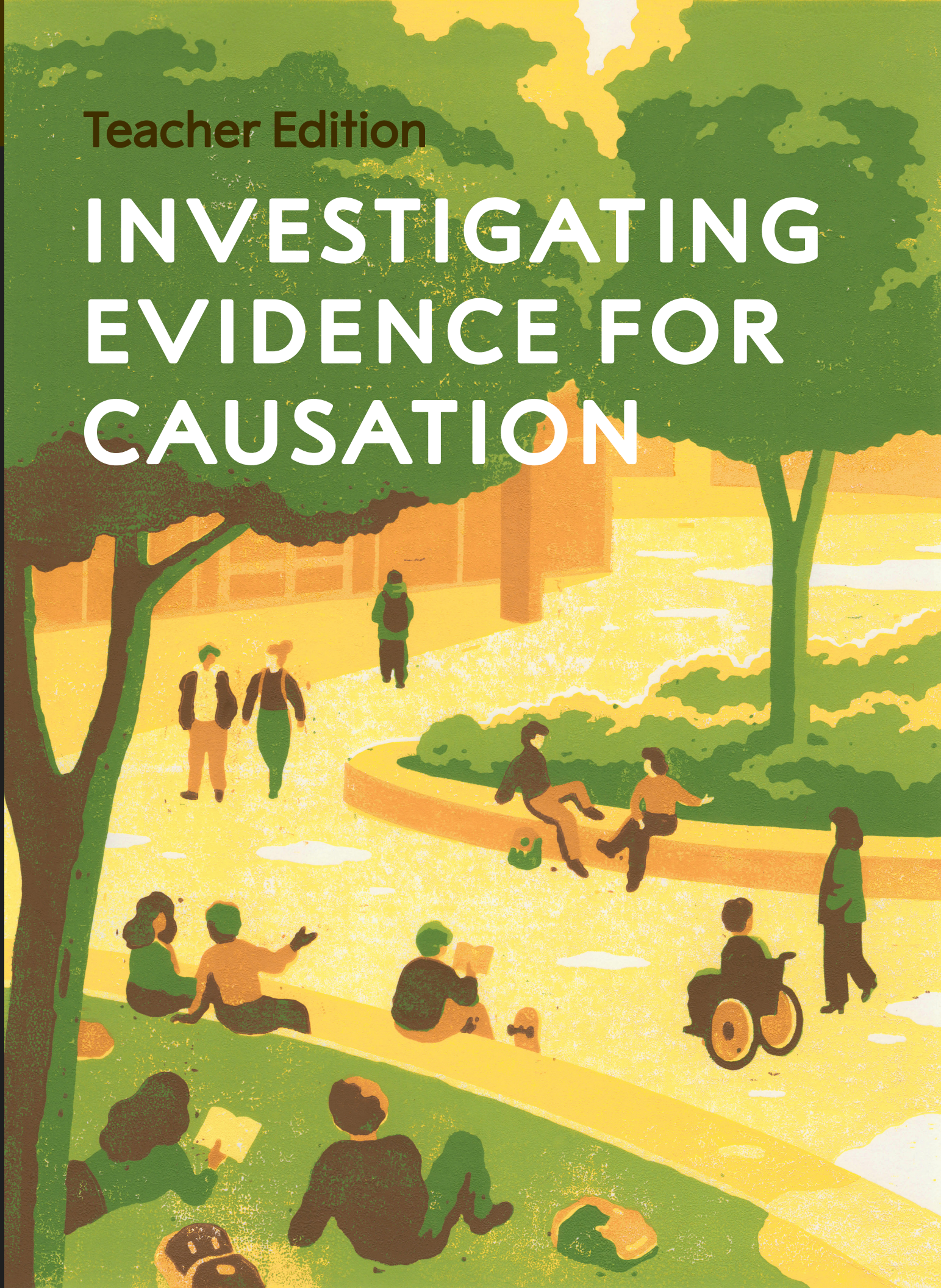


Teacher Edition

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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DEAR TEACHER,

In a world flooded with information, we continually make choices about what information to believe, and human limitations and biases can make it easy to fool ourselves.

Many people in the scientific community have worked to understand and counter these limitations, developing cognitive tools and techniques to minimize bias and avoid cognitive traps. Tools such as probabilistic reasoning, the use of multiple lines of evidence, and differentiating correlation from causation are essential to scientists' efforts to make sense of the world. For too long, these conceptual tools have been missing from much of high school education.

Scientific Thinking for All: A Toolkit is a curriculum designed to bring these ideas to students from all walks of life and cultural backgrounds. Our goal is to equip students with an everyday conceptual toolkit of some of the most powerful techniques from science. The curriculum situates the learning and practice of these techniques in real-world issue-based contexts of everyday importance that highlight the intersection of science and society. Your students will use these tools to ask questions, brainstorm ideas, interpret data, manage trade-offs, and develop solutions. The toolkit includes new and proven strategies to help students evaluate information, reflect on their thinking, and make more informed decisions. It is our hope that this science toolkit will empower your students to think more clearly about the things they care about, to provide them with strategies for addressing problems, and to help them achieve their personal goals.

As a teacher, you play a critical role in your students' lives and development. This work would not be possible without you. We invite you to work with us to help youth see the power and value of scientific thinking in their lives. Together, we can make scientific thinking more accessible, helping students to reimagine what science looks like and who gets to participate.

Sincerely,

Scientific Thinking for All Program Team

SCIENTIFIC THINKING FOR ALL

A TOOLKIT

COURSE DESCRIPTION

Scientific Thinking for All: A Toolkit is a high school curriculum designed to equip students with scientific tools and ideas for using and evaluating information. For example, conceptual scientific tools include modeling and strategies for probabilistic reasoning. Such conceptual tools can be used to interpret evidence, identify uncertainty, manage trade-offs, and develop iterative solutions. Students learn these ideas in the context of real issues at the intersection of science and society, ranging from medical treatments to land use.

The six-unit curriculum is divided into three major sections, each emphasizing different scientific tools. In Section 1, “Tools for Investigating the World,” students are introduced to the nature of science as an iterative process based on observation and measurement and use modeling to represent and predict specific aspects of the world. In Section 2, “Tools for Evaluating Data,” students evaluate different types of evidence for causation, discuss appropriate inferences and sources of uncertainty, and identify errors due to human bias. In Section 3, “Applying Science to Everyday Life,” students use techniques that encourage effective decision-making and consider science as a lens through which to understand the world.

COURSE DRIVING QUESTION

How do scientific tools and scientific thinking help people address complex challenges?

UNIT 4: INVESTIGATING EVIDENCE FOR CAUSATION

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UNIT 4

INVESTIGATING EVIDENCE FOR CAUSATION

UNIT SUMMARY

INTRODUCTION

In this unit, students are introduced to essential concepts related to **causal reasoning** in the context of scientific research on well-being. They explore cause-and-effect relationships by investigating how different strategies impact a person's overall well-being. Students learn causal reasoning by identifying **alternative explanations**, such as unnoticed variables or random chance, and by using **indicators of causation** such as association, plausible mechanisms, and timing. They practice how to distinguish **correlation** from causation and explore how scientists apply these methods in research, including through **randomized controlled trials**. These skills help students evaluate both everyday claims and scientific data, enabling them to make better-informed decisions for themselves and their 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?

PRIMARY CONCEPTUAL TOOL

Causal Reasoning

UNIT 4

INVESTIGATING EVIDENCE FOR CAUSATION

KEY CONCEPTS & PROCESS SKILLS



CAUSAL REASONING

- Causal reasoning can be used to identify the cause of an effect and to analyze the effectiveness of potential solutions.
- Some effects are difficult to identify due to insufficient evidence, multiple causes, delayed effects, or confounding factors.
- Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations.
- Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.



INDICATORS OF CAUSATION

- Indicators of causation include the timing of events, observed associations between variables, and plausible mechanisms for the possible cause and effect.
- A likely alternative explanation for an effect reduces the probability that the cause being investigated is the correct one.



CORRELATION

- A correlation indicates an association between variables but is not sufficient evidence to determine causation.



RANDOMIZED CONTROLLED TRIALS

- Randomized controlled trials (RCTs) are the most reliable method for identifying cause-and-effect relationships because they reduce the likelihood that alternative factors are influencing the effect.

While each activity focuses primarily on one or two of these concepts outlined in the following table, the concepts are addressed in multiple places throughout the unit. In the table, you can see where in the unit each of these Key Concepts & Process Skills is addressed.

KEY CONCEPTS & PROCESS SKILLS	ACTIVITY									
	1	2	3	4	5	6	7	8	9	10
Causal reasoning can be used to identify the cause of an effect and to analyze the effectiveness of potential solutions.										
Some effects are difficult to identify due to insufficient evidence, multiple causes, delayed effects, or confounding factors.										
Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations.										
Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.										
Indicators of causation include the timing of events, observed associations between variables, and plausible mechanisms for the possible cause and effect.										
A likely alternative explanation for an effect reduces the probability that the cause being investigated is the correct one.										
A correlation indicates an association between variables but is not sufficient evidence to determine causation.										
Randomized controlled trials (RCTs) are the most reliable method for identifying cause-and-effect relationships because they reduce the likelihood that alternative factors are influencing the effect.										

UNIT 4

INVESTIGATING EVIDENCE FOR CAUSATION

UNIT OVERVIEW

ACTIVITY TITLE AND SUMMARY	KEY CONCEPTS & PROCESS SKILLS	GUIDING QUESTION
1. Cause-and-Effect Claims INVESTIGATION Students are introduced to the concept of causal reasoning through a fictional high school (Salas High School) that seeks to improve student well-being. They examine statements from fictional members of the school community to identify cause-and-effect relationships of problems and solutions. Students complete a preliminary evaluation of four strategies proposed by the fictional school to improve well-being.	• Causal reasoning can be used to identify the cause of an effect and to analyze the effectiveness of potential solutions. • Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations. • Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.	Why is it important to identify possible cause-and-effect relationships?
2. Measuring Well-Being LABORATORY Students investigate the impact of exercise on short-term well-being by measuring changes in heart rate, alertness, and mood. They analyze their class data and explore the challenges of studying well-being by identifying other factors that might explain their results, such as music. Finally, students compare their results to existing research on exercise and discuss ways to design studies that limit alternative explanations.	• Some effects are difficult to identify due to insufficient evidence, multiple causes, delayed effects, or confounding factors. • Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations. • Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it. • NGSS Connection: Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.	What are the challenges of studying well-being?

UNIT OVERVIEW

CONTINUED

ACTIVITY TITLE AND SUMMARY	KEY CONCEPTS & PROCESS SKILLS	GUIDING QUESTION
3. Questioning Causation INVESTIGATION Students explore indicators of causation, such as timing, association, and mechanism, and also consider alternative explanations to events. They are presented with cartoons of everyday situations that they analyze for cause and effect. Then, students use this experience to reevaluate claims about causation in the social media posts about the Salas High School well-being initiative from Activity 1.	- Indicators of causation include the timing of events, observed associations between variables, and plausible mechanisms for the possible cause and effect. - A likely alternative explanation for an effect reduces the probability that the cause being investigated is the correct one. - Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.	How do people consider if one event caused another?
4. Interpreting Correlations DATA ANALYSIS Students explore what can and cannot be determined from associations between two variables. They familiarize themselves with scatter plots by creating one based on data for their own sleep quality and mood. They then compare and describe a set of scatter plots with associations ranging from strong negative to strong positive. Finally, students explore how to use indicators of causation (association, timing, and mechanism) and alternative explanations to analyze the possibility of a cause-and-effect relationship and understand why causation cannot be inferred from correlation.	- A correlation indicates an association between variables but is not sufficient evidence to determine causation. - Indicators of causation include the timing of events, observed associations between variables, and plausible mechanisms for the possible cause and effect. - A likely alternative explanation for an effect reduces the probability that the cause being investigated is the correct one. - NGSS Connection: Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.	What can be learned from an association between two variables?

