen. A claim about causation can be investigated by asking four basic questions about a possible cause-and-effect relationship where X is the cause, and Y is the effect.

Using the four questions listed in Table 3.1, follow your teacher's instruction to review the example claim and reevaluate the image of the cat and spilled paint.

TABLE 3.1
Four Questions to Determine Cause-and-Effect Relationships

CLAIM **It must have rained because there are dark clouds in the sky, and the ground is wet.**

QUESTION	DEFINITION	EXAMPLE
How often do X and Y happen together?	association is changes in two variables that tend to happen together	Dark clouds and rain often occur together.
Does X happen before Y?	timing is the order of events in time, where the possible cause comes before the effect	Dark clouds appear before it begins to rain.
How could a change in X lead to a change in Y?	mechanism is a reasonable idea for how the possible cause could have led to an effect based on logic and knowledge	Droplets of water in the sky condense to form clouds. When clouds become very heavy with water, they release the water as rain.
Given the evidence, how likely was the change in Y caused by something other than X?	An *alternative explanation* is another possible explanation for a result, such as an unnoticed variable or random chance	A sprinkler can release droplets of water and make the ground wet, even if the clouds are not producing rain.

2 With your group members, read Cartoon 1, Panel A, on Student Sheet 3.1, "Causation Cartoons," or in Figure 3.1. Identify the claim about cause and effect being made by the person in Panel A.

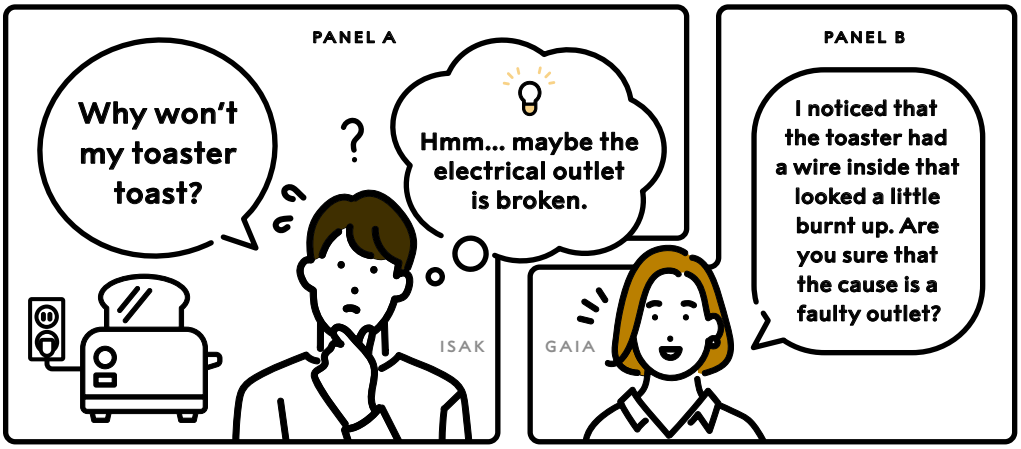


FIGURE 3.1
Cartoon 1

3 On Student Sheet 3.1, have one group member draw a circle around the supposed cause, draw a box around the supposed effect, and draw an arrow pointing from the cause to the effect.

4 As a group, read Cartoon 1, Panel B. Which kind of question about causation is the person in Panel B bringing up? Have the same group member record the type of question (association, timing, mechanism, or alternative explanation) in the box next to Panel B on the student sheet.

5 Does the information in Panel B strengthen or weaken the cause-and-effect claim in Panel A? Circle "Strengthens Claim" if it supports the claim and "Weakens Claim" if it weakens the claim.

6 Repeat Steps 2–5 for Cartoons 2, 3, and 4. For each cartoon, have a different group member record the information on the student sheet. Be ready to review your answers as a class.

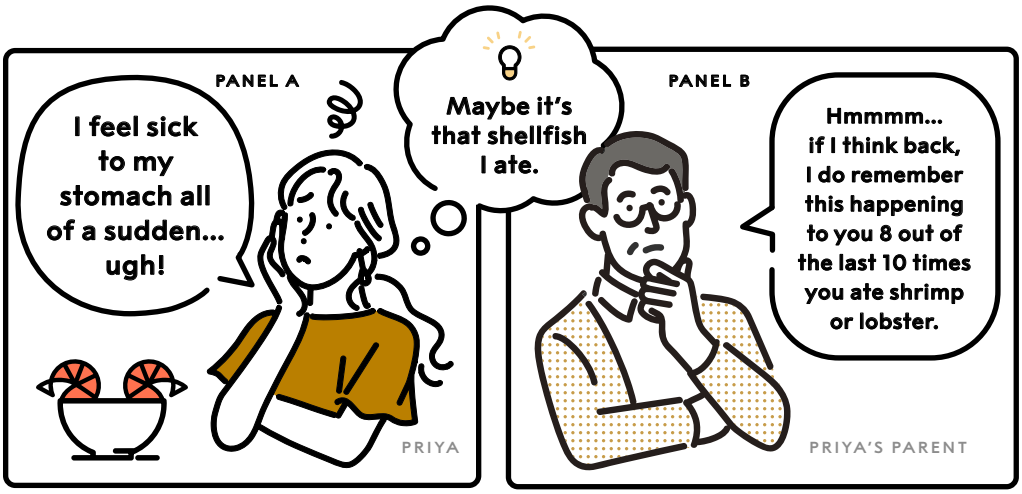


FIGURE 3.2
Cartoon 2

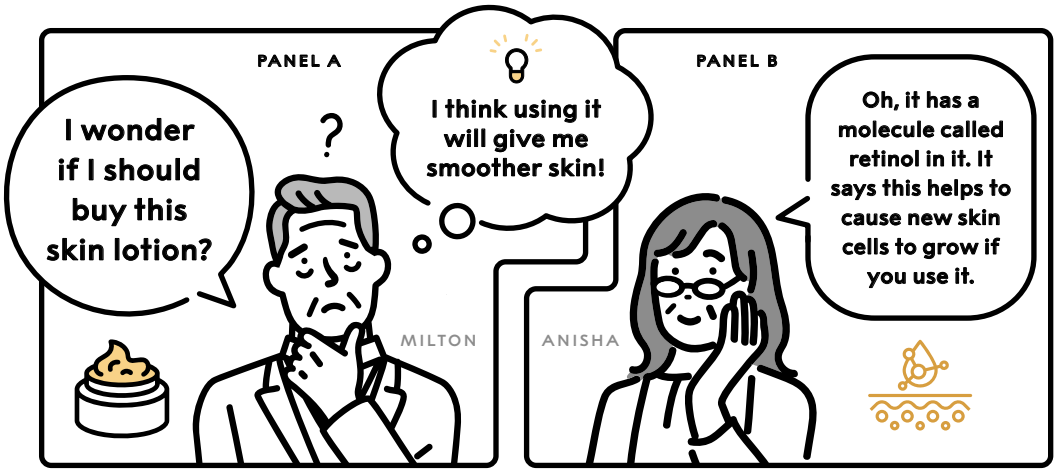


FIGURE 3.3
Cartoon 3

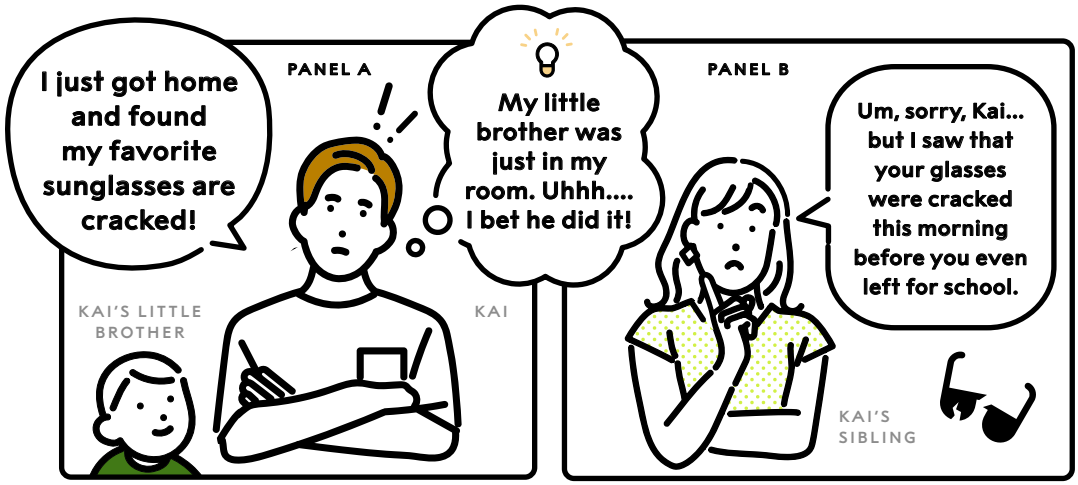


FIGURE 3.4
Cartoon 4

PART B: REEVALUATING SOCIAL MEDIA POSTS FOR WELL-BEING STRATEGIES

7 With your group, revisit the social media posts in Activity 1 and use the questions about causation to reanalyze the proposed solutions. Complete Student Sheet 3.2, "Reevaluating Salas High School Forum Posts." For each post:

- use the questions from Table 3.1 in Step 1 to decide if each indicator of causation (association, timing, and mechanism) is present or absent in each post. In the "Indicators of Causation" column on Student Sheet 3.2, make a check mark for each indicator that is present and make an *X* for each indicator that is absent.
- discuss with your group whether you think there might be an alternative explanation for the effect. Record any possible alternative explanations in the last column on the student sheet.

8 With your group, reevaluate which of the six solutions you think would be most effective and which would be least effective in improving well-being. Compare it to your ideas from Activity 1. Record your reasoning in your science notebook.

9 As a class, discuss how your ideas about the proposed solutions have or have not changed since Activity 1.

BUILD UNDERSTANDING

① Jaime says, "I have three different kinds of evidence that this new supplement is improving my grades. **1)** I've been getting better grades since I started taking it six months ago. That's timing. **2)** During the time I've been taking it, I've also been getting better grades. That's an association. **3)** On the bottle, it says it works by increasing blood flow to the brain. That's the mechanism. Since I have all three indicators for causation, the supplement must be improving my grades."

Can Jaime be absolutely confident in their cause-and-effect claim? Why or why not?

② Suppose you want to convince your friends that exercise increases muscle strength. Explain how each of the three indicators of causation (timing, association, and mechanism) could be used to provide scientific evidence to support this cause-and-effect claim.

CONNECTIONS TO EVERYDAY LIFE

③ Imagine you are feeling stressed and see the following advertisement for a stress-relief pill. Would you spend money you've saved on the pill or not? Explain your reasoning, using the four questions about causation (association, timing, mechanism, and alternative explanations).

Fictional advertisement for stress-relief pill

④ Think about a well-being strategy you have recently tried.

a Describe if the strategy was or wasn't effective.

b Based on what you learned in this activity about indicators of causation and alternative explanations, can you explain why the strategy did or didn't work?