UNIT OVERVIEW

CONTINUED

ACTIVITY TITLE AND SUMMARY	KEY CONCEPTS & PROCESS SKILLS	GUIDING QUESTION
5. Evidence of Well-Being INVESTIGATION Students use the indicators of causation to analyze the strength of a set of evidence for one of the four proposed strategies to improve well-being at Salas High School. Each group evaluates the strengths and weaknesses of three pieces of evidence for a strategy and considers alternative explanations. Then, using a classroom jigsaw approach, students discuss the evidence and collaboratively arrange the strategies from weakest to strongest evidence.	- Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it. - Indicators of causation include the timing of events, observed associations between variables, and plausible mechanisms for the possible cause and effect. - A likely alternative explanation for an effect reduces the probability that the cause being investigated is the correct one. - NGSS Connection: Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.	How do scientists use evidence to evaluate causation?
6. Understanding Well-Being Through Research READING Students read about the landmark Harvard Study of Adult Development that began in 1938 and continues today. The researchers conducted a long-term observational study to track patterns of happiness and well-being among a group of 19-year-old students for the rest of their lives. The study's design exemplifies some of the causal reasoning approaches students have been investigating in this unit, such as reducing the likelihood of alternative explanations. Students learn how scientists design studies and analyze data to be more confident in their findings. Students engage in a literacy strategy to support reading comprehension.	- Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations. - Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it. - A likely alternative explanation for an effect reduces the probability that the cause being investigated is the correct one.	What study designs and analysis methods increase confidence in results?

UNIT OVERVIEW

CONTINUED

ACTIVITY TITLE AND SUMMARY	KEY CONCEPTS & PROCESS SKILLS	GUIDING QUESTION
7. Improving Experimental Design COMPUTER SIMULATION Students use a computer simulation to see how adjustments to experimental design affect the reliability and interpretation of the results. First, they manipulate sample size to understand how results can vary widely even with the same experimental design. Then, they apply their understanding of sample size to explore different treatments and methods for assigning participants to experimental and control groups. As students progress, they explore how reliable results depend on large sample sizes and reducing confounds, which prepares them to design their own randomized controlled trial in Activity 8.	- Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations. - Randomized controlled trials (RCTs) are the most reliable method for identifying cause-and-effect relationships because they reduce the likelihood that alternative factors are influencing the effect. - NGSS Connection: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.	How do changes in study design affect the results?
8. Testing a Well-Being Strategy LABORATORY Students choose one of the four well-being strategies under consideration for Salas High School to test out in their classroom. First, they choose a strategy to investigate with a randomized controlled trial, and then they work as a class to generate a study design for a randomized controlled trial that can be conducted in the classroom. They run the experiment in their classroom and analyze the results. Finally, students compare their study design and results to those of a study on the same strategy published in a peer-reviewed scientific journal.	- Some effects are difficult to identify due to insufficient evidence, multiple causes, delayed effects, or confounding factors. - Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations. - Randomized controlled trials (RCTs) are the most reliable method for identifying cause-and-effect relationships because they reduce the likelihood that alternative factors are influencing the effect.	How do you design a randomized controlled trial?

UNIT OVERVIEW

CONTINUED

ACTIVITY TITLE AND SUMMARY	KEY CONCEPTS & PROCESS SKILLS	GUIDING QUESTION
9. Evaluating Randomized Controlled Trials DATA ANALYSIS Groups analyze short summaries of peer-reviewed randomized controlled trials (RCTs) related to the four well-being strategies being considered for Salas High School. Students examine key characteristics of each study, such as effect size, consistency across different settings, and sample size, to assess their confidence in the results. This prepares students for the final activity in which they will examine the data they have collected over the course of the unit to help them determine the best well-being strategy for Salas High School.	- Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it. - Randomized controlled trials (RCTs) are the most reliable method for identifying cause-and-effect relationships because they reduce the likelihood that alternative factors are influencing the effect. - NGSS Connection: Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.	How can randomized controlled trials be evaluated?
10. Making Decisions with Causal Reasoning DISCUSSION In this culminating activity, students participate in a group decision to choose which well-being strategy to recommend to Salas High School. Students summarize the evidence they've gathered throughout the unit to consider how well each strategy can improve well-being. Each group creates a plan for implementing one of the strategies, including practical considerations and potential challenges. Afterward, the class shares their ideas and comes to a consensus on the best recommendation for the school. Throughout this process, students draw from the unit's key concepts and process skills about causal reasoning to support their decision.	- Causal reasoning can be used to identify the cause of an effect and to analyze the effectiveness of potential solutions. - Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it. - Randomized controlled trials (RCTs) are the most reliable method for identifying cause-and-effect relationships because they reduce the likelihood that alternative factors are influencing the effect.	How can scientific evidence for causation be used to inform decisions?



ACTIVITY 1

Cause-and- Effect Claims

INVESTIGATION

ACTIVITY 1

Cause-and-Effect Claims

ACTIVITY SUMMARY

Students are introduced to the concept of causal reasoning through a fictional high school (Salas High School) that seeks to improve student well-being. They examine statements from members of the fictional school community to identify cause-and-effect relationships of problems and solutions. Students complete a preliminary evaluation of four strategies proposed by the fictional school to improve well-being.

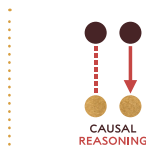
ACTIVITY TYPE
INVESTIGATION

NUMBER OF
40-50 MINUTE
CLASS PERIODS
1

KEY CONCEPTS & PROCESS SKILLS

- 1 Causal reasoning can be used to identify the cause of an effect and to analyze the effectiveness of potential solutions.
- 2 Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations.
- 3 Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.

CONCEPTUAL
TOOLS



VOCABULARY DEVELOPMENT

causal reasoning

the use of observations 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)

dependent variable

(assumed prior knowledge)

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)

independent variable

(assumed prior knowledge)

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

variable

(assumed prior knowledge)

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

TEACHER BACKGROUND INFORMATION

Causal Reasoning

Investigating and describing cause-and-effect relationships can inform decisions and enable predictions about future events by providing insight into the factors that drive outcomes. Causal reasoning is used not only in science but also in policy and in individual, group, and societal decision-making. It is crucial to understand which actions will bring about which effects when making decisions that will further our goals.

Well-Being

According to well-being researchers, part of a working definition for the term *well-being* (as stated in the journal *Affective Science*) is “...how positive an individual feels generally and about life overall...” There are many aspects to someone’s well-being, including how they feel and function, both personally and socially, based on their physical health, emotions, behaviors, thoughts, and relationships. Well-being is more than just momentary pleasure or being in a good mood—it includes life satisfaction, contentment, sense of purpose, and social connection.

Attending to one’s well-being goes beyond physical and mental health to incorporate social and emotional factors. The World Health Organization (WHO) defines *well-being* as “...a positive state experienced by individuals and societies. Similar to health, it is a resource for daily life and is determined by social, economic, and environmental conditions. Well-being encompasses quality of life and the ability of people and societies to contribute to the world with a sense of meaning and purpose.”

Although many variables that affect a person’s well-being are beyond their control or require long-term planning and work to influence them, there are also a number of strategies and actions that people can use in their lives to improve their well-being in the short term and, thus, in the long term overall. Many of these strategies have been studied in detail by researchers and promoted by organizations such as the [Greater Good In Action](#) project from the [Greater Good Science Center](#) at the University of California, Berkeley, and the [Happiness Lab Podcast](#) by Dr. Laurie Santos at Yale University. These organizations work with academics and the public to promote everyday strategies that scientific research suggests have a positive effect on well-being.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 1.1
“Understanding
Conceptual Tools”
(OPTIONAL)
- VISUAL AID 1.2,
“Developing
Communication Skills”
(OPTIONAL)
- VISUAL AID 1.3
“Proposed Well-Being
Strategies for Salas
High School”

FOR EACH STUDENT

- STUDENT SHEET 1.1
“Evaluating Salas High
School Forum Posts”
- STUDENT SHEET 1.2
“Unit Concepts
and Skills”
(OPTIONAL)

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (10 MIN)

1 Access students' prior knowledge about well-being.

- While many students will likely be familiar with the basic concept of cause and effect—where one variable (the cause) leads to another variable (the effect)—this unit is designed to deepen their understanding of the complexity of determining cause-and-effect relationships. Students will explore these concepts through the complicated issue of well-being, which is the focus of this introductory activity.
- Begin the activity by asking, **What do you think the term *well-being* means?** Have students briefly share their own understanding of the term based on their own lived experiences and prior knowledge. Ask, **What kinds of things do you think affect a person's well-being?** Compile a list of student suggestions that can be revisited later. Students may respond with ideas about being healthy or sick, amount of stress, time with friends, etc.
- Have students read the Introduction to Activity 1 in the Student Book, either as a class or individually. Connect students' prior knowledge and ideas about well-being to the information provided. **Students may have personal experience with and prior knowledge of issues related to well-being. Engaging students about their experiences can create a stronger foundation for learning. Support students, particularly those with varied life experiences, in sharing their prior knowledge of and personal experiences with this issue. Specifically validate funds of knowledge—not just textbook knowledge but also family or cultural insights, practices, and personal histories—by eliciting students' observations and experiences as assets to building understanding. Throughout this unit, encourage students to respond to any topics or questions that arise to which they feel a personal connection—during small-group or class discussions, when students respond to relevant Build Understanding items, and/or when they write reflections in their science notebooks.**
- Revisit the student list of things that affect well-being. Encourage students to think about various aspects of well-being including mental, physical, emotional, and social health. Students may have the misconception that well-being is limited to how happy or healthy they feel at the moment. Emphasize that well-being is more than just positive emotions. It also includes your overall life satisfaction, a range of emotions and thoughts, your day-to-day behaviors, and the feeling that you are valued. Some psychologists think of it as both being happy *in* your life and being happy *with* your life—this is referred to as subjective well-being.

TEACHER’S NOTE: Although mental health challenges can impact well-being, this unit will focus primarily on positive aspects of well-being such as happiness, life satisfaction, and belonging. If necessary, explain to students that the scope of the unit does not include addressing mental-health challenges directly. Support students in sharing their knowledge while remaining sensitive to students with personal experiences related to well-being and mental-health issues. This unit focuses on short-term strategies, as well as actions and methods, that students may be able to easily and effectively implement in their own lives to improve their well-being. It is beyond the scope of this unit to address more long-term and complex variables such as economic conditions, underlying physical and/or mental-health challenges, etc.

2 Introduce causal reasoning as the primary conceptual tool of the unit.

- Explain to students that this unit will focus on the methods scientists use to study cause and effect and how understanding these methods can be useful in students’ everyday lives.
- Review the term *causal reasoning* provided in the Introduction in the Student Book. Emphasize that understanding how one event causes another can help explain why things happen, guide decisions, and help make predictions. In this unit, students primarily engage in causal reasoning by evaluating evidence and assessing the likelihood of cause-and-effect relationships.
- Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by reviewing the terms presented in the activity and supporting the construction of a word wall. You may want to model a sample response as a class to help scaffold student understanding. For this activity, record the terms *well-being*, *causal reasoning*, *causation*, *cause*, and *effect*. Provide additional examples for each term as needed. For more information on a Word Wall, see [Appendix 1: Literacy Strategies](#).
- The scientific toolkit is intended to be a set of conceptual tools that can be applied to everyday life. With each new unit, students will add conceptual tools to their toolkits. Depending on your student population, use optional Visual Aid 1.1, “Understanding Conceptual Tools” to support the multiple contexts that are used with the word *tool*, which is defined as an implement used to carry out a particular function. The word is commonly used to refer to construction tools such as hammers, levels, and tape measures. In a science classroom, examples of scientific tools include beakers, graduated cylinders, and microscopes. There are also many tools from the last category presented on the visual aid—conceptual thinking approaches that are used to evaluate cause-and-effect relationships. In this unit, students consider conceptual tools, such as indicators of causation, as a way of exploring the application of science to everyday life.
- As students build understanding about the importance of causal reasoning, they will build a conceptual tool about this idea in their minds and develop skills to utilize it at various points in the unit. You may wish to use optional Student Sheet 1.2, “Unit Concepts and Skills,” to help students organize their learning. This course organizer is designed to help students reflect on their understanding of each conceptual tool, consider how they have used it to analyze problems throughout the unit, and how it may influence their decisions about unit topics.

- While a completed sample unit organizer is provided in the Teacher Edition at the end of this activity, students will not be able to complete it at this time; the ideas in the sample response will be built over the course of the unit. At the end of this activity, students can complete a row in the organizer about the main idea of causal reasoning and add an example from their classroom experiences. The Salas High School scenario provided in this activity is an example of when students had an opportunity to analyze evidence related to cause and effect to help inform a decision. As students engage in future activities, they can return to the organizer to add new examples of each concept they learn.

PROCEDURE SUPPORT (20 MIN)

3 Present the fictional scenario of Salas High School found in Procedure Step 1.

- The scenario presented in Step 1 can be shared with the class in multiple ways. Read the scenario aloud to the class or have individual students read it aloud while others follow along with the text (either as a whole class or in small groups).
- Reading the scenario aloud can better support comprehension for many students, including neurodiverse students and emerging multilingual learners who often have more highly developed listening and oral skills than reading comprehension skills. Alternatively, students can read the scenario independently.
- Let students know that this unit's scenario about Salas High School is designed to help them understand the concept of causal reasoning, which is the primary conceptual tool of the unit. In the activity, students begin to evaluate cause-and-effect relationships to support their choice of a well-being strategy. Point out that the strategies and skills explored in this unit can also be applied to managing their own well-being.

4 Students brainstorm well-being strategies.

- In Procedure Step 2, students' brainstorming sets the stage for later discussions in the unit about gathering evidence to support or refute causation. Brainstorming is intended to engage students in thinking about the real and relevant challenge of improving well-being, which they will pursue throughout the unit. If students are unclear about what is meant by strategies to improve well-being, consider providing examples such as the school sponsoring a well-being workshop, creating games to improve student connection, creating a relaxation space, promoting physical activity, starting a mindfulness program, or improving school nutrition.
- While groups work, walk around the classroom and ask students to share their thoughts on what types of information about the strategies might help them choose one for Salas High School. Encourage students to think about cause-and-effect relationships and how this relates to the

eventual selection of activities by the Salas High School Well-Being Task Force. Before adopting a strategy, students should recognize that it would be beneficial to look at evidence to see if an individual strategy will have an effect on well-being.

- To support students' discussion, you may wish to use optional Visual Aid 1.2, "Developing Communication Skills," to help guide student interactions. Visual Aid 1.2 is a tool to help students effectively participate in class discussions by providing sentence starters that students can use to initiate a conversation and express their ideas. For more information about Developing Communication Skills, see [Appendix 1: Literacy Strategies](#).

5 Students identify possible cause-and-effect relationships.

- Hand out Student Sheet 1.1, "Evaluating Salas High School Forum Posts." Let students know that they will be working in groups to review well-being problems and proposed solutions from fictional students at Salas High School for cause and effect.
- If students need support distinguishing between cause and effect or problem and solution, you may want to review the first social media post as a class and model how to fill out the first row on Student Sheet 1.1.
- In Procedure Step 4, if students are unfamiliar with the concept of scientific variables, remind them to refer to the Science Review at the end of the Student Book activity. This summary reviews basic concepts about independent and dependent variables and how they are related to cause and effect. If appropriate for your students, add the terms *variable*, *independent variable*, and *dependent variable* to the word wall.

6 Students share their analyses of the cause-and-effect claims.

- After students have completed Student Sheet 1.1, ask a few groups to share which social media posts they thought were *most likely* and *least likely* to be effective. For each post, have them share their answers for Procedure Steps 4 and 5:
 - the possible cause and possible effect for the problem.
 - the possible cause and possible effect of the proposed solution.
 - ideas that support their choices for the posts that are the most effective and least effective.
 - the kind of additional evidence they would want to gather.

After the first group shares their ideas, ask if other groups agree or disagree and why, so students can consider a range of answers. Sample responses for why a proposed solution was chosen as most effective or least effective might include: confidence or skepticism about how it works, whether it is supported by established science, whether it has been tested with evidence, how commonly the solution addresses the problem, or other possible reasons for the results mentioned in the social media post.

Sample Student Response, Procedure Step 4

a Problem:

Possible Cause X: trouble paying attention, not doing well on tests

Possible Effect Y: unhappiness

b Proposed Solution:

Possible Cause X: adding solid quartz crystals to school water

Possible Effect Y: more energy, focus, and happiness

Sample Student Response, Procedure Step 5

I think the crystal in the water would be the least effective.

a *I don't think quartz crystals in water would do anything to your mood. I can't think of any evidence out there that says it would work at all. Quartz resonating in water sounds wacky. Plus, the person was exercising too, so that was what probably actually caused the change in mood.*

b *I would want to see if there are studies that show that quartz crystals really affect mood. Also, It was just one person and one day after trying it. I'd want to see if it actually works for more people and more times.*

- After students complete Procedure Step 6, review the four proposed well-being strategies with the class. You may wish to display optional Visual Aid 1.3, “Proposed Well-Being Strategies for Salas High School,” to review them. This visual aid can also be used in later activities to remind students of the four well-being strategies being considered. Have students share which strategies they think are the most promising. There is no need for the class to come to consensus as these strategies will be revisited throughout the unit, and students will have opportunities to learn more about them and about the evidence that supports their effects on well-being. Encourage students to consider what evidence might help convince them of the strategy (or strategies) that would be the most effective.

SYNTHESIS OF IDEAS (15 MIN)

7 Facilitate a discussion about why causal reasoning can be useful.

- Evaluate if your students are able to identify the essential ideas of the activity. Start a brief discussion by asking, **Why is studying cause and effect for a problem and its potential solutions useful?** Students may respond with ideas about how causal reasoning can support finding solutions. Emphasize the role of causal reasoning in identifying effective strategies and the following specific ideas:
 - If you understand what is really causing the problem, you can come up with a solution that is more likely to work.

- If you study the effects of a possible solution, you can figure out how well it solves the problem.
 - By studying cause and effect, you can find the best solution and make sure it doesn't cause new problems.
 - Remind students that while trying to investigate a well-being strategy that works for the school, they can also evaluate how well some of these strategies might work to improve their own well-being. A prompt that asks students to apply what they have learned to their own life is provided in Connections to Everyday Life item 3. For emerging multilingual learners, students could describe this orally, through pictures and diagrams, through poetry, or with music. For example, you could use the prompt to ask students to come up with a creative way to express their approach to well-being before they describe evidence they have for its effectiveness.
- TEACHER'S NOTE: The Build Understanding and Connections to Everyday Life items are intended to guide student understanding. You may decide to assign some or all of them, depending on the needs of your students. However, some of the items are recommended in particular activities for use as assessments or to review key concepts.
- To conclude the activity, evaluate whether your students are able to answer the Guiding Question, *Why is it important to identify possible cause-and-effect relationships?* Use this as a chance to revisit and summarize the key concepts and process skills of the activity.

EXTENSION (30 MIN)

8 Use the Extension as an opportunity for advanced learning.

Students can learn about a variety of well-being strategies and investigate one or two of them by going to UC Berkeley's [Greater Good In Action](#) project or take short quizzes on well-being at the [Greater Good Magazine's Keys To Well-Being](#) page. Alternatively, you may want to share the website for students to learn more about Dr. Laurie Santos' [The Science of Well-Being for Teens](#) course through Yale University. For extra well-being resources to support students, you can also explore the [Greater Good in Education](#) website for educators.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

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.

- 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.

One well-being problem is that students feel tired and have trouble focusing in class. A possible cause of this is that students don't eat healthy meals and snacks, so they don't get the nutrients their bodies and brains need to work well.

- 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.

I think it's pretty likely that improving the school lunches to offer more nutritious options would help. Eating healthier with fruits, vegetables, and protein can help you stay focused. For example, if students eat candy, they might feel more tired a couple of hours later. To be sure the strategy would work, I'd want to see studies that show how eating healthier improves students' focus and energy levels. I'd also want to look at other schools where they improved school lunches to see if their students performed better in class or felt happier.

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.

This is an example of cause and effect. People recognize the siren (cause) as a signal of an emergency, and this causes them to move their cars (effect) and allow the fire engine to pass.

- b Doing my laundry on Thursday and spilling food on my shirt the next day.

This is not an example of cause and effect because it is more of a coincidence. It's not the fact that you did laundry that caused you to spill something a day later, but probably clumsiness or something else.

- c A cat sitting on a windowsill, and a bird flying past the window outside.

This is not an example of cause and effect. A cat sitting on a windowsill would have no effect on whether a bird starts flying outside—unless the bird saw it (cause) and that made it start flying (effect).

- d Someone swallowing acetaminophen, and the pain in their sprained wrist going away a short time later.

Yes, this is an example of cause and effect. Acetaminophen is a medicine that is known to reduce pain (effect) from things like headaches when it is taken (cause).

- ③ What do you do in your own life that helps your well-being? Describe any evidence you have that it works.

There are lots of things in my life that help with my well-being, but I think two of the most important ones are having a dog and having a best friend I can talk to when I'm stressed or upset. I know that having a dog helps my well-being because I always feel happier and more relaxed after I take him for a walk. If I'm upset, it helps me feel better to sit with him and pet him. I know that having a best friend I can talk to helps when I'm stressed or upset because after I talk to her, I always feel much better even if I haven't fixed the problem. I feel more calm and able to come up with solutions after I talk things over with my friend.

- 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.

It's important to investigate cause and effect because you need to be sure you're fixing the right thing to actually solve the problem. If using their phone is the actual cause of the problem, then Avery will spend a lot of money but not solve the problem. The real cause might be staying awake and on their phone.

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POSTED BY	PROBLEM		PROPOSED SOLUTION	
	POSSIBLE CAUSE (X)	POSSIBLE EFFECT (Y)	POSSIBLE CAUSE (X)	POSSIBLE EFFECT (Y)
@whizza457				
@artLion22				
@newGirl\$haz				
@buddys2010				
@MrHendrick_ SuperTeacher				
@2goBerock				

POSTED BY	PROBLEM		PROPOSED SOLUTION	
	POSSIBLE CAUSE (X)	POSSIBLE EFFECT (Y)	POSSIBLE CAUSE (X)	POSSIBLE EFFECT (Y)
@whizza457	sugar	bad for minds and bodies, increases anxiety	ban sugar from food at school	less anxious
@artLion22	stress from school	less happy	wearing yellow and green	happier and less stressed
@newGirl\$haz	stuck indoors	bad mood	school flower garden	feel better, less grumpy
@buddys2010	students are lonely	not happy	spending time with a dog	feel less lonely, happier
@MrHendrick_SuperTeacher	trouble paying attention, not doing well on tests	unhappy	add solid quartz crystals to school water	more energy, focus, and happiness
@2goBerock	not enough sleep	tired and cranky	change school start time, more sleep	better mood and health

UNDERSTAND		ANALYZE
CONCEPT	DESCRIPTION	UNIT EXAMPLE(S)

WHAT DECISION(S) WERE MADE OR ACTION(S) TAKEN?

UNDERSTAND		ANALYZE
CONCEPT	DESCRIPTION	UNIT EXAMPLE(S)
Causal Reasoning	<i>using logic and observations to figure out if one thing causes another and to help evaluate problems and solutions</i>	• social media posts on well-being • everyday situation cartoons • comparing evidence about the well-being data for four well-being strategies
Alternative Explanations	<i>another possible reason for why you got a certain result or why something happened</i>	• music affects mood in the lab instead of exercise • social media posts on well-being • well-being correlation scatter plots • sleep and studying Build Understanding item
Indicators of Causation	<i>evidence that supports if one thing actually causes another thing, like an association, correct timing, and a likely mechanism</i>	• image of the cat and spilled paint • using questions to explore the social media posts on well-being • using questions to compare evidence about the four well-being strategies
Correlation	<i>two things changing together in a pattern does not mean one causes the other</i>	• sharks and ice-cream sales correlation • comparing scatter plots on the four well-being strategies
Causal Reasoning	<i>a cause-and-effect relationship depends on the quality of the evidence supporting it</i>	• choosing a strategy for Salas High • comparing research evidence about the effectiveness of the four well-being strategies
Randomized Controlled Trials	<i>the most reliable method for identifying cause-and-effect relationships</i>	• designing a better Dapple game study to support causation • class experiment on a well-being strategy

WHAT DECISION(S) WERE MADE OR ACTION(S) TAKEN?