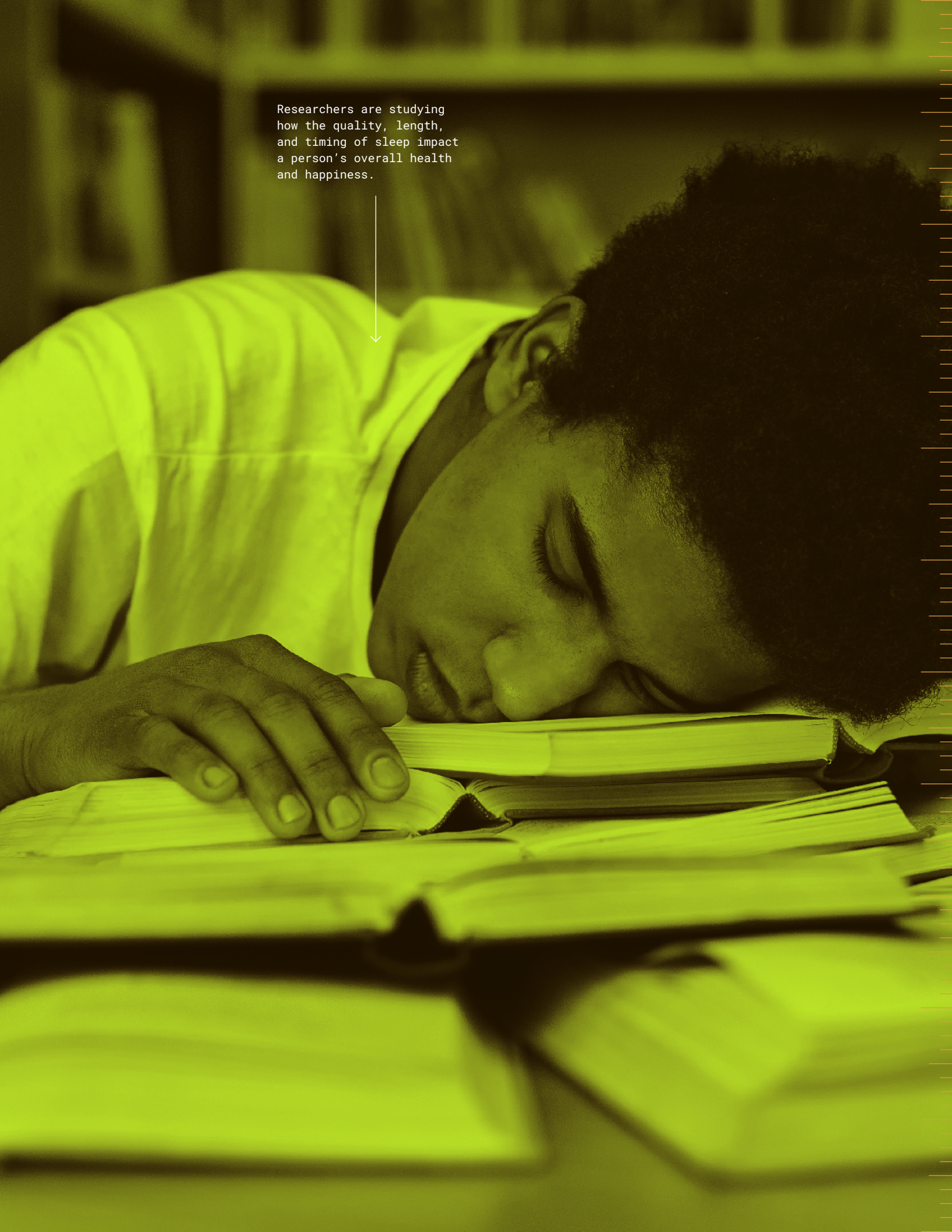
KEY SCIENTIFIC TERMS

association
mechanism
timing

ACTIVITY 4

Interpreting Correlations

DATA ANALYSIS


Researchers are studying how the quality, length, and timing of sleep impact a person's overall health and happiness.

4 : INTERPRETING CORRELATIONS

GUIDING QUESTION

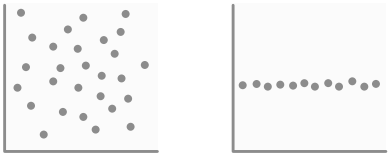
What can be learned from an association between two variables?

INTRODUCTION

Scientists use the term *association* to describe a general relationship between variables, where one provides information about another. For example, there is an association between how much sleep you get and how alert you are the next day. When data from two variables forms a pattern that is unlikely to happen by chance, it may indicate an association. The clearer the pattern, the stronger the association, as shown in Figure 4.1.

FIGURE 4.1
Recognizing Associations

Associations appear as patterns in a graph, where both X (the cause) and Y (the effect) change together. The four graphs above are examples of associations. The two graphs below do not show an association.



CONCEPTUAL TOOLS

MATERIALS LIST

FOR EACH GROUP OF STUDENTS

- 7 SCATTER PLOT CARDS

FOR EACH STUDENT

- DOT STICKER

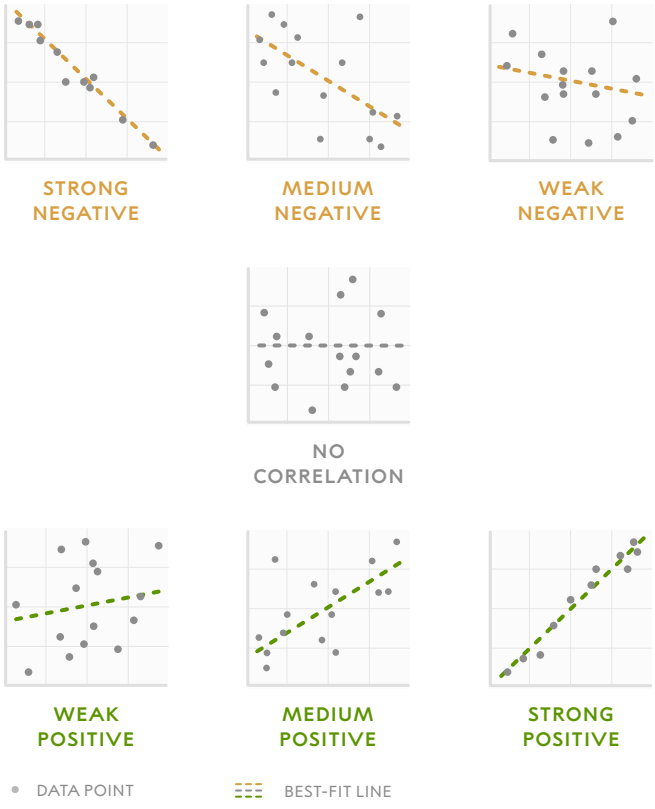
Graphed data from associations sometimes show that two variables increase or decrease together in a somewhat straight line. For example, studies have shown that consistently getting good sleep is associated with an increase in test scores. This type of association, where two variables change together in a linear pattern, is called a correlation. A correlation is just one indicator of a possible cause-and-effect relationship. In this activity, you will explore what correlations can and cannot tell you about causation.

PROCEDURE

PART A: DESCRIBING CORRELATION DATA

1 A correlation can be described by its strength (strong, weak, or no correlation) and direction (positive or negative). The strength is determined by how tightly the data points are clustered together. The direction is determined by whether the data trends upward (positive) or downward (negative). With your group, refer to Figure 4.2 to help you arrange the Scatter Plot cards on your desk from strongest negative to strongest positive correlation.

FIGURE 4.2
Correlation Reference Key



2 A best-fit line is a line on a scatter plot used to analyze general trends in the data. Best-fit lines, like the ones shown in Figure 4.2 and on the Scatter Plot cards, can be helpful for analyzing possible correlations. Examine the best-fit lines and the data points on each Scatter Plot card and discuss how the best-fit line helps to analyze the strength of an association in a scatter plot.

HINT: Look for how close the dots are to the best-fit line.

3 Correlations can also be analyzed by calculating a correlation coefficient. A correlation coefficient (*r*) is a measurement ranging from –1 to +1 that indicates how strongly and in what direction two variables are associated with each other, also referred to as an *r*-value. The *r*-value can range from –1 to +1. With your group, compare the *r*-value for each Scatter Plot card and respond to the following questions:

   a How does the *r*-value indicate the direction of a correlation (positive or negative)?

   b How does the *r*-value indicate the strength of a correlation (weak, strong, or no correlation)?

   Record your responses in your science notebook.

4 With your group, compare the order of your Scatter Plot cards (from Step 1) with your ideas from Steps 2–3. After your group discussion, identify any changes your group wants to make to the order of the Scatter Plot cards. Be ready to share your ideas with the class.

PART B: CORRELATION AND CAUSATION

5 Work with your group to examine Figure 4.3. (Note that the data used is fictional.) Then, complete the following:

   a Identify the two variables shown on the scatter plot.

   b Describe the strength and direction of the correlation.

   c Discuss if you think there is a cause-and-effect relationship between the two variables and provide reasoning to support your answer.

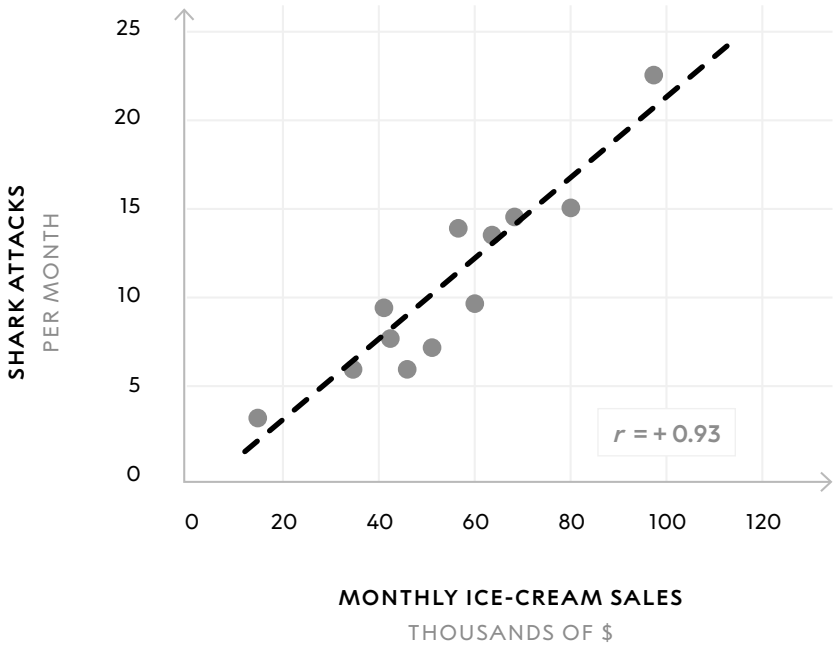


FIGURE 4.3
Shark Attacks vs.
Ice-Cream Sales For One Year

6 Imagine a friend looks at Figure 4.3 and claims, "Buying ice cream must cause shark attacks!" With your group, respond to the questions that follow about causation in order to evaluate the claim that ice-cream sales (X) cause shark attacks (Y). Be ready to share your ideas with the class.

   a Association: Do X and Y tend to change together?

   b Timing: Do you know from the graph if X or Y happened first?

   c Mechanism: Is there a reasonable idea for how X could lead to Y happening?

   d Alternative Explanations: What are other possible explanations for what could have caused the correlation between X and Y?

7 Return to the Scatter Plot cards. With your group, select one card with variables that all group members agree might be a cause-and-effect relationship. Use that card to respond to the questions in Steps 6a–d and discuss whether you think there is a cause-and-effect relationship.

8 Repeat Step 7 with a Scatter Plot card that your group agrees is not likely to have a cause-and-effect relationship.

BUILD UNDERSTANDING

① Examine the data in Figure 4.4.

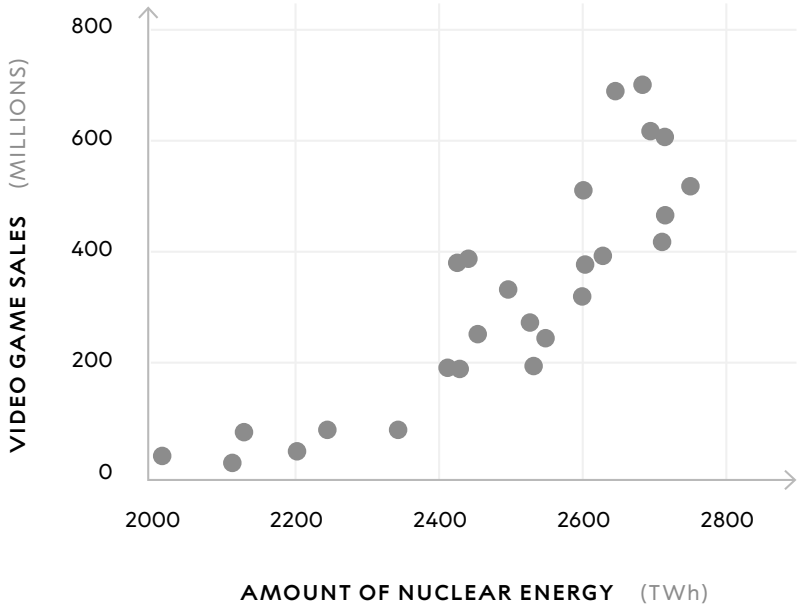


FIGURE 4.4
Video Game Sales vs. Nuclear Energy Production 1990–2015

One terawatt-hour (TWh) is enough energy to power about 100 million homes for one hour.

a Is there a correlation between the two variables? If so, describe it.

b Do you think it's likely that there is a cause-and-effect relationship between the two variables? Explain your answer using one or more of the questions about causation: timing, association, mechanism, and/or alternative explanations.