Choosing a well-being strategy for Salas High School, evaluating scientific research, identifying ways to improve personal well-being, examining health-related ads and claims.

CONSTRUCTION TOOLS



SCIENTIFIC TOOLS



SCIENTIFIC TOOLS + TECHNOLOGY



CONCEPTUAL TOOLS



COMMUNICATION	SENTENCE STARTERS
to better understand	One point that was not clear to me was... What if we tried...? I have an idea. We could try...
to disagree	I see your point, but what about...? Another way of looking at this is... I'm still not convinced that...
to challenge	How do you reach the conclusion that...? What makes you think that...? How does it explain...?
to look for feedback	What would help me improve is... Does it make sense, what I said about...?
to provide positive feedback	One strength of your idea is... Your idea is good because...
to provide constructive feedback	The argument would be stronger if... Another way to do it would be... What if you said it like this...?



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.



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.



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.



ACTIVITY 2

Measuring Well-Being

LABORATORY

ACTIVITY 2

Measuring Well-Being

ACTIVITY SUMMARY

Students investigate the impact of exercise on short-term well-being by measuring changes in heart rate, alertness, and mood. They analyze their class data and explore the challenges of studying well-being by identifying other factors that might explain their results, such as music. Finally, students compare their results to existing research on exercise and discuss ways to design studies that limit alternative explanations.

ACTIVITY TYPE
LABORATORY

NUMBER OF
40-50 MINUTE
CLASS PERIODS
1-2

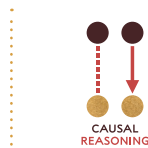
KEY CONCEPTS & PROCESS SKILLS

- 1 Some effects are difficult to identify due to insufficient evidence, multiple causes, delayed effects, or confounding factors.
- 2 Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations.
- 3 Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:

Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. (*Science and Engineering Practice: Analyzing and Interpreting Data*)

CONCEPTUAL
TOOLS



VOCABULARY DEVELOPMENT

alternative explanation

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

TEACHER BACKGROUND INFORMATION

Alternative Explanations

Philosophers of science argue that for any set of evidence, there is usually more than one possible explanation for it. In other words, having evidence for one specific theory or idea isn't enough to prove it's correct—an alternative explanation could be responsible. However, when the alternative explanations are highly unlikely, overly complex, or both, we can feel more confident in the accuracy of our original explanation.

Considering alternative explanations is a crucial step in evaluating the strength of evidence. If there is an alternative explanation for a result, then the evidence is weaker. Alternative explanations can apply in different ways when evaluating cause-and-effect relationships. One type of alternative explanation questions the cause of an effect. For example, if a study finds that students who sleep more tend to have higher well-being, an alternative explanation could be that another factor, such as lower stress, causes both better sleep and higher well-being. This challenges whether sleep itself is the true cause. Another type of alternative explanation questions whether the study's results are accurate. Even if sleep genuinely improves well-being, the findings of a study might be misleading due to random chance. For example, if the study includes only a small number of participants, the results might not represent what would happen in a larger group. In this case, the issue isn't whether sleep affects well-being, but whether the study's evidence is strong enough to confidently support that claim.

A common mistake in evaluating evidence is ignoring possible alternative explanations, even when they seem obvious later on. For this reason, we ask students to practice thinking about both types of alternative explanations throughout the unit—questioning the cause of an effect and questioning the accuracy of a study's results.

Exercise and Well-Being

There are numerous studies showing that exercise boosts many aspects of well-being, including both physical and mental health. Exercise triggers the release of endorphins, which help reduce anxiety and depression. A large study of 1.2 million American adults, published in the journal *Lancet Psychiatry*, found that people who exercised had 40% better mental health than those who didn't exercise, even after accounting for factors such as body mass index (BMI), physical health, age, and race. Team sports had the strongest connection to better mental health, likely because it combines physical activity with social interaction.

Both short-term and regular exercise can be beneficial. Short-term bouts of exercise can lead to immediate improvements in mood and cognitive function. For instance, studies have shown that a single session of physical activity can enhance attention, working memory, and problem-solving skills for up to two hours post-exercise. Regular physical activity offers more substantial long-term advantages, including sustained improvements in mental health, reduced risk of chronic diseases, and better overall well-being.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 2.1
“Class Results: Change in Heart Rate, Alertness, and Mood”
(OPTIONAL)
- VISUAL AID 2.2
“Sample Class Results”
(OPTIONAL)
- VISUAL AID 2.3
“Studies on Exercise and Well-Being”
- COMPUTER TO PLAY
A 3-MINUTE VIDEO OR
A CLASSROOM AUDIO
DEVICE

FOR EACH PAIR OF STUDENTS

- TIMER THAT
DISPLAYS SECONDS
- CALCULATOR
- STUDENT SHEET 2.1
“Measuring Physical
and Mental Responses
to Exercise”

Each pair of students should receive one copy of the student sheet to complete together.

Consult with a physical education teacher about what types of exercises might be most appropriate for your student population (see Teaching Step 2). Inform students in advance that they will be exercising in class. Encourage them to wear appropriate attire, including appropriate shoes, and be prepared to perspire.

Choose a 3-minute song or video with music that will be likely to affect students' moods and act as a possible confound during the experiment. This could be a popular, high energy, or funny dance song that is played for the duration. If a video with a countdown is used, a timer is not required for each pair of students.

While the Student Book includes instructions for measuring pulses at the wrist or neck, you might prefer to have students use heart monitors/sensors, such as those available from science or sports-gear suppliers. Alternatively, students can download and use free heart rate monitoring apps on their phones or watches.

Safety Note

Do not allow students to participate in this activity if they have any condition that prevents them from exercising.

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (10 MIN)

1 Have students read the Introduction and discuss how well-being can be measured.

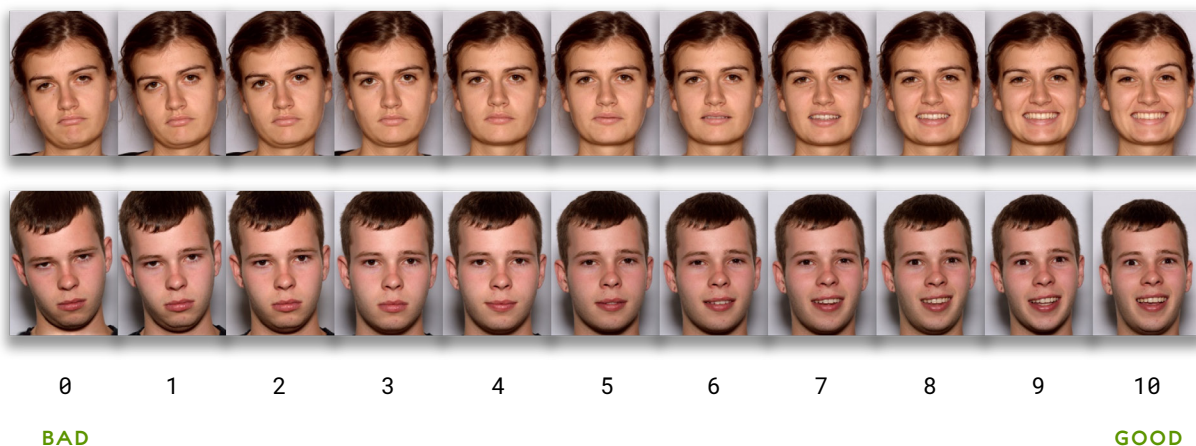
- Ask, **If you decided to exercise for a little while, what kinds of changes—mental or physical—would you expect to notice?** Students may share various answers such as feeling tired, sweaty, satisfied, happier, less stressed, more pained, more focused. Let students know that in this activity, they will be thinking about both physical and mental aspects of well-being.
- When students finish reading the Introduction, have them consider how well-being can be measured. Ask, **Do you think it's easier to measure physical changes, such as heart rate and breathing, or mental changes, such as mood and feelings?** Encourage students to briefly share their thoughts, highlighting that both physical and mental measurements have their own challenges and benefits. Sample responses include thinking that physical measures of well-being are better because they can't be faked or misreported. Some students may feel that mental changes are better to measure because emotions and feelings are a more important aspect of well-being. Explain to students that understanding both types of changes are important, as physical and mental measurements together provide a more complete picture of how well-being strategies, such as exercise, affect a person.

PROCEDURE SUPPORT (20 MIN)

2 Prepare students for the laboratory.

- The scenario presented in Step 1 can be shared with the class in multiple ways. Read the scenario aloud to the class or have individual students read it aloud while others follow along with the text (either as a whole class or in small groups).
- **Reading the scenario aloud can better support comprehension for many students, including neurodiverse students and emerging multilingual learners who often have more highly developed listening and oral skills than reading comprehension skills. Alternatively, students can read the scenario independently.**

- Decide how you would like to pair students for this activity. The procedure is set up so that one student in each pair will perform the exercise and rate their mood (the test partner), while the other student acts as a timer and records the data (the recorder). If you prefer, you can adjust the roles or group sizes to ensure all students can participate in the exercise. Be aware of any student who might have a physical reason why they cannot perform the exercise and assign them to be the recorder. **Since this is an inquiry-based lab, you may want to use heterogeneous groups to help support the needs of all learners and encourage all students to participate. Create specific groupings that might encourage greater participation and best support your student population.**
- Opportunity for advanced learning.** If you want students to explore another way researchers measure well-being, consider adding an objective behavioral measurement, using a scale for facial expression. The recorder would use the scale to rate and record the test partner's mood before and after exercise, alongside the other measurements on the student sheet used in this activity. To do this, the recorder asks the test partner to look at them for 5 seconds and then selects the mood that best matches the partner's natural facial expression. Comparing self-ratings and observer ratings can lead to discussions about how mood perception differs between oneself and others. You can find a facial expression scale online by searching for standardized emotion rating charts similar to the one shown here.



- Select an aerobic exercise that test partners will perform for 3 minutes. You may want to reach consensus as a class to decide on the exercise. Some options are jogging in place, a step exercise, jumping jacks, or squats. You can have students do the exercise in the classroom, outside, or in the gym—as long as there's a way to play a song or music video while they exercise.

TEACHER'S NOTE: Inform students that all test partners must wait for your signal to start the exercise (Procedure Step 7) so they are all exercising at the same time. Let students know that test partners will only exercise once. Afterward, the recorder will take 3 readings for heart rate, one after the other, and calculate the average. Taking the average of 3 30-second intervals leads to a more accurate reading but has the disadvantage of a heart rate returning to baseline during the post-exercise measurement. If students recognize this, add it to the list of things that could be changed about the experiment in order to be more confident in the results (in Teaching Step 6).

3 Review how to measure heart rate.

- In Procedure Step 4, hand out one copy of Student Sheet 2.1, “Measuring Physical and Mental Responses to Exercise,” to each pair of students. Review how to measure heart rate, as described in Procedure Steps 4 and 5. Explain that test partners should sit in a relaxed manner and breathe as normally as possible. Show them how to find their pulse. Observe them as they practice taking their pulse and assist as necessary until you are reasonably confident that all test partners know how to proceed. Check that most of them are getting resting heart rate data within a reasonable range (normally 60–100 beats per minute). If anyone is having trouble or getting extremely high or low results, assist as needed. However, problems with measuring heart rate by students can also be discussed as another challenge for the experiment later in the activity.
- To help students better understand their heart rate measurements, you may want to review the content on the circulatory system found in the Science Review at the end of the Student Book activity. To provide further context, you may also want to review the respiratory system or other body systems to discuss how and why exercise leads to changes such as faster breathing, sweating, or muscle fatigue.