② Scientists use correlation data to study many types of possible cause-and-effect relationships. Examine Figure 4.5, which shows the number of bees compared to the number of flowers found in a meadow.

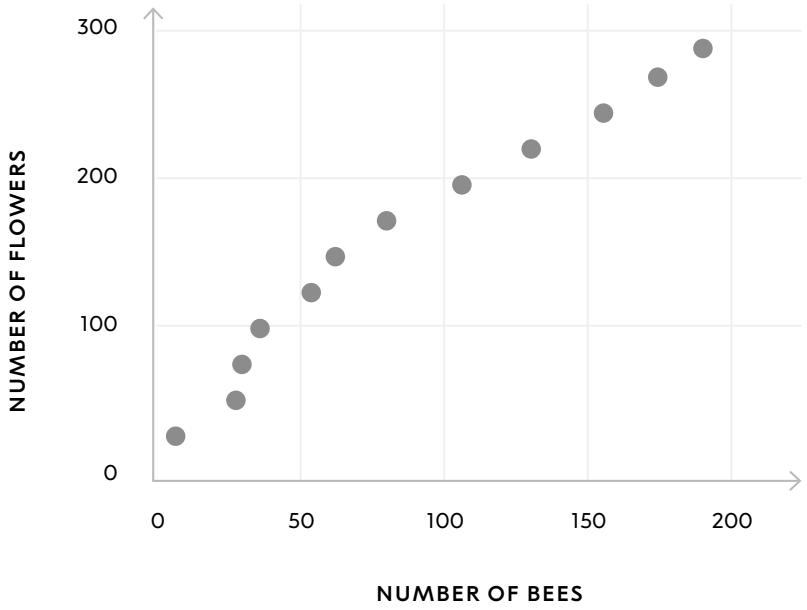


FIGURE 4.5
Flowers vs. Bees

Answer the following questions:

a Based only on the information in the scatter plot, is there a correlation between number of bees and number of flowers? Explain your answer.

b Based on the patterns in the data, would knowing the number of bees in a meadow help you predict the number of flowers in that meadow? If so, predict whether a higher number of bees would result in a higher or lower number of flowers. If knowing the number of bees in a meadow wouldn't help you predict the number of flowers in that meadow, explain why not.

c Can you determine if there is a cause-and-effect relationship between the number of bees and the number of flowers based only on the information from the graph? Explain your answer.

d Do you think it's likely that there is a cause-and-effect relationship between the number of bees and the number of flowers? Explain your answer and describe any background knowledge you have that helps support your answer.

③ Cy and Jenine are investigating what factors influence how much kids play sports. Cy believes the number of siblings plays a role, while Jenine thinks height is more important. They each collect data from their class of 30 students. Cy finds a correlation of $r = 0.40$ between number of siblings and sports hours, while Jenine finds a correlation of $r = 0.20$ between height and sports hours.

a Which correlation is weaker and more likely to be the result of random chance? Explain your answer by describing the strength of the correlations.

b Is it possible that neither relationship is real because both are due to chance? Why or why not?

c What steps should they take to be more sure of their correlation results?

④ Scientists have a common phrase: *Correlation does not equal causation*.

a What do you think this phrase means?

b A correlation is a type of association. In what ways can each of the following support the idea that *Correlation does not equal causation*, even when a correlation is present?

- the timing of the possible cause and effect
- the mechanism for the possible cause and effect
- if alternative explanations exist

CONNECTIONS TO EVERYDAY LIFE

⑤ Your friend sees Figure 4.6, which shows data from a 2019 research study comparing the average number of hours of sleep per night and academic performance for college students during a semester. Your friend says, "Aha. There is an association between the two. More sleep causes better grades. I'm going to stop studying and just sleep more!"

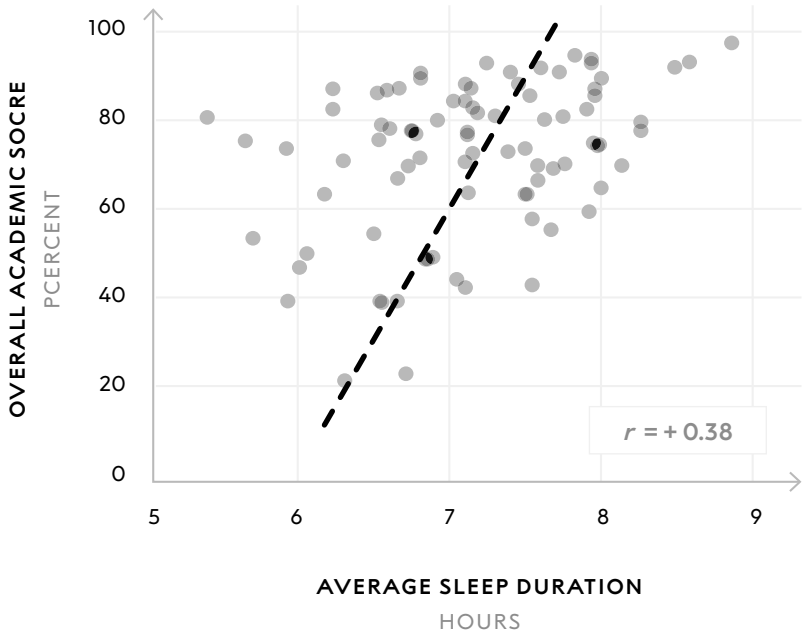
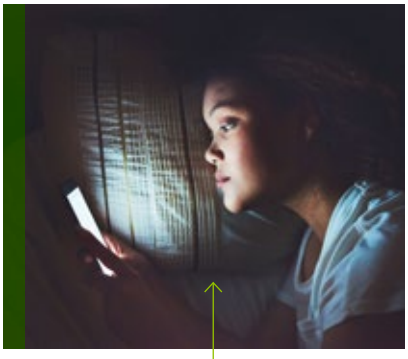


FIGURE 4.6
Sleep vs. Academic Performance

a Do you agree with your friend's claim that sleep is the only thing they need to do to improve their grades? Base your answer on the data in the scatter plot and by explaining what the data does and does not show about association, timing, mechanism, and alternative explanations.

b What other evidence might help you decide if there is a cause-and-effect relationship between sleep and better academic performance?



Scientists are studying how sleep affects academic performance and well-being.

KEY SCIENTIFIC TERMS

best-fit line
correlation
correlation coefficient (*r*)

ACTIVITY 5

Evidence of Well-Being

INVESTIGATION

Social scientists often gather data using surveys or in-depth interviews to study and observe human behavior.

5 : EVIDENCE OF WELL-BEING

GUIDING QUESTION

How do scientists use evidence to evaluate causation?

INTRODUCTION

Studies have found that well-being can actually spread throughout a community. Inspired by these findings, the East Boston Social Centers in Massachusetts have a mission to support the health and overall well-being of local residents by spreading joy in the community. Mr. Justin Pasquariello, the center's director, explains that if a friend becomes happier, your own happiness is likely to increase too. "Happiness is more contagious than sadness," he says. Programs like the one he runs demonstrate that well-being doesn't just affect individuals—it shapes how people work together and support one another.

Programs like those at East Boston Social Centers (pictured) can boost individual and community well-being. "Generational Spirit" mural by Felipe Ortiz and Silvia López Chávez. COURTESY OF HarborArts.

Understanding this connection helps researchers find ways to improve well-being for both individuals and society. But as you've learned, studying well-being is complicated. That's why researchers use careful methods to figure out what really affects well-being. When direct experiments aren't possible, scientists look for strong correlations, check the timing of events, and consider possible reasons one thing might cause another. Scientists also examine whether any of these types of evidence could have happened for other reasons, always looking for alternative explanations. In this activity, you will use these methods to evaluate the four well-being strategies that Salas High School is considering.

CONCEPTUAL TOOLS

MATERIALS LIST

FOR EACH STUDENT

- STUDENT SHEET 5.1 (a, b, c, or d) "Evaluating Indicators of Causation"

PROCEDURE

PART A: EVALUATING INDICATORS OF CAUSATION

1 Your teacher will assign your group to one of the four topics corresponding to the four possible well-being strategies. Read the three studies for your strategy that are summarized in the "Evidence Statement" column on the version of Student Sheet 5.1 (a, b, c, or d), "Evaluating Indicators of Causation," that your group received.

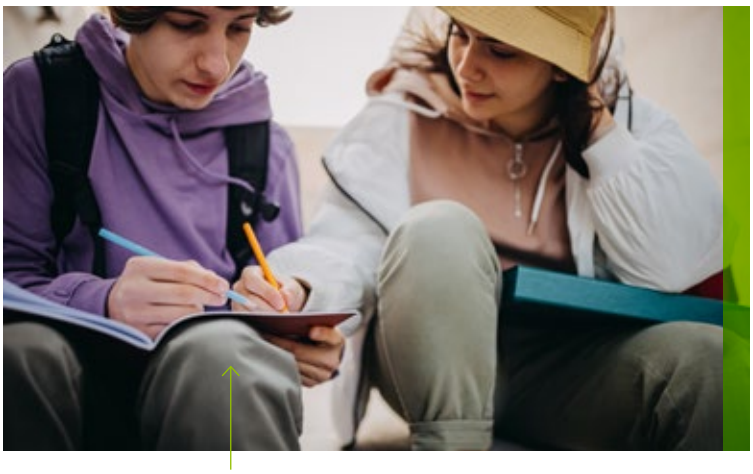
2 With your group, record the following for each of the three studies:

- the type of indicator for causation: timing, association, or mechanism.
- how strongly the Evidence Statement supports the cause-and-effect claim, on a scale from 0 (no evidence at all or irrelevant) to 5 (extremely strong evidence).

3 Together, brainstorm possible alternative explanations for each Evidence Statement. Think of a way the result could have come about that was not because of the cause-and-effect claim for your strategy.

a Identify at least one possible alternative explanation for one Evidence Statement and record it at the bottom of the student sheet.

b If your group discussion of alternative explanations makes you change your mind about the strength of the evidence, cross out your Strength of Evidence rating and record your new rating.



What does the evidence say about gratitude writing and other well-being strategies?

PART B: COMPARING THE WELL-BEING STRATEGIES

4 Follow your teacher's instructions to join a new group in which you are an expert on the strategy you investigated. Each student in a new group should be an expert about a different strategy, as indicated by the letter on their student sheet (a, b, c, or d).

5 In your new group, take turns sharing your evidence and conclusions from Part A.

6 As a group, use your discussion of the evidence to arrange the four student sheets (representing the four strategies) from weakest overall evidence to strongest overall evidence. For each strategy, evaluate the overall strength of the evidence. Consider Studies 1–3 and any possible alternative explanations. Discuss and record how sure you are of each strategy's evidence, using a scale of 0–5, where 0 means no relevant evidence and 5 means extremely strong evidence.

7 Share your results with the class and discuss which strategy had the most convincing evidence of its effectiveness.

BUILD UNDERSTANDING

① How does what you've learned about indicators of causation and alternate explanations influence your thoughts about the choice of the four well-being strategies for Salas High School?

② In Activity 3, you explored questions about cause and effect in everyday life. In this activity, you applied those questions about causation to research on well-being. What are similarities and differences in how these questions are used in everyday life and in scientific research?

③ How do alternative explanations impact the strength of a piece of evidence about cause and effect? Explain your reasoning.

CONNECTIONS TO EVERYDAY LIFE

④ After learning about each of the four well-being strategies and considering what you know about yourself, which one do you think would be most effective for improving your own well-being? Explain why you believe it would work best for you.

Individual needs and preferences play a big role in well-being. Find what works best for you.

ACTIVITY 6

Understanding Well-Being Through Research

READING

Well-being is influenced by many factors, such as health, life events, relationships, and cultural backgrounds.

6: UNDERSTANDING WELL-BEING THROUGH RESEARCH

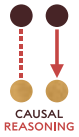
GUIDING QUESTION

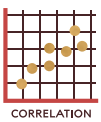
What study designs and analysis methods increase confidence in results?

INTRODUCTION

When trying to understand the world, people often look for simple cause-and-effect explanations. For example, flipping a light switch (the cause) makes a light turn on (the effect). However, many real-world causes, such as those affecting well-being, are more complex. For example, switching to a healthier breakfast might cause a person to live longer, but many other factors—such as genetics and lifestyle—could also play a role. In this activity, you will read about how scientists design and analyze studies when there are complex factors in order to prevent misleading results.