4 Students perform the exercise experiment.

- Review Procedure Steps 5 and 6 to make sure all students understand the “before exercise” part of the experiment and how the recorder in each pair will fill in the data for Trials 1–3 in the Before Exercise table on the student sheet.
- In Procedure Step 7, after students have collected their baseline data, have them prepare for exercising. Have students wait for your cue to begin. After 3 minutes, end the music and have test partners stop exercising.

TEACHER’S NOTE: Have students carry out the exercise test at the same time while the music plays. Later in the activity when students are introduced to alternative explanations (Teaching Step 5), they should realize that the music (and/or other factors) may have affected their results. Therefore, wait until after students have completed all the trials and analyzed the data as a class to discuss factors besides exercise or any potential issues with the experiment.

- Support students in determining their average (mean) heart rates before and after exercise. In general, students should find that exercise increases heart rate and alertness. It may also improve mood. A sample student response for Student Sheet 2.1 can be found at the end of this activity. You should expect exercise to increase test partners’ heart rates by as much as 40–50 beats per minute.

5 Guide students as they analyze the class results.

- After Procedure Step 9, ask students to briefly share any differences they noticed between the before exercise data and the after exercise data. To set up a later discussion about variability, ask students to share their individual results, making sure to hear from at least one student whose results are the opposite of another’s. Encourage comparisons to highlight differences in outcomes.

- In Procedure Step 10, compile all the test partners' values for the three variables (heart rate, alertness, and mood) for both before and after exercise. You may want to create a spreadsheet and have students share their data. Students may share data with their names, or each student can be assigned a number instead. Average the variables and display the results for the class. Alternatively, as a class, fill out optional Visual Aid 2.1, "Class Results: Change in Heart Rate, Alertness, and Mood." Then, create and display the data in the bar graphs. You can refer to optional Visual Aid 2.2, "Sample Class Results," to see a completed sample table and graphs from Visual Aid 2.1.
- Lead a discussion with the class to analyze the results. Encourage students to share their observations and conclusions based on the class data. Ask, **How did the averages change from before exercise to after exercise, and what do your results suggest?** Answers may vary. The class averages are likely to show an increase for heart rate and alertness but less so for mood. Students may suggest that exercise could or could not be causing an increase in well-being. Ask, **How does the data differ from person to person?** Students may notice that some individuals showed significant changes, while others remained the same. If there is a lot of variability between individuals, some students may question if enough people were tested. If they raise this concern, acknowledge their reasoning and explain that they will learn more about sample size in an upcoming activity. Students may also discuss whether variation in results from person to person were caused by factors such as measurement inaccuracies, varying levels of motivation, or other individual factors.
- Explain that averages help smooth out individual differences and reveal overall trends in data. Rather than focusing on one person's results, which might be affected by many factors, an average combines everyone's data for a clearer picture of the overall effect of the target factor. This also reduces the impact of extreme values or outliers. For example, if some students' heart rates increased significantly after exercise while others changed only slightly, the average change in heart rate provides a more reliable understanding of the class's response to exercise.
- Before students start Procedure Step 11, prepare them to think about more than individual differences in the data. Explain that they will consider factors that might impact everyone's participation in the experiment and the overall average.
- After Procedure Step 11, have students share their ideas about factors other than exercise that may have influenced their results. Students should recognize that the music or the way they reacted to one another during the exercise could have been large factors that influenced their class results for mood. Encourage students to consider other possible factors affecting heart rate, alertness, and mood. See the following sample student responses for various examples.

Sample Student Responses, Procedure Step 11

The dance music was loud and fun. Plus, everyone was reacting to each other. These things seemed like they made a bigger difference on people's moods than the exercise.

Some people might have felt self-conscious or annoyed that they had to exercise in front of others, so their moods might have been lower afterward because of that.

Being nervous about exercising in front of others could have made some people's heart rates go up a little instead of the exercise.

Most people were not really trying, so they didn't exercise much. This is probably why we didn't see much of a change in heart rate or alertness.

- If students have trouble recognizing factors such as those listed above, guide them by asking questions such as *What kind of music did we play? How could it have affected someone's mood? Could the way we all did the exercise influence someone's mood?*
- Introduce the term *alternative explanation*. Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by adding the term to the word wall and provide an example as needed. For more information on a Word Wall, see [Appendix 1: Literacy Strategies](#). Emphasize that alternative explanations for results can come from either:
 - random chance—if a small number of people are tested or there are extreme data points (outliers), as was discussed after Procedure Step 10. For example, data might show that people's math test scores increase when there are more flowers blooming, but only a few people were surveyed.
 - other possible causes for the effect—a few examples of alternative explanations are the music, how students interacted with one another in the experiment they performed, or concluding that spring causes allergies when the actual cause is the increase in pollen during the spring season.

SYNTHESIS OF IDEAS (20 MIN)

6 Discuss how alternative explanations complicate studying cause and effect.

- Ask students to share their ideas from Procedure Step 13. Ask, *Based on the data we collected and the possible alternative explanations, how sure are you that exercise improves mood?* Answers may vary but should reflect alternative explanations that address both chance and other possible causes for the experiment results.

Sample Student Responses, Procedure Step 13

I'm not sure at all. We saw a big effect on mood, but this could be because of the music playing, not the exercise.

I think exercise helped, but we only tested a few people. Maybe if we had more data, it would be clearer whether exercise alone makes a difference.

I'm a little unsure. We did not see a big change in average mood, but it could be because some people were less excited to exercise, while others didn't really participate, so it's hard to say if exercise improves mood.

I don't think exercise made a difference at all because there were a lot of things influencing mood, like how people felt about exercising in front of others.

- Based on their responses, ask students to brainstorm and share ways they could have modified the class experiment to increase their confidence in the results. Student responses may include removing the music during exercise, having people exercise individually, and making sure everyone does the same amount of exercise. Some students may also recognize that using more accurate measurement tools, testing a larger number of individuals (sample size), having another group for comparison, or repeating the experiment more times may increase confidence in the results as well.
- Explain that scientists must think about alternative explanations when they design and analyze their research studies. With the class, review Visual Aid 2.3, “Studies on Exercise and Well-Being,” to compare the class results to data on exercise and well-being from published studies. You may want to share that while the effects of brief exercise on well-being were tested, research shows that both a single session and regular exercise have positive impacts on well-being. Numerous studies now support the idea that exercise can reduce feelings of stress, enhance mood, increase energy level, and improve sleep.
- Conclude the activity by revisiting the Guiding Question, *What are the challenges of studying well-being?* Use responses to this question to formatively assess students’ understanding of the key concepts and process skills related to causal reasoning, such as difficulties in studying effects and avoiding incorrect conclusions due to alternative explanations.

EXTENSION (10 MIN)

7 Use the Extension as an opportunity for advanced learning.

Show students Dr. Laurie Santos’s video, *What Does It Even Mean to Be Happy? The Science of Well-Being for Teens*, to review how scientists view well-being and why they consider surveys reliable for measuring mental well-being. If necessary, review the term *subjective well-being* beforehand (being happy *with* your life and *in* your life). Then, have students conduct their own research to explore why surveys are trusted as tools for assessing mental aspects of well-being.

SAMPLE STUDENT RESPONSES

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.

Sample Response 1

I think other factors, like the music or exercising in front of others, could be why we saw an increase in mood in our average class results. For example, the music could have made some people feel happier or more relaxed, which might have improved their mood, even if they weren't exercising. Or, since everyone was having fun at the same time, they were feeling happier. Exercise might be part of the reason, but we can't be sure.

Sample Response 2

Our class results showed a small decrease in average mood after exercise. Instead of exercise, I think it's because a lot of people were feeling self-conscious or annoyed by having to do jumping jacks, which could have negatively affected their mood. There was a lot of variability though, and we did not test that many people, so it could be from chance. Some people felt more alert and happy, while others shared that they might not have gotten enough sleep the night before and that could have affected their mood. So, I think these factors had a bigger effect on our results than the exercise itself.

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?

If I did the walks for a long time, like for a few months, the data could be helpful because I could see if I always, or most of the time, slept better.

- b What other data could you record that might offer alternative explanations for a change in well-being?

It might also help to record if there was anything stressing me out or maybe how much caffeine I had each day, because those are other things that could affect my sleep. The combination of data could help me decide if the walks were helpful or not.

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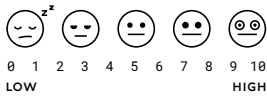
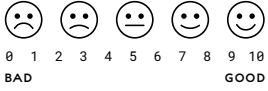
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Data Table for Test Partner

	AVERAGE HEART RATE IN BEATS PER MINUTE see Before Exercise and After Exercise tables for how to calculate	ALERTNESS RATING  0 1 2 3 4 5 6 7 8 9 10 LOW HIGH	MOOD RATING  0 1 2 3 4 5 6 7 8 9 10 BAD GOOD
Before Exercise			
After Exercise			
Change in Each Measure After Exercise value minus Before Exercise value			

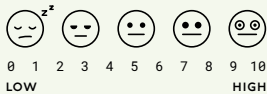
Before Exercise:
Average Heart Rate Calculation

	NUMBER OF HEART BEATS IN 30 SECONDS	BEATS PER MINUTE (60 SECONDS) FOR EACH TRIAL
TRIAL 1		x2 =
TRIAL 2		x2 =
TRIAL 3		x2 =
Total =		
Average beats per minute =		

After Exercise:
Average Heart Rate Calculation

	NUMBER OF HEART BEATS IN 30 SECONDS	BEATS PER MINUTE (60 SECONDS) FOR EACH TRIAL
TRIAL 1		x2 =
TRIAL 2		x2 =
TRIAL 3		x2 =
Total =		
Average beats per minute =		

Data Table for Test Partner

	AVERAGE HEART RATE IN BEATS PER MINUTE see Before Exercise and After Exercise tables for how to calculate	ALERTNESS RATING  0 1 2 3 4 5 6 7 8 9 10 LOW HIGH	MOOD RATING  0 1 2 3 4 5 6 7 8 9 10 BAD GOOD
Before Exercise	72.0	5	4
After Exercise	95.3	7	5
Change in Each Measure After Exercise value minus Before Exercise value	23.3	2	1

Before Exercise:
Average Heart Rate Calculation

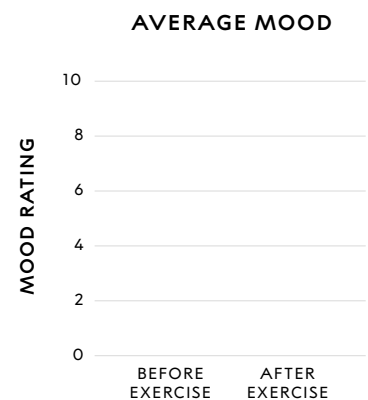
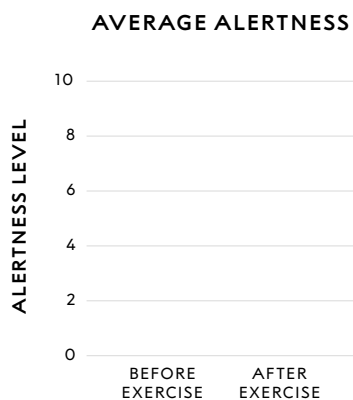
	NUMBER OF HEART BEATS IN 30 SECONDS	BEATS PER MINUTE (60 SECONDS) FOR EACH TRIAL
TRIAL 1	38	x2 = 76
TRIAL 2	32	x2 = 64
TRIAL 3	38	x2 = 76
Total =		216
Average beats per minute =		72.0

After Exercise:
Average Heart Rate Calculation

	NUMBER OF HEART BEATS IN 30 SECONDS	BEATS PER MINUTE (60 SECONDS) FOR EACH TRIAL
TRIAL 1	52	x2 = 104
TRIAL 2	46	x2 = 92
TRIAL 3	45	x2 = 90
Total =		286
Average beats per minute =		95.3