CONCEPTUAL TOOLS





MATERIALS LIST

FOR EACH STUDENT

- STUDENT SHEET 6.1 "DART: Research Methods in the Harvard Study of Adult Development"
- 3–5 STICKY NOTES

PROCEDURE

1 Read about how studies are designed and how their results are analyzed. Use the Read, Think, and Take Note Guidelines as you read.

READ, THINK, AND TAKE NOTE GUIDELINES

Stop at least three times during each section of the reading to mark on a sticky note your thoughts or questions about the reading.

As you read, use a sticky note from time to time to:

- explain a thought or reaction to something you read.
- note something in the reading that is confusing or unfamiliar.
- list a word from the reading that you do not know.
- describe a connection to something you've learned or read previously.
- make a statement about the reading.
- pose a question about the reading.
- draw a diagram or picture of an idea or connection.

After writing a thought or question on a sticky note, place it next to the word, phrase, sentence, diagram, drawing, or paragraph in the reading that prompted your note.

After reading, discuss with your partner the thoughts and questions you had while reading.

2 After you complete the reading, work with a partner to complete Student Sheet 6.1, "DART: Research Methods in the Harvard Study of Adult Development."

3 Compare and discuss your answers with those of your partner. Be ready to share your thoughts with the class about how each research method can increase confidence in results.

READING

THE HARVARD STUDY OF ADULT DEVELOPMENT

What makes for a happy life? Some people think that having more money will make them happier, and others believe a healthy lifestyle is the key. Scientists have spent decades studying well-being, tracking people's happiness to understand what factors affect it, and which factors have the greatest impact.

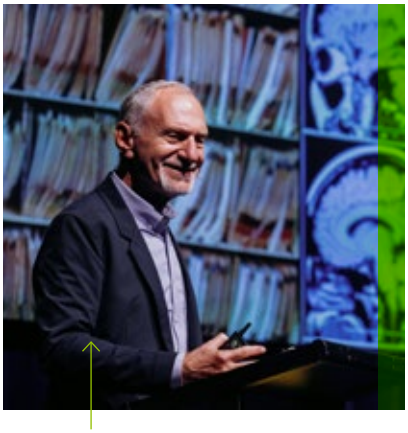
One of the longest-running studies on human well-being, the Harvard Study of Adult Development, followed participants from their teenage years into old age to explore what influences happiness. Beginning in 1938, researchers collected detailed data on participants' health, income, jobs, relationships, and overall well-being. They used medical exams, interviews, and even brain scans to analyze patterns in happiness over a lifetime. Unlike many studies that ask people to remember past experiences, researchers gathered data in real time and over many years. This made the findings more reliable. The data was used to look for associations between happiness, physical and mental health, and lifespan.

The Harvard Study of Adult Development tracked individuals from adolescence to old age to compare factors that affect well-being.

There are many interesting stories about people who participated in the Harvard Study. Some people who seemed to have it all—wealth, good health, or a great career—ended up struggling to be happy. Others who faced tough situations, such as poverty or illness, experienced greater happiness as they aged. One participant, Leo (not his real name), led a simple, steady life. Like many of the young people of that time, he served in World War II. When he returned from the war, he went home to care for his aging mother. He stayed in his hometown for the rest of his life, working as a history teacher and dreaming of becoming a famous writer. The study's current director, Dr. Robert Waldinger, said that his predecessor thought that Leo was so boring. Yet, according to the study measurements, Leo was very happy. Data such as Leo's eventually provided researchers with many insights.

STUDY CONCLUSIONS

After decades of research, the Harvard Study revealed that wealth and physical health influence mental well-being, but they are not the strongest factors. Financial security matters, but beyond a certain income level, wealth does not have a strong influence on well-being. Good physical health supports well-being, but by itself does not guarantee it. The Harvard Study found one factor that stood out above all: social connection. The strongest predictor of long-term well-being was having meaningful, supportive relationships. Dr. Waldinger summarized the findings by saying, "People who stayed the healthiest, lived the longest, and were the happiest were the ones who were most connected to others." People with strong friendships, family bonds, or romantic relationships also tended to have lower rates of heart disease and diabetes and less cognitive decline in old age.



Dr. Robert Waldinger is the current director of the Harvard Study of Adult Development.

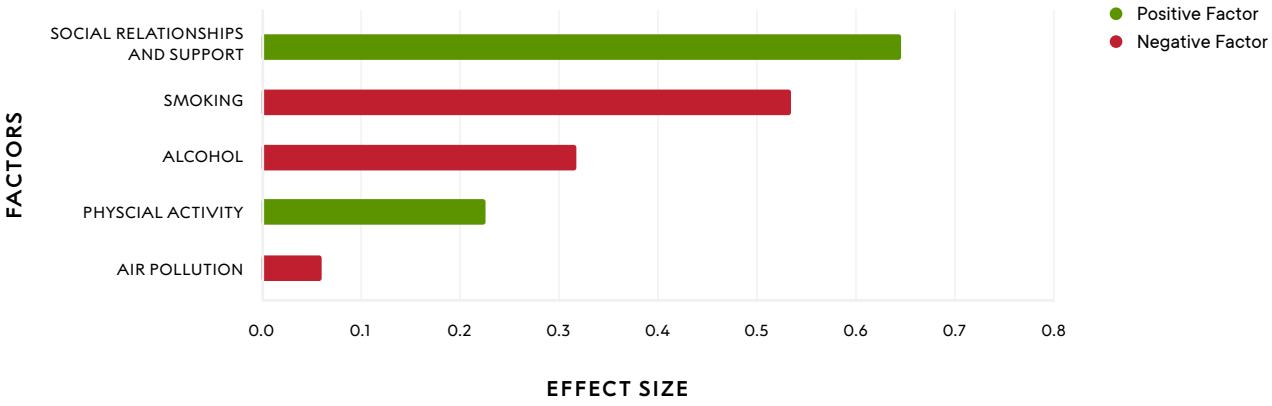
The scientific community had more confidence in the study's findings because of its clear results and careful design. The researchers used four well-established study design elements and analysis methods to help rule out alternative explanations—measuring effect size, using a large sample size, comparing consistency across settings, and accounting for confounds.

MEASURING EFFECT SIZE

Effect size is the strength of an association between two variables, such as a correlation or the difference between two groups in an experiment. Larger effect sizes give researchers more confidence that their findings are not due to chance. Correlation coefficients and differences in averages between groups are both types of effect sizes.

Researchers use effect sizes to compare how strongly different factors affect outcomes. The Harvard Study found that social connection had a larger effect size on well-being than other factors such as wealth. Since patterns of wealth over time did not strongly correlate with changes in happiness, the study suggested that income had a small effect size on well-being. In comparison, having supportive social connections had a stronger correlation with happiness across all socioeconomic classes—reflecting a larger effect size. The study also found that social connection was more strongly associated with how long a person lived than lifestyle factors such as smoking, alcohol use, or exercise. Data from other studies have confirmed these findings, as shown in Figure 6.1.

FIGURE 6.1
Relative Effect Sizes for Different Factors on Length of Life



USING A LARGE SAMPLE SIZE

A sample size is the number of individuals participating or items included in a study. Having a small sample size increases the chance of misleading results. If only a few people are studied, their unique differences might make the findings from the data less accurate for a larger population. By increasing the sample size, these individual differences average out and make the results more generalizable. While the initial sample size of the Harvard Study was relatively small (268 participants), the study improved over time by adding more participants. Today, the study includes 1,300 participants. This helps ensure that current and future findings are more reliable and can be applied to a larger population.

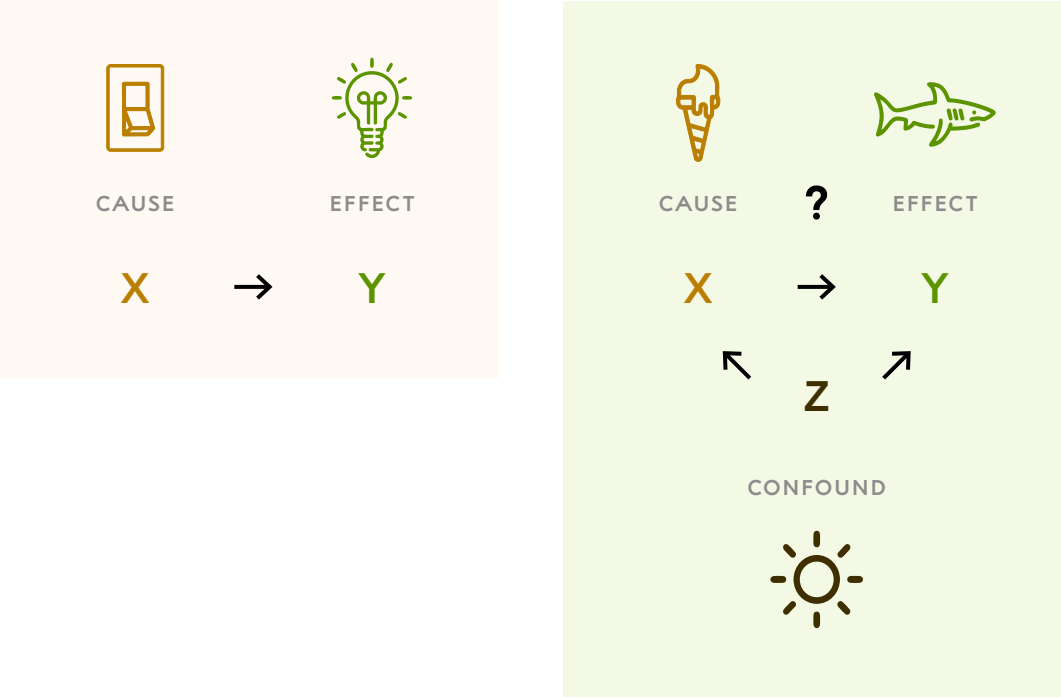
COMPARING CONSISTENCY ACROSS SETTINGS

To make sure their results apply to everyone, researchers often design their studies to compare results between different types of people and different situations. The Harvard Study began with students at Harvard University and then added participants from low-income neighborhoods in Boston. This was intended to examine whether the study's findings would be similar for people with different social and economic backgrounds. However, even the newer participants were all white male individuals from Boston. This raised concerns about whether other factors—such as gender, ethnicity, and location—also impacted well-being. To further improve the study, the researchers expanded it to include women and people from different backgrounds and places. Their findings were consistent across groups: happiness in life was associated with meaningful social connection across locations, ethnicities, income levels, and genders. For example, for both men and women, happiness increased as they spent more time with people they liked.

ACCOUNTING FOR CONFOUNDS

One of the challenges of studying complex topics such as well-being is that an association can occur between two variables without one directly causing the other to change. In Figure 6.2, the diagram on the left shows a simple cause-and-effect relationship (a light switch turning on a light). The diagram on the right represents the example of ice-cream sales (X) and shark attacks (Y). In the example of shark attacks and ice-cream sales, both variables increase at the same time, but the cause is a third variable, such as warmer weather (Z). In this case, the warmer weather is causing both the increase in ice-cream sales and more people going swimming in the ocean, and more people swimming in the ocean increases the likelihood of shark attacks. This is called a confound—a factor that can distort or hide the relationship bewteen two variables being investigated in a study.

FIGURE 6.2
Simple Cause and Effect vs. A Hidden Confound



Confounds can impact just the possible effect or both the possible cause and the possible effect. This makes it more difficult to determine whether there is a cause-and-effect relationship.

When studying well-being, the Harvard Study researchers had to consider many possible confounds, such as personality traits, life events, social and economic backgrounds, and cultural differences. The researchers checked if these factors could be confounds by comparing results for different subgroups in the study. For example, they found that the positive association between social relationships and physical health was just as strong for both low- and high-income participants. This was also true for male and

female participants. This suggested that neither wealth nor gender explained the association between social connection and well-being. By tracking various factors over time, the researchers were able to control for many possible confounds.

LESSONS FOR TODAY

So what about Leo, the study participant who turned out to be among the happiest? His life seemed quite ordinary compared to other participants. Leo never achieved his dream of becoming a famous writer, but he had strong and supportive connections with his family, his school community, and beyond. These relationships brought him real and lasting happiness. Leo is a good example of how social connection plays a key role in happiness.

Scientists don't rely on just one person or one study to form conclusions. They use many studies and a broad range of evidence to identify cause-and-effect relationships. Today, the link between social connection and well-being is widely accepted in the scientific community. It is supported by many studies that back up the findings of the Harvard Study. While the Harvard Study didn't analyze race, other research has found that strong social connections are one of the biggest factors in happiness, no matter a person's race, income level, or cultural background. Additionally, many of these studies also used experiments. Experiments are a stronger approach for investigating cause and effect than observational studies, such as the Harvard Study, because in experimental studies, researchers test for causation rather than just looking for an association.

New technology and changing ways of life make the conclusions from the Harvard Study even more important today. Researchers are studying how changes in the way people communicate, the use of social media, and how societal pressures impact social connection and well being. Just as it did for the Harvard Study, investigating how these factors affect well-being could offer valuable insights into improving well-being for individuals and communities.

Social interactions have changed since the introduction of smartphones and other technologies.

BUILD UNDERSTANDING

1. The Harvard Study of Adult Development was a longitudinal study, meaning that it tracked participants over time, which helped strengthen its findings. What other study design elements or analysis methods made the study's results more reliable? List at least four and describe how each helped strengthen the study's findings.

2. The Harvard Study of Adult Development found that well-being is strongly associated with social connection. How does this impact your ideas about which well-being strategy might work best for Salas High School?

3. The Harvard Study reported a correlation between social connection and well being. Which of the following reasons could explain this association? (Choose all that apply.)

   a social connections (X) increase well-being (Y)

   b well-being (Y) increases social connections (X)

   c being kind (Z) increases both social connections (X) and well-being (Y)

   For each reason that could be true, draw a diagram showing the possible cause and effect between X, Y, and Z. Label and explain your diagram(s).

Strong social connections are essential—not just for happiness, but for health and resilience.

CONNECTIONS TO EVERYDAY LIFE

4. Scientists who study the effects of loneliness are researching the following strategies to help people feel more connected:
   - improving social skills,
   - finding more chances to interact with others, and
   - changing negative thoughts about social situations.

   Which of these strategies could you use in your everyday life, and how do you think they could help you build stronger social connections?

5. Researchers are studying how social media affects our well-being, but this is complicated because people use social media in different ways and for different amounts of time. Evidence suggests that using social media to connect with people can support well-being, while using it too much or to compare oneself to others can lower well-being. What might be some examples of using social media in ways that promote positive connections?

EXTENSION

The World Happiness Report is a yearly study that explores what makes people happy in different countries. Read the online chapter provided by your teacher to explore topics such as the happiness trends across countries and why people often underestimate how much others care about them. Share what you learn with the class through a presentation.

KEY SCIENTIFIC TERMS

confound
effect size
sample size

ACTIVITY 7

Improving Experimental Design

COMPUTER SIMULATION


Studying a sample of people is a practical way to learn about a larger population.

7: IMPROVING EXPERIMENTAL DESIGN

GUIDING QUESTION

How do changes in study design affect the results?

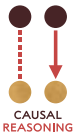
INTRODUCTION

In Activity 6, you learned how observational studies are designed and how they can reveal associations. Now, you'll explore how experimental studies are set up to test cause-and-effect relationships. In an experiment, researchers introduce a treatment—the procedure or situation that is changed only for the experimental group in a scientific study. The experimental group is the group in an experiment that receives the treatment and is compared to the control group. The control group is the group in an experiment that does not receive the treatment and is compared to the experimental group. Using these two groups allows scientists to compare the outcome of an experiment and determine its effects. However, simply having these two groups isn't enough; other parts of the experiment design matter as well. In this activity, you'll use a computer simulation to test different study designs and see how they affect experiment results.

FIGURE 7.1
Experimental vs. Control Groups

The experimental group receives the treatment and is compared to the control group. All other variables are kept the same in both groups.

CONCEPTUAL TOOLS



MATERIALS LIST

FOR EACH PAIR OF STUDENTS

- COMPUTER WITH INTERNET ACCESS

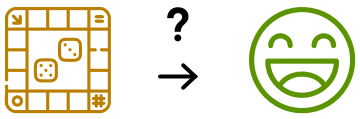
FOR EACH STUDENT

- STUDENT SHEET 7.1 "Comparison of Study Designs"

PROCEDURE

PART A: HOW SURE ARE YOU?

1 With your group, read the following fictional scenario about a new game that has become popular in the city of Salas where Salas High School is located.

> RESEARCH QUESTION **Does playing Dapple increase well-being for kids in Salas?**
>
> *Some kids in Salas have invented a new game called Dapple, which is played in groups of 2–10 players. The game has become popular in Salas, with Dapple players claiming it makes them less stressed and happier.*
>
> *Dr. Gilly is a local researcher. She decided to run a series of experiments to see if Dapple really does increase well-being and, if so, by how much. She randomly assigns kids to play Dapple or not to play Dapple.*
>
> 

2 You will use a computer simulation to identify whether playing Dapple affects well-being and, if so, in what direction (positive or negative) and by how much (effect size). Follow your teacher's instructions for accessing the simulation.

3 Begin the simulation by evaluating Part A: Trial 1. Discuss the results with your partner.

4 Explore the missing information in Trial 1 and run additional trials with the same sample size. Discuss with your partner how each new piece of information affects your confidence in the cause-and-effect claim. Each time you run a new trial, new participants are randomly sampled from the population.

5 When you've run at least 8 trials in Part A, look at how much the results vary from trial to trial. Discuss possible explanations for this with your partner. Record your ideas in your science notebook and be ready to discuss them with the class.

PART B: GETTING CONSISTENT RESULTS

6 In Part B, explore how sample size affects the results by running trials with sample sizes from 6 to 120. On the Effect Sizes for Different Sample Sizes graph, each set of 4 arrows represents Trials 1–4 at a different sample size. Compare the lengths (effect sizes) and colors (effect directions) of the 4 arrows at each sample size to see how consistent the results are. You may want to repeat trials to check the reliability of the results. Completing trials for all sample sizes (6–120) is required to move on.

7 After completing the graph up to a sample size of 120, select the Next button to clear the graph. Select the Run 25 Trials At A Time button to generate a new graph showing 25 trials at each sample size instead of just 4. Displaying more trials per sample size will give you a better sense of how consistent the results are at different sample sizes. With a partner, review the graph and identify your best estimate for:

- the smallest sample size where the results become consistent (the arrows are similar enough), and
- the true effect size of playing Dapple. (The true effect size is the actual strength of a relationship or difference in a population, not just what a small number of trials finds.)

Be ready to share your ideas with the class.

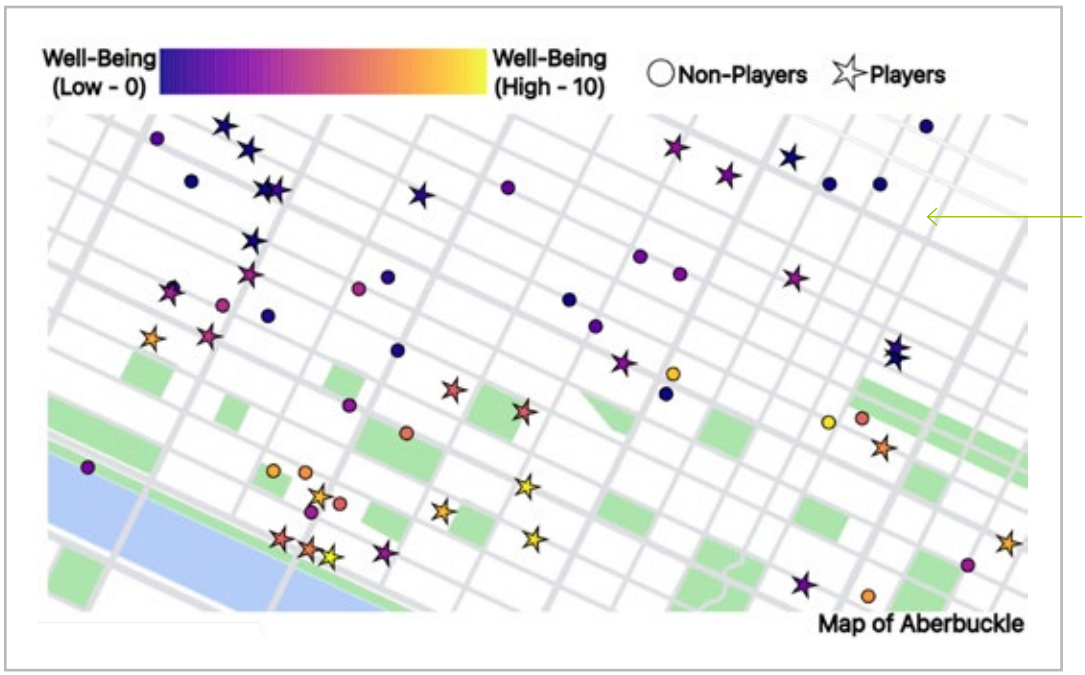
PART C: COMPARING STUDY DESIGNS

8 Your goal is to determine the best experimental design to find out if playing Dapple improves well-being. Besides sample size and effect size, you will want to consider other aspects of studies, such as confounds, that could affect the results. Review Part C in the simulation and look through your options for experimental design.

9 To set up your first study, select the following study design elements:

- an appropriate sample size (6–120) based on your findings in Parts A and B of the simulation.
- a treatment for the experimental group (plays the game once or plays the game once a day for a week).
- a no-treatment condition for the control group (gathering in groups somewhere else or watching from the sidelines).
- a method of assigning participants to the groups (by neighborhood, coin flip, or grade: middle school vs. high school).

FIGURE 7.2
Map Used in Part C of the Simulation



In the simulation, study participants are shown on the Aberbuckle town map as circles or stars.

10 Select the View Assignments button to see which participants were assigned to which group on the simulation map (stars indicate the experimental group, circles indicate the control group). Then, select the Perform the Experiment button to see each participant's rating after receiving the treatment or control.

11 Select the Analyze Results button to see an average for both groups—the players and non-players. On Student Sheet 7.1, "Comparison of Study Designs," record your study design elements from Step 9 in the "Study Design #1" row. Draw a bar graph of the results (from the simulation) and circle whether the experimental group had a lower, equal, or higher value than the control group.

12 Explore additional study designs and record each in a different row of the table on the student sheet. As you experiment, find and record information for at least one study in which:

- **players have higher well-being than the non-players.**
- **results show very little or zero difference between groups**.
- **non-players have higher well-being than the players.**
- **results show the biggest effect you found.**
  Draw a circle around the study design number that has the biggest difference between the players and non-players. If there could be an alternative explanation for this result, record it in your science notebook.

- **there is at least one confound.**
  In the "Control" column and/or the "Assignment to Group By" column, write "confound" and draw an arrow pointing to the confound. If the study you pick has more than one confound, draw an arrow pointing to each confound. Repeat this for at least one other study that has a confound.

13 Use your ideas from Procedure Step 12 to identify which of the studies you investigated has the best experimental design. (Refer to the study design elements in Step 9.) Draw a star next to that study design number on the student sheet. Explain why that study design is the strongest and record your ideas in your science notebook.

14 Share your strongest study design with the class. Compare the strengths and weaknesses of the studies. Discuss which study design helps you feel most confident in answering the research question: *Does playing Dapple increase well-being for kids in Salas?*

BUILD UNDERSTANDING

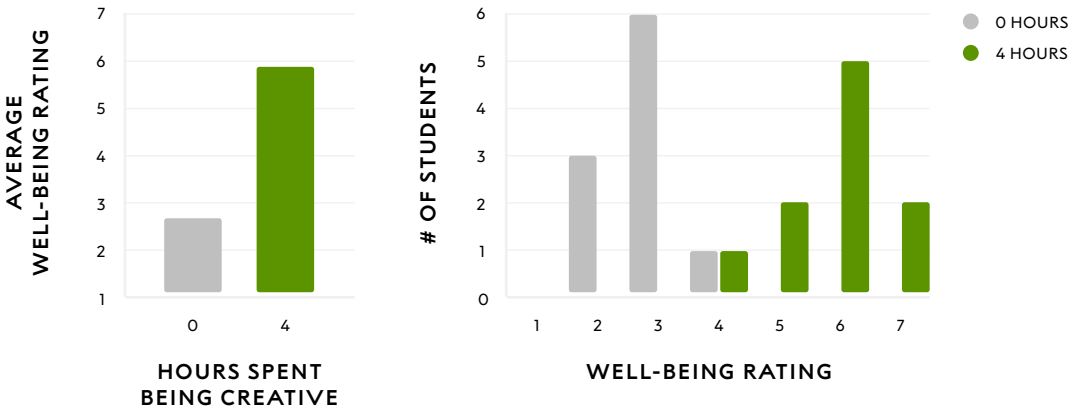
1. Think of a study in which you would want a really large sample size, such as studying a new medicine for asthma.
   a. How would a bigger sample size affect your confidence in the results? Explain your answer.
   b. Does having a really big sample size guarantee that your results will be accurate? Why or why not?