CLASS RESULTS:

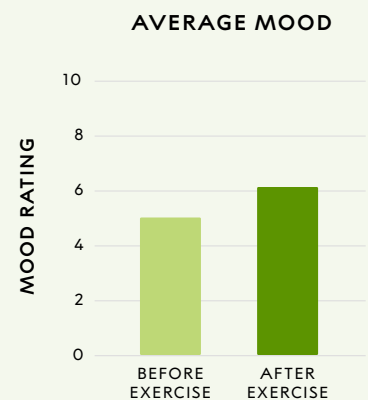
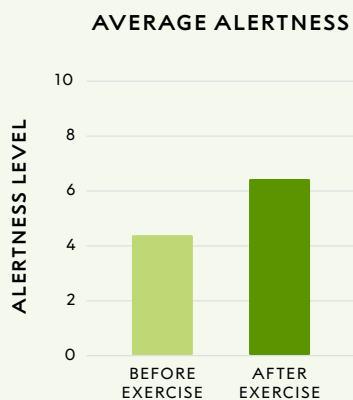
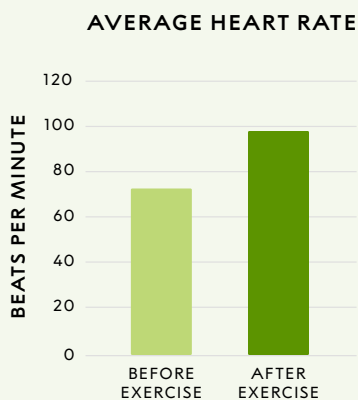
CHANGE IN HEART RATE, ALERTNESS, AND MOOD

[illegible]

VISUAL AID 2.2

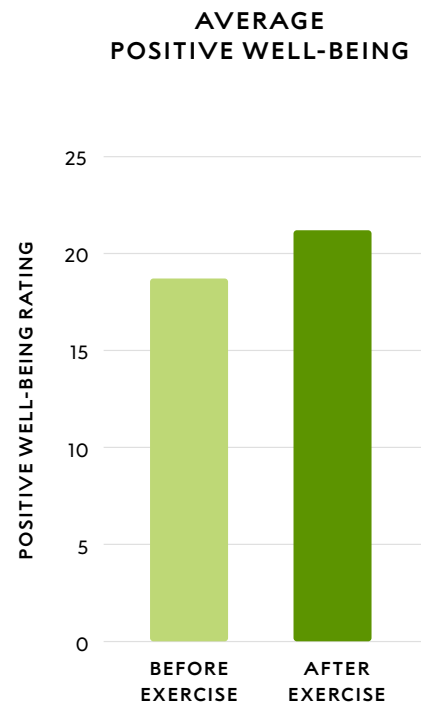
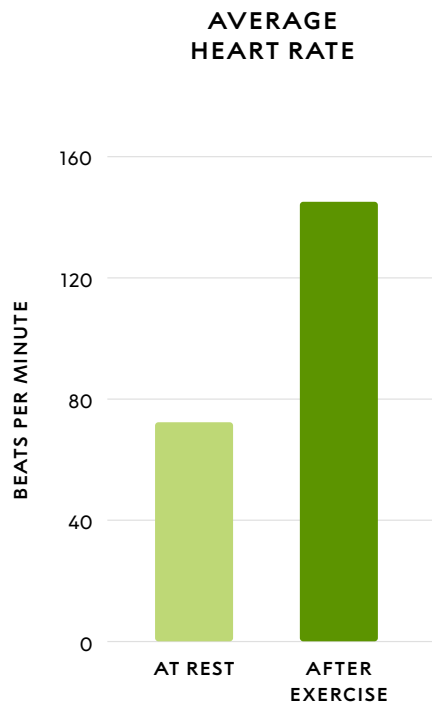
SAMPLE CLASS RESULTS

Student	HEART RATE BEATS PER MINUTE		ALERTNESS LEVEL 0-10		MOOD RATING 0-10	
	BEFORE EXERCISE	AFTER EXERCISE	BEFORE EXERCISE	AFTER EXERCISE	BEFORE EXERCISE	AFTER EXERCISE
1	72.0	77.3	5	5	5	5
2	64.0	116.7	3	8	3	5
3	79.3	92.7	4	8	6	8
4	84.0	92.7	6	9	6	4
5	72.0	87.3	5	6	5	2
6	72.0	95.3	5	7	4	5
7	68.7	105.3	5	4	5	6
8	84.0	111.3	4	6	6	9
9	60.7	93.3	3	6	5	7
10	72.0	92.0	6	10	5	8
11	84.7	97.3	5	8	6	5
12	70.0	112.7	5	4	5	5
13	74.7	108.0	2	7	6	10
14	74.7	83.3	5	5	2	6
15	78.0	114.0	4	7	5	6
Averages	74.0	98.6	4.5	6.7	4.9	6.1



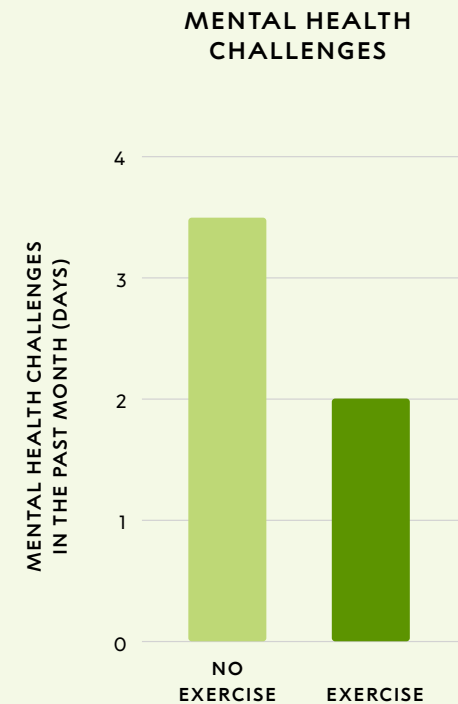
Brief Exercise

Healthy young adults were tested for 36 minutes of moderate-intensity exercise at 75% of maximal heart rate.



Regular Physical Activity

In a sample of 1.2 million people, individuals who exercise daily had a 43% reduction in mental health challenges. Researchers asked, “How many days during the past 30 days was your mental health not good?”





ACTIVITY 3

Questioning Causation

INVESTIGATION

ACTIVITY 3

Questioning Causation

ACTIVITY SUMMARY

Students explore indicators of causation, such as timing, association, and mechanism, and also consider alternative explanations to events. They are presented with cartoons of everyday situations that they analyze for cause and effect. Then, students use this experience to reevaluate claims about causation in the social media posts about the Salas High School well-being initiative from Activity 1.

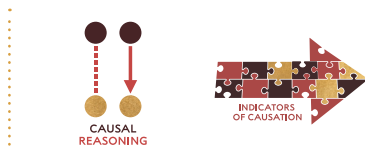
ACTIVITY TYPE
INVESTIGATION

NUMBER OF
40-50 MINUTE
CLASS PERIODS
1-2

KEY CONCEPTS & PROCESS SKILLS

- 1 Indicators of causation include the timing of events, observed associations between variables, and plausible mechanisms for the possible cause and effect.
- 2 A likely alternative explanation for an effect reduces the probability that the cause being investigated is the correct one.
- 3 Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.

CONCEPTUAL
TOOLS



VOCABULARY DEVELOPMENT

association

changes in two variables that tend to happen together

mechanism

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

timing

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

TEACHER BACKGROUND INFORMATION

Indicators of Causation

The indicators of causation covered in this unit are the most essential and straightforward parts of the Bradford Hill Criteria for Causation. Austin Bradford Hill was a 20th-century British epidemiologist who, in 1965, introduced a set of 9 criteria to assess whether a causal relationship exists between two variables. These criteria serve as guidelines rather than a strict checklist. A causal relationship can still exist even if some criteria are not met, and meeting all criteria does not guarantee causation. In general, the more types of indicators present and the stronger the evidence (temporality, strength of association, and plausibility), the stronger the case for causation. Later in this unit, students will learn about randomized controlled trials (RCTs), considered the gold standard for establishing causation. RCTs allow researchers to systematically test many of Hill's criteria by controlling variables such as timing and specificity while measuring associations.

This unit focuses on three key criteria as indicators of causation that are easier for students to grasp without requiring complex background knowledge. The three criteria referred to in this unit are:

- **Temporality (timing)** is the principle that a cause must occur before its effect. Since all events occur in time, simply noticing that one event happens before another is weak evidence for causation. However, an effect cannot happen before its cause, so if timing doesn't line up, it can strongly suggest there is no causal relationship. Timing provides stronger support if the cause consistently and immediately precedes the effect, though some causes have delayed effects. Still, timing alone is not enough to prove causation.
- **Strength of association** refers to how strongly two variables tend to occur together. A strong association suggests a possible causal relationship, while a weak association could be due to random errors or variation in data instead of a real cause-and-effect relationship. However, even a strong association does not guarantee causation since other factors (confounding variables) might be responsible. Associations can exist between two continuous variables (e.g., age and height) or between a continuous and a categorical variable (e.g., urban vs. rural).
- **Plausibility (mechanism)** means that there is a logical explanation for how one thing could cause another, based on prior knowledge. These explanations, also called causal links, help support causal claims. For example, if a new drink contains caffeine, and caffeine is known to improve alertness, then it would be reasonable to infer that the drink might help students be more alert and, thus, perform better on tests. A plausible mechanism should fit within established scientific principles (e.g., a car breaking down because it ran out of gas is more reasonable than blaming planetary orbits). However, even a very logical explanation might turn out to be incorrect, so this factor alone does not prove causation.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 3.1a
"The Case of the Spilled Paint"
- VISUAL AID 3.1b
"The Case of the Spilled Paint:
Questions About Causation"
- VISUAL AID 3.2
"Social Media Posts
from Activity 1"
(OPTIONAL)

FOR EACH GROUP OF FOUR STUDENTS

- STUDENT SHEET 3.1
"Causation Cartoons"
- STUDENT SHEET 3.2
"Reevaluating
Salas High School
Forum Posts"
- STUDENT SHEET 1.2
"Unit Concepts
and Skills"
(OPTIONAL)

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (10 MIN)

1 Students explore how to evaluate evidence for a claim about cause and effect.

- Before students read the Introduction in the Student Book, display Visual Aid 3.1a, “The Case of the Spilled Paint.” Ask, **What do you think caused the paint to spill?** Have partners describe the evidence that supports their answer. Example responses might include the idea that the cat’s paw is reaching toward the paint can or that the paint is dripping, so it was spilled recently. Discuss students’ responses as a class, encouraging them to use observations to support their claims. Help students focus on what they can observe, rather than what they infer from their observations.
- Remind students that claims about cause and effect should be based on evidence, such as observations, to strengthen claims about cause-and-effect relationships. If needed, help students distinguish between the cause and the effect for the example. Discuss how prior knowledge (e.g., cats often knock things over) and direct observation can both play a role in reasoning. Highlight that while observations are useful, they may still leave some uncertainty about what actually happened.
- Prompt students to think critically about alternative explanations for the paint spilling. Ask, **Can you be sure of the cause of the spilled paint?** Have students conduct a pair-share to answer the question. Encourage students to imagine another explanation that can also explain the situation. Students might suggest that the cat could have moved toward the paint after it was spilled. Use this example to make the point that the same evidence can be consistent with different cause-and-effect claims.
- Let students know that in this activity, they will learn how to better analyze claims about causation—such as, *The cat spilled the paint*. Students will do so by considering some important questions that help evaluate if a cause-and-effect claim is supported by evidence. This approach will help them evaluate the well-being strategies being considered by Salas High School.