2. Why do confounding variables make it harder to interpret the results of a study? Use the example of green spaces from the simulation to illustrate your answer.

   HINT: Consider the results in Part C of the simulation when assigning participants by neighborhood.

3. Ms. Lee's class decided to conduct an experiment to test the effect of time spent being creative on a person's well-being. They had 20 students from the class choose to do something creative for 4 hours that week or do nothing creative that week, even if they normally would. Then they asked the participants to rate their well-being. Their results are shown in Figure 7.3.

FIGURE 7.3
Ms. Lee's Class Results Testing Creativity and Well-Being



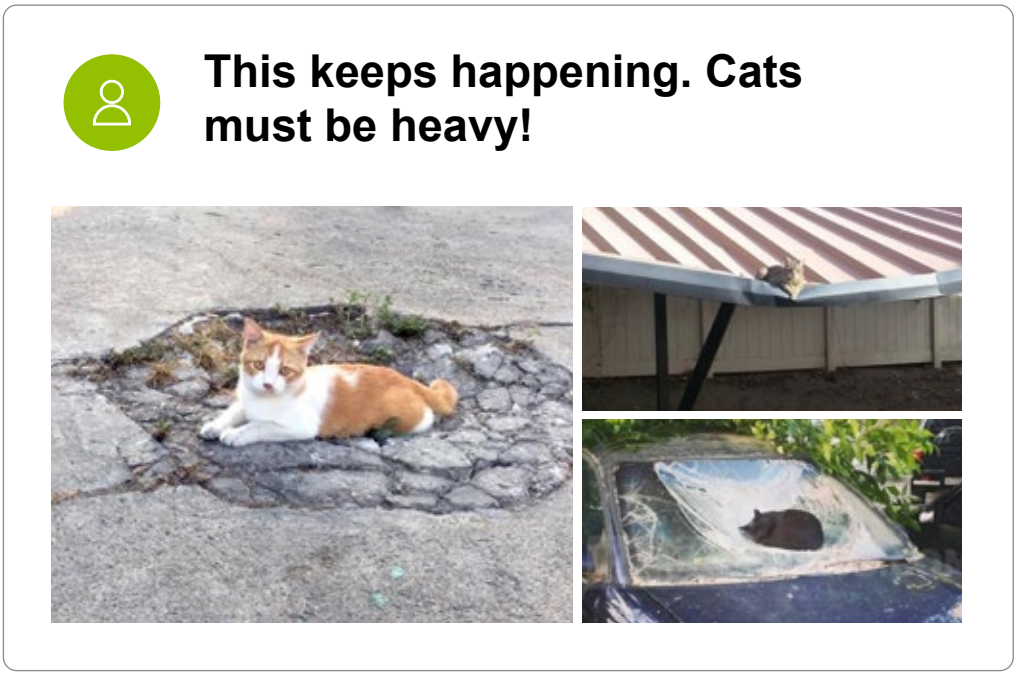
a Does the data support the class's idea that creativity improves well-being? Why or why not?

b What elements of the study design could be improved? Explain how changing these elements would improve your confidence in the study results.

c If you were going to run this experiment in your class, would you change the study design? If yes, how would you change it? If no, why not?

CONNECTIONS TO EVERYDAY LIFE

④ A friend claims, "Those cats are crushing things!" and sends you the following social media post:



Explain why this post does not demonstrate causation. In your response, include sample size and at least two of the four key questions about causation.

5. Why is it sometimes difficult to get a really large sample size for an experiment with people as participants? Provide a few examples.

KEY SCIENTIFIC TERMS

control group
experimental group
treatment

ACTIVITY 8

Testing a Well-Being Strategy

LABORATORY

Be thoughtful when designing an experiment to control for variables that might affect your results.

8: TESTING A WELL-BEING STRATEGY

GUIDING QUESTION

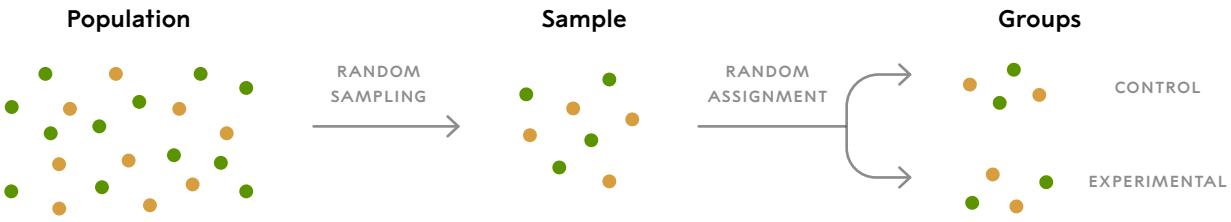
How do you design a randomized controlled trial?

INTRODUCTION

Experiments provide strong evidence for cause and effect when they are designed to prevent alternative explanations, such as confounding variables. A type of experiment called a randomized controlled trial (RCT) is an experiment in which participants are randomly assigned to an experimental group or a control group. The experimental group receives the treatment, while the control group does not. By keeping everything the same except for the treatment, researchers can be more confident that any differences between groups are due to the treatment itself. RCTs provide stronger evidence than associations alone because they control timing and eliminate most confounds. In this activity, you will run and participate in a randomized controlled trial in your classroom.

FIGURE 8.1
Randomized Controlled Trials

Participants in an RCT are randomly selected from the population and randomly assigned into an experimental group or a control group.



CONCEPTUAL TOOLS

CAUSAL REASONING

RANDOMIZED CONTROLLED TRIALS

MATERIALS LIST

FOR EACH GROUP OF FOUR STUDENTS

- RCT SUMMARY CARD (corresponding to the chosen strategy)

FOR EACH STUDENT

- STUDENT SHEET 8.1 "Experimental Design of RCTs"

PROCEDURE

PART A: TESTING A STRATEGY

1 With your class, read the following fictional scenario.

> *The Well-Being Task Force wants to gather evidence for the four well-being strategies under consideration. The task force decides to design and run a simple randomized controlled trial to see if one of the strategies affects their school population.*

2 As a class, choose one of the four well-being strategies from Salas High School to investigate.

FIGURE 8.2
Proposed Well-Being Strategies for Salas High School

Gratitude Writing

A way for students to express gratitude through writing such as keeping a journal, writing a letter to someone, sharing thank-you notes, or another form of written expression.

Pet Therapy

A way for students to interact with animals such as helping at an animal shelter, visiting with a therapy animal, or providing time to spend with a dog at school.

Green Spaces

A way for students to spend more time in natural places such as tending a school garden, regular visits to a park, adding more plants around campus, or another way to bring nature into their routine.

Quality Sleep

A way to help students get more and better sleep such as starting school later, teaching about healthy sleep habits, or some other way of helping students get better rest.

3 With your group, brainstorm treatments you could realistically do in your classroom in order to test the strategy your class has chosen.

4 As a class, discuss your ideas and come to consensus for a treatment that is a version of the strategy, could easily be done in the classroom, and is likely to have an effect. At the top of Student Sheet 8.1, "Experimental Design of RCTs," record the well-being strategy and the treatment your class chose.

5 With your group, make a plan to test the treatment idea your class chose. Use the following questions to guide your plan, based on each row of the table on the student sheet. Record your design ideas in the "Group Proposal" column.

   a Hypothesis
   What do you think the results will show?

   b Sample Size
   What is your sample size? Who are your participants?

   c Method of Assignment to Group
   How will you assign participants to the control group and the experimental group?

   d Experimental Group
   What treatment will the experimental group receive?

   e Control Group
   What will the control group do instead of the treatment?

   f Measurement of Effect
   How will you measure the effect on well-being?

   g Possible Confounds
   What are possible confounding variables? Is there a way to avoid them?

6 As a class, review each group's experimental design and identify its strengths and weaknesses, including possible confounds. Combine the best ideas into one experimental design to perform as a class. Record your consensus design for a classroom RCT in the "Classroom RCT" column of the table on the student sheet.

7 Conduct the randomized controlled trial as a class and record the data according to your teacher's instructions.

8 Analyze your results by identifying any differences between the experimental group and the control group. Record your findings in the last row ("Results") of the "Classroom RCT" column on the student sheet.

9 Revisit your hypothesis from the first row ("A. Hypothesis") on the student sheet and discuss with your group whether your results do or do not support your hypothesis. Discuss your reasoning and decide what can and cannot be concluded about causation from your experiment.

A published randomized controlled trial describes a study's design and its results.

PART B: COMPARING THE CLASSROOM RCT TO A PUBLISHED RCT

10 With your group, read the RCT Summary card that your teacher handed out.

11 Describe the experimental design (summarized on the card) for the published RCT by completing the "Published RCT" column on Student Sheet 8.1.

12 With your partner, compare your experimental design and results with the published RCT and its results. Identify the similarities and differences between the two experiments in terms of design, results, and limitations. Record your ideas in your science notebook.

13 With the class, share your comparison of the classroom RCT findings with those of the published RCT.

BUILD UNDERSTANDING

① There are limitations in any scientific experiment, but this is especially true for the RCT you conducted in your class. Now that you've compared your class experiment to a published RCT, describe at least three ways you could improve your class study design to reduce confounds and make the results more reliable.

② Researchers sometimes call RCTs the strongest kind of evidence for cause-and-effect relationships. What features of RCTs help make them better for studying cause and effect than an observational study, which just looks for a correlation? In your response, explain how RCTs compare to correlation studies in terms of the following:

- **a** timing
- **b** association
- **c** mechanism
- **d** alternative explanations

CONNECTIONS TO EVERYDAY LIFE

3. Randomized controlled trials are used in many different fields of science, such as medicine, psychology, and education, to test the effects of treatments or interventions. Imagine a friend is choosing between two medicines to take for their stomach pains. There is a strong correlation between taking Medicine A and reporting less stomach pain. People who took Medicine B in an RCT experienced significantly greater relief from stomach pain than those who took a sugar pill. Which medicine, A or B, would you recommend to your friend and why? Base your answer on the kinds of evidence a correlation provides and an RCT provides.

4. You read an article online that described a new pain medication awaiting approval from the Food and Drug Administration (FDA), a federal agency within the United States Department of Health and Human Services. The article mentioned that the researchers who developed the medication ran an RCT to test it before it could be approved for sale to the public.

   a. Why would it be important to use an RCT to test a new medication before it is sold to the public?

   b. Why is it important to have a control group when testing a new medication?

   c. Why is it important to randomly pick who goes into the experimental and control groups when testing the medication?

New medications must be tested carefully in labs and with human trials before they're approved.

EXTENSION

When a new medication is developed, the manufacturer is required to show effectiveness in a randomized controlled trial (RCT) before it can be approved by a regulatory agency, such as the Food and Drug Administration (FDA) in the United States. Investigate a recent RCT for a medication related to health and well-being and identify the key components of the RCT for that study.

KEY SCIENTIFIC TERMS

randomized controlled trial (RCT)

ACTIVITY 9

Evaluating Randomized Controlled Trials

DATA ANALYSIS

The quality of a research study depends on how well it was designed and the strength of its evidence.

9: EVALUATING RANDOMIZED CONTROLLED TRIALS

GUIDING QUESTION

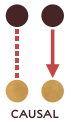
How can randomized controlled trials be evaluated?

INTRODUCTION

As you saw in previous activities, a larger sample size can help ensure that a research study's findings are not a result of coincidence or random chance. One of the largest and most widely known clinical trials ever conducted was in 1955 for a polio vaccine. There is no cure for polio; before the vaccine, the polio virus paralyzed tens of thousands of children across the world, and large hospital wards were filled with patients on respirators. In less than one year, 1.8 million people participated in the study to test the polio vaccine. The fact that so many people were tested helped to make both researchers and the public confident in the results—the vaccine was both safe and effective.

Besides sample size, you've learned about other study design elements and analysis methods of research studies that can help boost confidence in their results. For instance, the polio vaccine study was done in different locations across the United States, Canada, and Finland to look for consistency across different settings. Also, the trials had a very large effect size, with a 90% success rate at preventing paralysis in children. If the results had shown only a 10% success rate, then it would have been more likely that this effect came about by chance. However, there was also another way the study was designed that made it valuable. The polio vaccine was tested on children, not adults, because children were the *target group* for the vaccine—the group most affected by polio, and the ones who needed the vaccine the most. In this activity, you will analyze the following characteristics: sample size, target group, consistency across settings, and effect size in randomized controlled trials (RCTs) to help evaluate the effectiveness of the four different well-being strategies that Salas High School is considering.

CONCEPTUAL TOOLS



MATERIALS LIST

FOR EACH STUDENT

- STUDENT SHEET 9.1 "Comparing RCTs Related to the Well-Being Strategies"

People of all ages line up to receive polio vaccines in Los Angeles, California, 1960.

PROCEDURE

PART A: EVALUATING A RANDOMIZED CONTROLLED TRIAL (RCT)

1 With your group, read the following fictional scenario.

The Well-Being Task Force is ready to dig deeper into each of the four well-being strategies that Salas High School is considering. The task force decides to compare randomized controlled trials (RCTs) for each strategy.




2 Each group member will be assigned an RCT to analyze for a different well-being strategy. Follow your teacher's instructions to form an expert group with other students who have the same RCT study.

3 Work with your expert group to read your assigned study. Complete Section 1 on Student Sheet 9.1, "Comparing RCTs Related to the Well-Being Strategies" for your RCT. Be ready to share your findings with your original group afterward.

FIGURE 9.1
Research Summary for a Randomized Controlled Trial on Gratitude Writing

RCT A

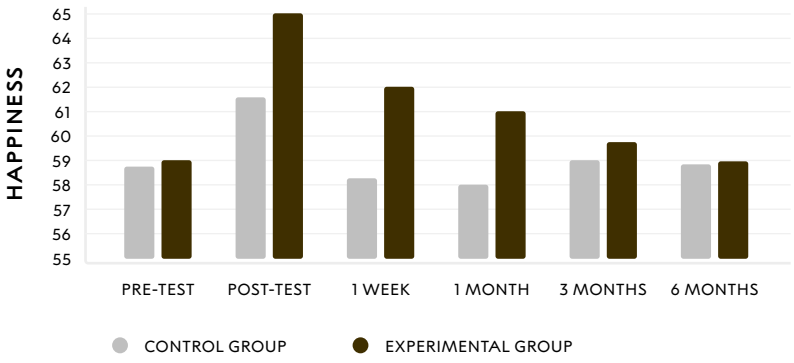
Gratitude Writing

STUDY DESIGN

Scientists wanted to find out if writing and delivering a gratitude letter could increase happiness and how long the effects would last. Volunteers were recruited from a website promoting a book about improving happiness, and they took online surveys to measure their happiness over a 6–month period. Most participants were between the ages of 35 and 54 and white, and about ⅔ had college or graduate degrees. Researchers randomly divided participants into 2 groups: a control group (70 participants) and an experimental group (80 participants). The control group wrote about their early memories each night for 1 week. The experimental group spent 1 week writing a letter to someone who had been kind to them but hadn't been properly thanked, and then they delivered the letter in person. Both groups completed happiness surveys before the writing week; immediately after; and again 1 week, 1 month, 3 months, and 6 months later. The survey provided an overall happiness score by having participants rate different areas of happiness, such as positive emotions, their connection with others, and how meaningful their lives felt.

STUDY RESULTS

Average happiness scores for the two groups over time:



Participants in the experimental group had significantly higher happiness scores than those in the control group immediately after the test, 1 week later, and 1 month later.

CONCLUSION

Researchers concluded that writing and expressing gratitude in person can lead to significant positive changes for up to 1 month.

FIGURE 9.2
Research Summary for a Randomized Controlled Trial on Pet Therapy

RCT B

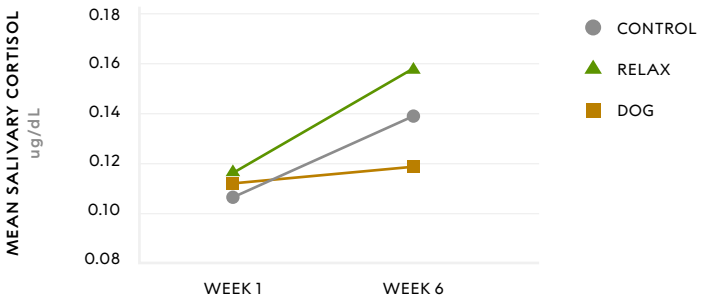
Pet Therapy

STUDY DESIGN

Scientists wanted to study how spending time with dogs affects stress by measuring cortisol, a hormone the body releases in response to stress. Higher cortisol levels mean more stress. The study involved students aged 8–10 from 4 elementary schools in the United Kingdom. Students were randomly divided into 3 groups: control group, no treatment (19 students), experimental group 1, dog treatment (33 students), and experimental group 2, relaxation (35 students). The control group continued with their regular school lessons as usual. Experimental group 1 spent about 20 minutes interacting with and learning about a dog. Experimental group 2 had about 20 minutes of activities such as stretching or listening to a story. Both experimental groups 1 and 2 had 2 20–minute sessions each week for 4 weeks. Before and after the experiment, saliva samples were taken 3 times a day for 3 days in a row, and the average cortisol levels were calculated before and after each treatment or control period.

STUDY RESULTS

Average cortisol levels from saliva samples for the three groups:



Students in experimental group 1 (dog group) did not show a noticeable change in their average cortisol levels. However, students in the control group and experimental group 2 (relaxation group) showed significant increases in cortisol levels, meaning that their stress levels went up. In other words, spending 20 minutes with a dog helped the children keep their cortisol levels steady, while the other groups experienced more stress.

CONCLUSION

Researchers concluded that spending time with dogs may help lower stress in children at school.

FIGURE 9.3
Research Summary for a Randomized Controlled Trial on Quality Sleep

RCT C

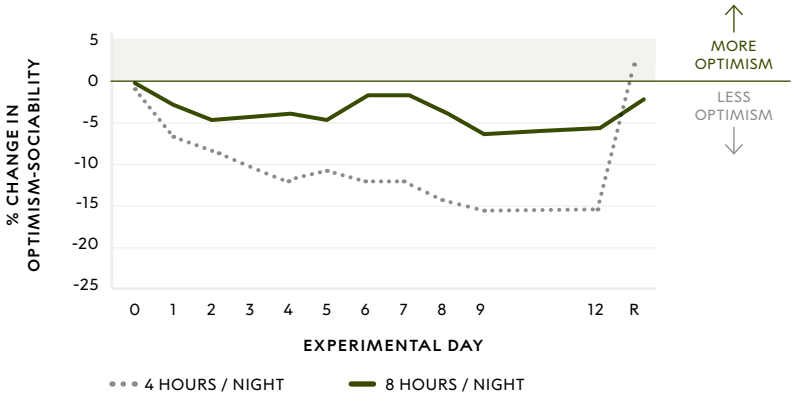
Quality Sleep

STUDY DESIGN

This study was designed to investigate how getting less sleep affects well-being. Participants were healthy; aged 21–41 (14 females and 26 males); from the Boston, Massachusetts, area; and were recruited through advertisements in newspapers and websites. They were randomly assigned into two groups: the control group was allowed 8 hours of sleep per night for 12 days in a row (18 people), and the experimental group was allowed 4 hours of sleep per night for 12 days in a row (22 people). Participants rated their levels of optimism-sociability on days 0–9, day 12, and after a full night of recovery sleep (12 hours in bed). Optimism-sociability is a combination of how they rated their well-being based on words such as *friendly, optimistic, sociable, cheerful, energetic, motivated*, and *creative* (for example: *How friendly do you feel on a scale from 1 to 10?*).

STUDY RESULTS

Average optimism-sociability ratings over 12 days in both groups:



The 0 on the y-axis refers to each participant's rating before the experiment started (Day 0). Participants in the control group (8 hours of sleep) showed slightly lower ratings of optimism-sociability over the 12 days, while those in the experimental group (4 hours of sleep) showed a bigger drop in their optimism-sociability ratings. Both groups recovered after a full night of rest (R on the x-axis).

CONCLUSION

Researchers concluded that not getting enough sleep can lower feelings of friendliness, optimism, and sociability.

FIGURE 9.4
Research Summary for a Randomized Controlled Trial on Green Spaces

RCT D

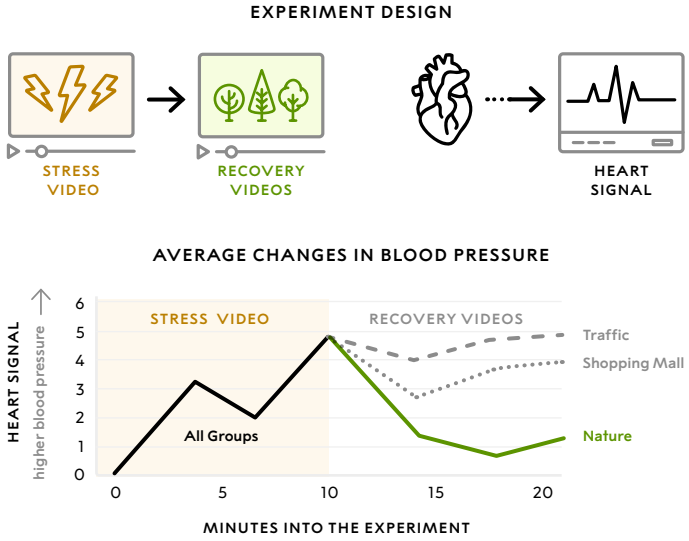
Green Spaces

STUDY DESIGN

Researchers wanted to test if watching videos of nature or urban environments could reduce stress levels. The study involved 120 university students (60 males and 60 females, mostly between the ages of 18 and 22) from a university in the Northeast United States. Each participant was monitored throughout the experiment by recording electrical signals from their heart. Participants also rated their well-being before and after the experiment. Each participant sat in a comfortable chair during all 3 parts of the experiment. In Part 1 (baseline), normal stress levels were recorded for 2–5 minutes. In Part 2, stress was triggered by a 10–minute video showing work accidents with injuries. In Part 3, participants were randomly assigned to 1 of 3 groups to watch different 10–minute stress-recovery videos: a control group (shopping mall) watched a video of an outdoor shopping area with people but no cars (40 students); experimental group 1 (nature) watched a video of trees, plants, and sounds of birds or a stream (40 students); experimental group 2 (traffic) watched a video of a commercial street with traffic (40 students).

STUDY RESULTS

Experiment design and average changes in blood pressure for the 3 groups:



All groups showed an increase in blood pressure during Part 2 compared to the control/baseline (0 on the graph). However, in Part 3, participants in experimental group 1 (nature video) had bigger and faster decreases in blood pressure than those in experimental group 2 (traffic video) or the control group (shopping mall video). Those in experimental group 1 (nature video) also had greater reductions in fear, negative feelings, and anger. There were no significant differences in sadness ratings between the groups.

CONCLUSION

Researchers concluded that watching nature videos help people recover from stress more quickly and completely than watching urban videos. Researchers suggested that nature may lower stress by activating the nervous system's calming and resting functions.

4 Return to your original group and have each group member share their study information. Complete Section 1 of the student sheet for the other three studies.

5 Review the text for the four RCTs again. Work as a group to search for the study design elements and analysis methods listed below and record your answers for each RCT in Section 2 of the student sheet.

   a **Sample size**
   How many participants were tested in each group of the experiment?

   b **Target group of the study**
   Which age was chosen to be studied?

   c **Consistency across settings**
   What location(s) and/or type(s) of people (gender, occupation) were included in the study?

   d **Effect size**
   Was there a difference between the groups and, if so, how large was it?

6 As a class, evaluate the studies by discussing how each study was designed and which confounds could have affected the results. Record those ideas about possible confounds for each of the four studies in Section 3 on the student sheet.

7 In your group, evaluate the strengths and limitations of each study based on the characteristics you recorded in Steps 5 and 6. Discuss how sure your group is of each study's conclusion(s) and record that in the last row of Section 3 on the student sheet. Use a scale of 0–5, where 0 means no relevant evidence and 5 means extremely strong evidence. Record your ideas in your science notebook.