PROCEDURE SUPPORT (30 MIN)

2 Guide students to use questions about causation to evaluate claims in Part A.

- Have students read the Introduction in the Student Book and Procedure Step 1, either as a class or individually. Support students, particularly emerging multilingual learners, in sensemaking and language acquisition as they read the text. Circulate around the room and check in with students as they use the strategy to decode scientific ideas and construct meaning as they read.
- Provide a concrete example of the information students just read about by revisiting the image of the cat and the spilled paint. Display Visual Aid 3.1b, “The Case of the Spilled Paint: Questions About Causation.” Have students reevaluate their claim(s) about the cat by using the four types of questions about causation: association, timing, mechanism, and alternative explanation. Encourage students to reflect on how the answers to each question either support or weaken the claim. In Visual Aid 3.1b, the cat’s paw reaching toward the can of paint is the possible cause, and the spilled paint is the possible effect. Students should recognize the question about timing—*Does X happen before Y? (Does the possible cause occur before the possible effect?)*—doesn’t have a clear Yes answer. This suggests a possible alternative explanation and creates uncertainty about the cause-and-effect relationship between the two events.
- In Procedure Step 2, hand out one copy of Student Sheet 3.1, “Causation Cartoons,” to each group of four. As students work in their groups to complete Student Sheet 3.1, assist them in identifying which question about causation is being brought up in each cartoon. Students should refer back to Table 3.1 in Procedure Step 1 as they complete the activity. You may find students improve their comprehension of the situations in the cartoons by role-playing or acting out the parts in the cartoons. A sample student response for Student Sheet 3.1 is shown at the end of this activity.
- After students complete Part A, ask groups to share which type of question was illustrated in each cartoon. For each cartoon, review whether the details provided in Panel B strengthened or weakened the cause-and-effect claim. Point out that the presence of any one of the three indicators of causation strengthens a claim about causation, while finding an alternative explanation that is likely can weaken it. Sample student responses for Student Sheet 3.1 can be found at the end of this activity and show that the statements in Panel B weaken the claims in Cartoons 1 and 4 but strengthen the claims in Cartoons 2 and 3.
- If you have begun a word wall, add the terms *association*, *timing*, and *mechanism*. Due to the abstract nature of these terms, it may help to provide an additional simple example for each term identified in Table 3.1 in the Student Book.

3 In Part B, students reevaluate the social media posts from Activity 1.

- In Procedure Step 7, hand out one copy of Student Sheet 3.2, “Reevaluating Salas High School Forum Posts,” to each group of four and have students refer to the four questions about causation in Table 3.1 in the Student Book. At the same time, you may wish to display optional Visual Aid 3.2, “Social Media Posts from Activity 1,” while students review the posts.
- For those students who may need extra support identifying the indicators of causation in each post, use Visual Aid 3.2 to highlight key terms in the statements such as *after* for timing or *many times* for association. When considering possible mechanisms, encourage students to focus on statements that include relevant scientific concepts, as these can help explain how one variable might cause a change in another. Note that while each post contains at least one alternative explanation, the presence of some indicators (timing, association, or mechanism) might not always be as clear to students. The goal is not necessarily for students to provide the exact answers on the student sheet; rather, it is for students to practice using all four questions. A sample student response for Student Sheet 3.2 can be found at the end of this activity.
- In Procedure Step 9, ask one or two groups to share which proposed solutions from the social media posts they now find most effective and least effective. If choices remain the same as in Activity 1, prompt students to articulate their reasoning, using what they learned in this activity by referencing timing, mechanism, association, or alternative explanations. For instance, instead of saying, “Crystals don’t make sense,” students might show causal reasoning more effectively by saying, “Crystals resonating in water is not a reasonable mechanism.” Encourage students to reflect on how their thinking about the strategies has or has not changed since Activity 1.

Sample Student Response, Procedure Step 9

I still think @artLion22’s idea of wearing green and yellow to reduce stress is a bad one. The timing is unclear because we don’t know how people felt before they wore the colors. For the mechanism, maybe colors do affect us a little, like red getting our attention, but I don’t think it would change moods much. @artLion22 saw an association for just 5 days, which isn’t enough to prove it works. A much bigger reason people were happier is because it was game day and there was a rally, which is way more likely to explain their good moods.

SYNTHESIS OF IDEAS (10 MIN)

4 Consider how questions about causation can be used in everyday life and in scientific investigations.

- Review student responses to Build Understanding item 1, which addresses key content of the activity. Discuss how overlooking alternative explanations is a frequent mistake in reasoning. Discuss other everyday situations in which students could stop and ask if there is an alternative explanation. You may want to bring up a few of the social media posts from Activity 1 related to well-being and brainstorm alternative explanations for the information that is presented.
- Ask, **How could the questions used in this activity be used in a scientific investigation about a phenomenon?** Students' responses will vary but may include ideas such as analyzing data sets for how often things occur (association), using a tool to measure timing, or designing experiments to test possible mechanisms. Emphasize in the discussion that the questions used in this activity are valuable both for everyday situations and in scientific studies of cause and effect. Even complex scientific inquiries, such as those about well-being, rely on them. However, the approach may be more systematic and detailed. Let students know that they will begin learning more about the scientific use of these questions in subsequent activities to help evaluate the well-being strategies at Salas High School.
- You may wish to revisit optional Student Sheet 1.2, "Unit Concepts and Skills," to help students formally organize the ideas introduced in the unit so far. Students can place the headings of the main ideas related to alternate explanations and indicators of causation into the organizer and add examples from their classroom experiences. See the end of Activity 1 in the Teacher's Edition for a sample student response.
- Finish the activity by revisiting the Guiding Question, *How do people consider if one event caused another?* Use the responses to this question to formatively assess students' understanding of the key concepts and process skills related to indicators of causation and alternative explanations. Students should recognize that evidence supports a cause-and-effect relationship when events are associated, the supposed cause happens before the effect (timing), and a plausible mechanism exists. However, the presence of likely alternative explanations can weaken confidence in the cause-and-effect relationship.

SAMPLE STUDENT RESPONSES

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?

No, because there could still be other explanations. Maybe other things happened differently in the last six months, like maybe Jaime started at a new school, or started studying more, or got help, or started taking easier classes. There’s not enough information to know. The timing, association, and mechanism are all important, but they don’t prove causation on their own.

- 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.

You could convince friends that exercise increases muscle strength by measuring the heaviest weight someone can lift before vs. after arm exercises for a month (timing) and by seeing if they can lift more. It would also help to look for a link between the amount of time exercising and muscle strength (association). Lastly, it would help to find out what exercise does to muscles and see if there is a protein or other molecules that are released during exercise that might be causing the muscles to strengthen (possible mechanism).

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).



Stress Relief
in less than a minute.

EVIDENCE-BACKED

- Boosts levels of GABA to calm nerve cells
- 90% of users felt more calm after 1 pill

Fictional advertisement for stress-relief pill

I wouldn't buy this pill because the ad doesn't convince me it works for sure. First, 90% of users feeling calm afterward seems like a strong association, but that doesn't mean the pill caused it. It also could be that they only asked a few users. Second, it seems too good to be true that the pill suddenly made you feel better after just 1 minute, so the timing does not seem real. Third, the mechanism seems weird because the pill has caffeine, which usually makes people feel more energized, not calmer. Lastly, there could be other explanations, like people's individual stress levels, which could mean the pill isn't the actual cause of their calmness. Without much better evidence, I wouldn't risk spending my money on it.

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

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

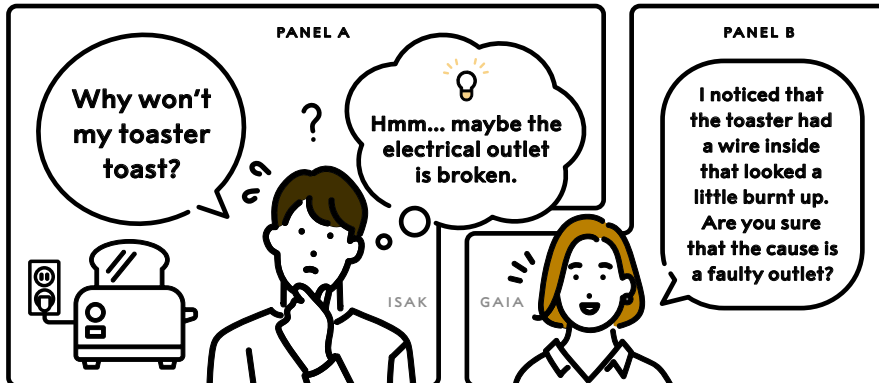
I tried listening to calming music before bed to help me sleep better. It was effective because I felt more relaxed and fell asleep faster than usual.

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

I felt more relaxed after the music, so the timing works. I only did it once, so I'm not sure if there's an association. For mechanism, it could be that it worked by calming my mind and body to help me fall asleep. So, it's possible that the music helped, but there could be other reasons, too. Maybe I was just extra tired that night, or maybe I had less homework, so I wasn't as stressed. I'd have to test it for multiple nights to be sure the music was the real cause.

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Hill, A. B. (1965). The environment and disease: Association or causation? *Journal of the Royal Society of Medicine*, 58(5), 295-300. <https://doi.org/10.1177/003591576505800503>