BUILD UNDERSTANDING

① Of the four RCTs you investigated in this activity, which one do you think supports its conclusion with:

a the most convincing evidence?

b the least convincing evidence?

Consider the characteristics of confounds, sample size, target population, and effect size for the four different RCTs. Use your responses from Procedure Step 7 to back up your claims and include your group's rating (on a scale of 0–5) for how strong the evidence is in supporting the study's conclusion.

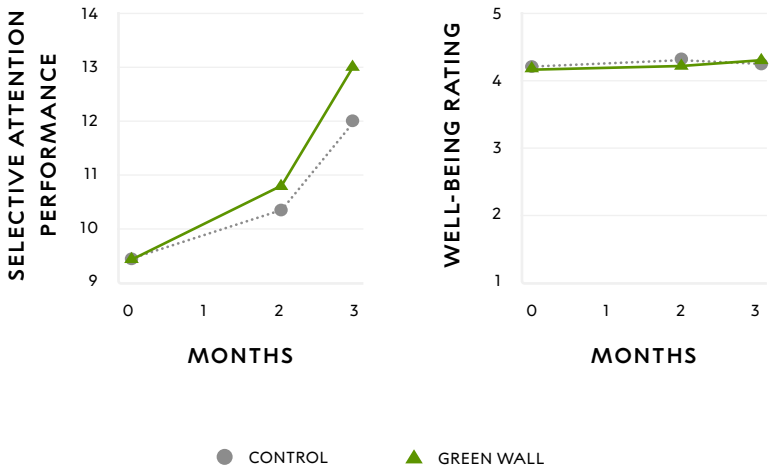
② Imagine that you are about to recommend adding a school garden at Salas High School to increase student access to green spaces to improve students' well-being. Then you come across another RCT for green spaces. In that study, researchers added green walls with living plants to four classrooms.

The classrooms were in two elementary schools in a medium-sized city in the Netherlands. The green walls were all the same size and placed in the same location in each classroom. Researchers tested students for attention to task and well-being before adding the plants and again two and three months after the plants were added. Compared to classrooms without green walls, students' attention scores increased. However, there was no measurable effect on student's self-reported well-being.

An example of a green wall at a school in Australia.

COURTESY OF Evergreen Infrastructure

FIGURE 9.5
Changes in Attention and Well-Being With and Without Green Walls



a Does the data support the claim that access to green spaces improves well-being? Why or why not?

b What are the main limitations of this study? Explain how the limitations affect your confidence in the study results.

c Given your answers to (a) and (b) and other evidence from this activity, would you still recommend the green spaces well-being strategy for Salas High School? Explain why or why not.

CONNECTIONS TO EVERYDAY LIFE

③ Think about a well-being claim you've seen in the media. Using what you've learned about sample size, consistency across settings, and effect size, how could you design an experiment to test if that well-being claim is true?

ACTIVITY 10

Making Decisions with Causal Reasoning

DISCUSSION

Making decisions based on cause-and-effect evidence can increase confidence in the outcome.

10: MAKING DECISIONS WITH CAUSAL REASONING

GUIDING QUESTION

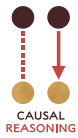
How can scientific evidence for causation be used to inform decisions?

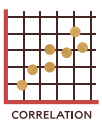
INTRODUCTION

In this unit, you have learned how to use different types of evidence to understand cause and effect. Causal reasoning can help individuals and communities identify the cause of a problem, develop solutions, and predict outcomes—for example, evaluating the evidence to determine where a new community park should be located or which after-school programs are the most effective. In this activity, you will apply what you have learned throughout the unit to make a decision about the Salas High School Well-Being Task Force scenario. You will review evidence for the four proposed strategies—Gratitude Writing, Pet Therapy, Green Spaces, and Quality Sleep—and compare plans for making the strategies happen. You will then choose the most promising strategy to recommend to the school.

You will be choosing a well-being strategy based on how effective it is and how practical it will be to implement.

CONCEPTUAL TOOLS





MATERIALS LIST

FOR EACH GROUP OF FOUR STUDENTS

- 4 RCT SUMMARY CARDS
- STUDENT SHEET 10.2 "Proposing a Plan"

FOR EACH STUDENT

- STUDENT SHEET 5.1 (a,b,c,or d) "Evaluating Indicators of Causation" (COMPLETED)
- STUDENT SHEET 9.1 "Comparing RCTs Related to the Well-Being Strategies" (COMPLETED)
- STUDENT SHEET 10.1 "Weighing Evidence for the Well-Being Strategies"
- STUDENT SHEET 10.3 "Comparing Well-Being Strategies and Proposed Plans"

PROCEDURE

PART A: REVIEWING EVIDENCE FOR THE FOUR WELL-BEING STRATEGIES

1 Read the following scenario.

The Salas High School Well-Being Task Force is meeting one final time to decide on a strategy and a plan for implementation to improve student well-being. A plan will be designed from one of the following four well-being strategies: Gratitude Writing, Pet Therapy, Green Spaces, and Quality Sleep. The recommendation depends on:

1. *strong evidence that the well-being strategy increases teenage well-being.*
2. *a practical way to implement the strategy at Salas High School.*

The Task Force will consider both of these criteria before making a recommendation.

Gratitude Writing

Pet Therapy

Green Spaces

Quality Sleep

2 Gather your student sheets from Activities 5 and 9. Your teacher will also give you 4 RCT Summary cards that describe published studies for each well-being strategy, including the one you compared to your class experiment in Activity 8.

3 Work as a group to complete Student Sheet 10.1, "Weighing Evidence for the Well-Being Strategies" for each well-being strategy. *Each group member will record the information for a different well-being strategy on their copy of the student sheet.* Use the evidence from Activities 5 and 9, along with the RCT Summary cards, to complete the table on the student sheet. Consider what you've learned in this unit—indicators of causation and study design elements—as you evaluate the evidence. Be sure to record the name of the well-being strategy you are responsible for at the top of the student sheet.

4 As a group, compare the research findings for each of the four strategies. Discuss how strong the evidence is for each strategy in improving well-being. Record your ideas in your science notebook.

5 Have a class discussion about the strength of the evidence for each well-being strategy. Then, decide for yourself how strong the scientific evidence is for each one. Record your ratings from 0 (no relevant evidence) to 5 (very strong evidence) in the first row of the table on Student Sheet 10.3, "Comparing Well-Being Strategies and Proposed Plans." (You will complete this student sheet in Steps 8 and 9.)

PART B: DESIGNING AND EVALUATING PROPOSED PLANS FOR IMPLEMENTING THE STRATEGIES

6 Your group will be assigned one well-being strategy. Brainstorm ways to implement that strategy at an actual school and choose the best idea. Decide on a name for your proposed plan and discuss how it could be carried out, keeping in mind how practical it would be to do at a school. On your copy of Student Sheet 10.2, "Proposing a Plan," record the name of your proposed plan. Also record all the details of your plan in the "Specific Plan Description" table.

7 Work with your group to identify all the supplies that would be needed to carry out your proposed plan, including supplies that could be donated. Also identify any possible implementation challenges that might arise, along with suggested solutions. Record your ideas in the "Practical Considerations" table on Student Sheet 10.2.

8 Share your proposed plan and practical considerations with the class. As other groups present their proposed plans, record notes on Student Sheet 10.3, "Comparing Well-Being Strategies and Proposed Plans."

9 Have a class discussion about how practical each plan is, considering both its strengths and weaknesses. As a class, choose the best proposed plan for each well-being strategy and record each name in the second row of the table on Student Sheet 10.3. Then, on your own, rate each selected plan, using a scale from 0 (extremely impractical) to 5 (very practical) and record your ratings in the last row of the table.

Evaluating research studies can help you make informed decisions for yourself and your community.

PART C: DECIDING ON A PLAN FOR SALAS HIGH SCHOOL

10 Participate in a Walking Debate to discuss which plan your class should recommend to the Well-Being Task Force at Salas High School. Use evidence about the well-being strategies and information about the proposed plans from Student Sheets 10.1, 10.2, and 10.3 to support your position.

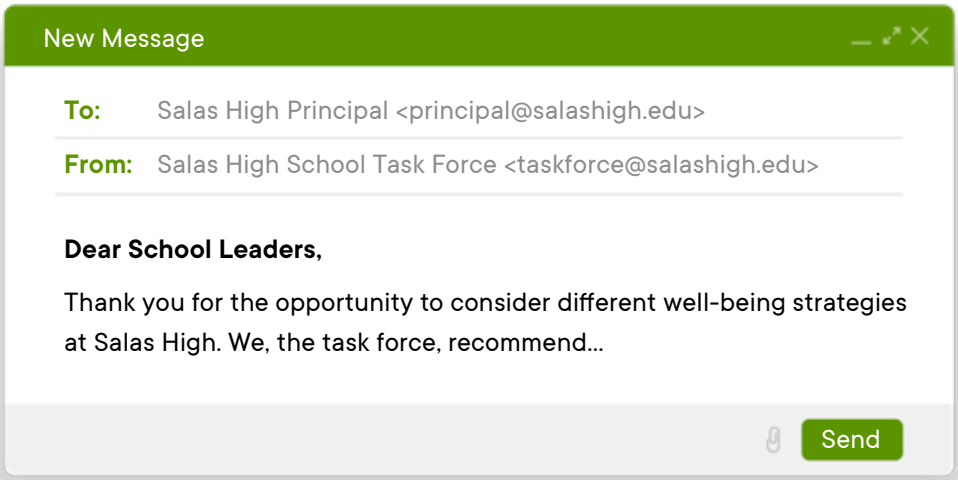
11 As a class, decide which of the four proposed plans the Task Force should recommend to their school based on:

- the strength of the evidence for each well-being strategy, and
- the practical considerations for each proposed plan.

BUILD UNDERSTANDING

① From all the plans your class discussed, which do you think is the best choice for Salas High School? Write a letter to the school leadership with your recommendation. You may choose any of the four plans, as long as you explain your evidence and reasoning. Be sure to include the following:

- **a** a description of the proposed plan,
- **b** evidence that supports the effectiveness of the well-being strategy,
- **c** practical considerations for implementing the proposed plan, and
- **d** any additional information you think they should consider.



CONNECTIONS TO EVERYDAY LIFE

② Would the recommendation you made for Salas High School also work in your own school? Explain why or why not. If you don't think it would work, describe what you think would be a better option.

③ If you were going to try one of the four well-being strategies in your life, which one would you choose and why? Explain by discussing how effective the strategy is at improving well-being and by describing why it might work best for you.

EXTENSION

In collaboration with your class and teacher, create a letter or presentation for your school administration proposing a plan to improve well-being at your own school. Use what you have learned in this unit to make an argument and address likely concerns.

STUDENT GLOSSARY

alternative explanation
another possible explanation for a result, such as an unnoticed variable or random chance

association
changes in two variables that tend to happen together

best-fit line
a line on a scatter plot used to analyze general trends in the data

causal reasoning
the use of observation and logic to identify cause-and-effect relationships

causation
when a change in one factor leads to a change in another

cause
a factor that produces a change in another factor (the effect)

confound
a factor that can distort or hide the relationship between two variables being investigated in a study

control group
the group in an experiment that does not receive the treatment and is compared to the experimental group

correlation
a type of association where two variables change together in a linear pattern

correlation coefficient (*r*)
a measurement ranging from –1 to +1 that indicates how strongly and in what direction two variables are associated with each other, also referred to as an *r*-value

dependent variable
the variable in an experiment that is measured after the independent variable has been manipulated to see if it changes as a result of the manipulation

effect
a factor that is changed by another factor (the cause)

effect size
the strength of an association between two variables, such as a correlation or the difference between two groups in an experiment

experimental group
the group in an experiment that receives the treatment and is compared to the control group

factor
something that actively contributes to the production of a result

independent variable
the variable in an experiment that is manipulated (typically using a treatment) to test its effect on the dependent variable

mechanism
a reasonable idea for how the possible cause could have led to an effect based on logic and knowledge

randomized controlled trial (RCT)
an experiment in which participants are randomly assigned to an experimental group or a control group

sample size
the number of individuals participating or items included in a study

timing
the order of events in time, where the possible cause comes before the effect

treatment
the procedure or situation that is changed only for the experimental group in a scientific study

variable
a feature, factor, or result that can change or vary

well-being
a combination of a person's mental, physical, emotional, and social health, both short-term and long-term

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