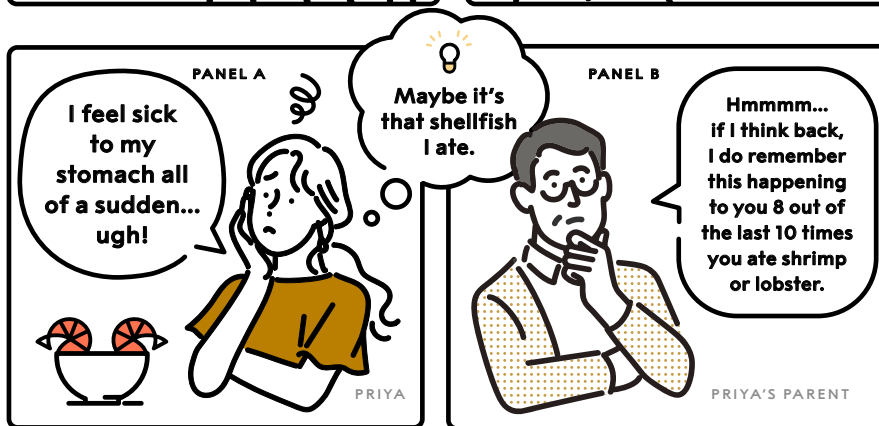
Cartoon 1

KIND OF QUESTION ABOUT CAUSATION

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



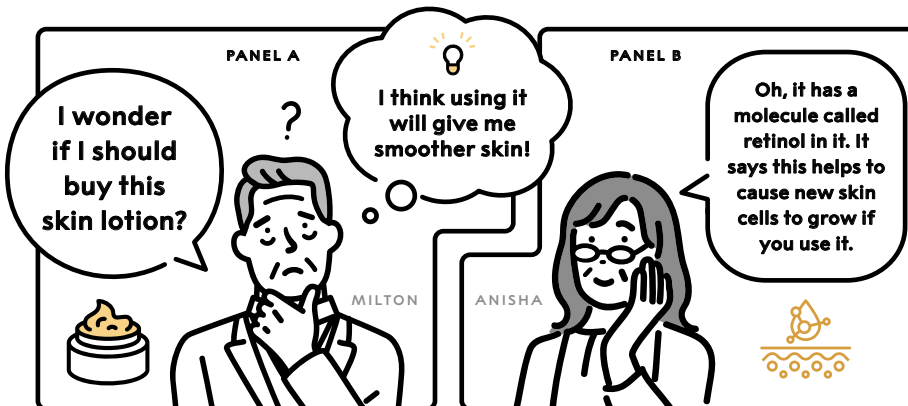
Cartoon 2

KIND OF QUESTION ABOUT CAUSATION

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



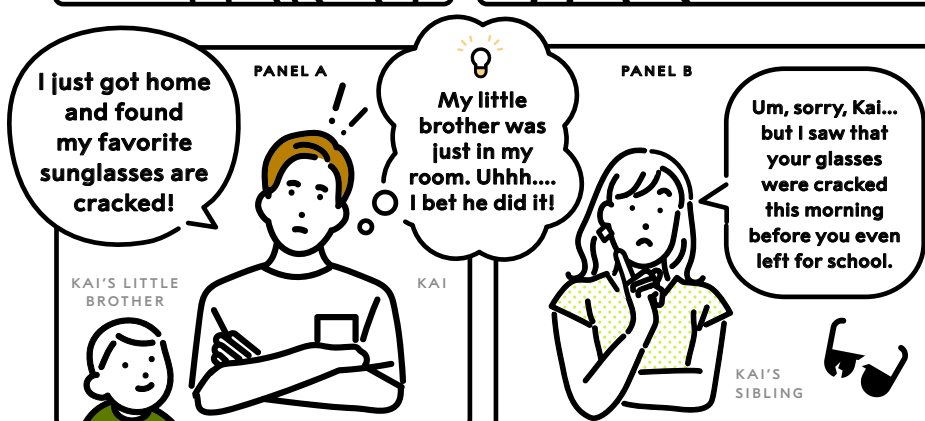
Cartoon 3

KIND OF QUESTION ABOUT CAUSATION

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



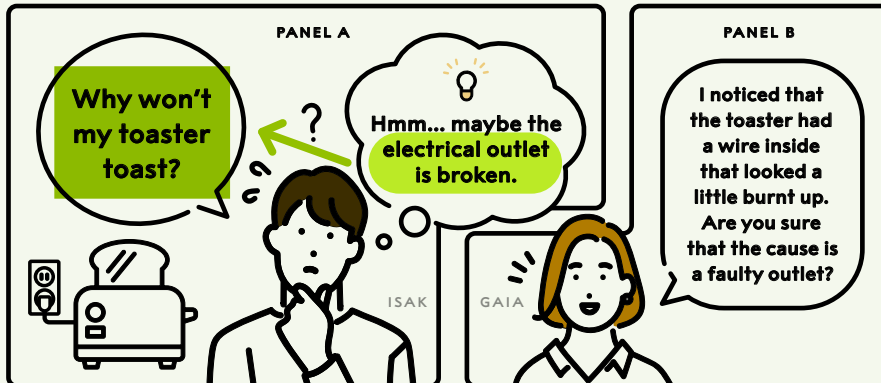
Cartoon 4

KIND OF QUESTION ABOUT CAUSATION

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM

SAMPLE STUDENT
RESPONSE

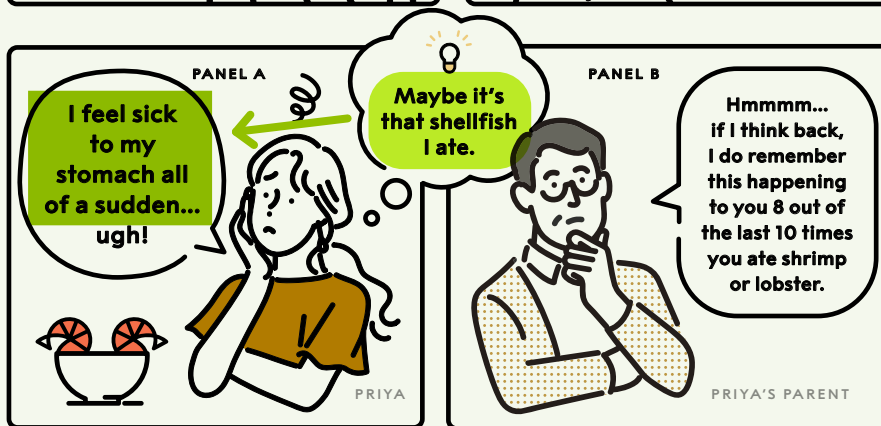
Cartoon 1

KIND OF QUESTION
ABOUT CAUSATION*Alternative Explanation*

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



Cartoon 2

KIND OF QUESTION
ABOUT CAUSATION*Association*

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



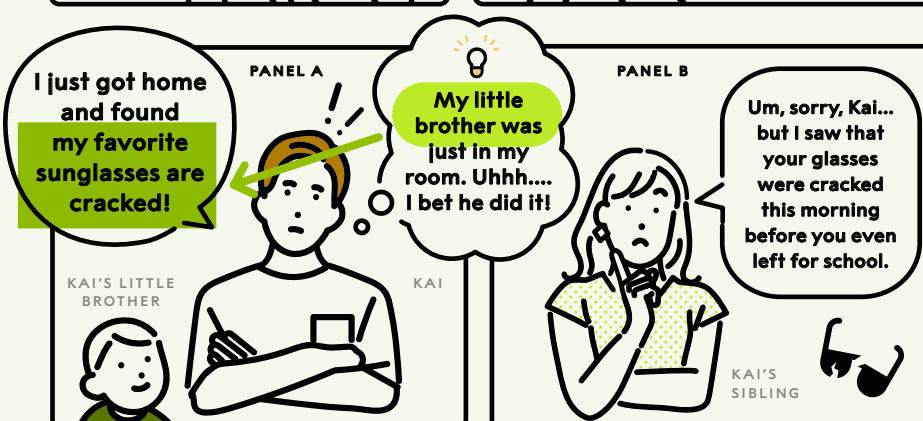
Cartoon 3

KIND OF QUESTION
ABOUT CAUSATION*Mechanism*

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



Cartoon 4

KIND OF QUESTION
ABOUT CAUSATION*Timing*

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM

POSTED BY	PROPOSED SOLUTION		INDICATORS OF CAUSATION			ALTERNATIVE EXPLANATION
	POSSIBLE CAUSE (X)	POSSIBLE EFFECT (Y)	TIMING	ASSOCIATION	MECHANISM	
@whizza457	ban sugar from food at school	less anxious				
@artLion22	wearing yellow and green	happier and less stressed				
@newGirl\$haz	school flower garden	feel better, less grumpy				
@buddys2010	spending time with a dog	feel less lonely, be happier				
@MrHendrick_ SuperTeacher	add solid quartz crystals to school water	more energy, focus, and happiness				
@2goBerock	change school start time, more sleep	better mood and health				

POSTED BY	PROPOSED SOLUTION		INDICATORS OF CAUSATION			ALTERNATIVE EXPLANATION
	POSSIBLE CAUSE (X)	POSSIBLE EFFECT (Y)	TIMING	ASSOCIATION	MECHANISM	
@whizza457	ban sugar from food at school	less anxious	✓	✗	✗	eating more green vegetables
@artLion22	wearing yellow and green	happier and less stressed	✓	✓	✗	the game day or the rally
@newGirl\$haz	school flower garden	feel better, less grumpy	✗	✓	✓	doing homework at home or walking
@buddys2010	spending time with a dog	feel less lonely, be happier	✓	✓	✓	spending time with other people or taking more walks (although this can also be a mechanism)
@MrHendrick_SuperTeacher	add solid quartz crystals to school water	more energy, focus, and happiness	✓	✗	✓	exercising
@2goBerock	change school start time, more sleep	better mood and health	✓	✓	✗	no school on Saturday morning



What caused the paint to spill?

How do you know?

How can you be sure?

**ASSOCIATION**

How often do cats tend to knock things over?

TIMING

Did the paint can spill before or after the cat arrived?

MECHANISM

How could the paint have been spilled by the cat?

ALTERNATE EXPLANATION

Could something else have caused the paint to spill instead of the cat?



Salas High School Well-Being Forum



@whizza457

Sep 27, 1:48 PM

I've heard that sugar is bad for our bodies and minds. I think we should ban sugar from food at school. If we get rid of it, I bet everyone would feel less anxious. I know because I felt less anxious after I changed my diet and started eating more green vegetables. Let's make our school a sugar-free zone and see how much better we feel. #GoHornets #HornetSting!



@artLion22

Sep 27, 2:15 PM

Kids are less happy because of stress from school. I think we should have days where everyone wears colors to feel better. Wearing specific colors can change your mood and emotions. The last 5 times we've had a game day and everyone was wearing our green and yellow colors, I noticed everyone feeling happier and a lot less stressed, especially after the rallies. Plus, it would be really easy to do. #GoHornets @SalasHighSchool



@newGirl\$haz

Sep 27, 2:19 PM

Everyone at school is in a bad mood because we are stuck indoors all the time. I've been stuck at home because of homework, but I've noticed that on days when I go to the park that has flowers, I'm rarely grumpy; but the days when I stay home all day, I'm pretty grumpy. I think going to the park cheers me up because seeing nature and flowers helps me relax. Why don't we have a school flower garden to help everyone feel better? #SHSgardenclub



@buddys2010

Sep 27, 4:15 PM

Students are not happy because they are lonely. Spending time with dogs in class would make everyone feel less lonely. Getting my dog, Bucky (who is a beagle), is the best thing that ever happened to me! Bucky bounces around until I get up and take him for a walk. Since getting him, I've met so many people who stop me to talk about how cute he is! I've been going on a lot more walks than before. Sometimes I go to the park with Bucky's best friend Luna the Labrador and Luna's owner. I feel so much less lonely! #buckysthebomb @lunathelab



@MrHendrick_SuperTeacher

Sep 27, 4:33 PM

Some students have trouble paying attention in class. They are not doing as well on tests and this makes them unhappy. I think we should try infusing our school water supply with solid quartz crystals. It can improve overall well-being and make people feel more energized, focused, and happy. The quartz resonates in the water, changing the properties of the water molecules so they affect mood and attention centers in the brain. I started a new exercise plan and drank quartz water yesterday, and I already feel great! I think it would make our school a more positive place. #gohornets @SalasHighSchool



@2goBerock

Sep 27, 11:57 PM

Let's make the start time for school later in the morning. This way we could all get more sleep, and that would improve our mood and health. Not enough students (including me) are getting enough sleep because we have to get up so early, and this makes us tired and cranky. If I get a great night's sleep on Friday, I wake up the next morning, on Saturday, feeling great. I've noticed this many times. #HornetSting! #sleepplzzz



ACTIVITY 4

Interpreting Correlations

DATA ANALYSIS

ACTIVITY 4

Interpreting Correlations

ACTIVITY SUMMARY

Students explore what can and cannot be determined from associations between two variables. They familiarize themselves with scatter plots by creating one based on data for their own sleep quality and mood. They then compare and describe a set of scatter plots with associations ranging from strong negative to strong positive. Finally, students explore how to use indicators of causation (association, timing, and mechanism) and alternative explanations to analyze the possibility of a cause-and-effect relationship and understand why causation cannot be inferred from correlation.

ACTIVITY TYPE
DATA ANALYSIS

NUMBER OF
40-50 MINUTE
CLASS PERIODS
2-3

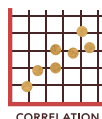
KEY CONCEPTS & PROCESS SKILLS

- 1 A correlation indicates an association between variables but is not sufficient evidence to determine causation.
- 2 Indicators of causation include the timing of events, observed associations between variables, and plausible mechanisms for the possible cause and effect.
- 3 A likely alternative explanation for an effect reduces the probability that the cause being investigated is the correct one.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:

Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. (*Science and Engineering Practice: Analyzing and Interpreting Data*)

CONCEPTUAL
TOOLS



VOCABULARY DEVELOPMENT

best-fit line

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

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

TEACHER BACKGROUND INFORMATION

Best-Fit Lines

A best-fit line, sometimes also referred to as a trend line, is a line on a scatter plot used to analyze a general trend in the data. For a correlation, a best-fit line will be straight and have a slope that indicates how variables are changing (e.g., if two variables both change in a positive direction, the best-fit line will have a positive slope; if the two variables are inversely related, the best-fit line will have a negative slope). The best-fit line ($y = mx + b$) for a correlation is calculated using a linear regression such that the square of the distance to the data points on either side of the line is minimized. Although this unit does not cover nonlinear relationships, some data patterns require curved best-fit lines instead of straight ones (see Figure 4.1 in the Student Book). If a scatter plot forms a curve, an exponential or U-shaped line may better represent the relationship. Researchers can still analyze these trends for associations to understand how the variables interact.

Correlation Coefficient (r)

A correlation coefficient (also referred to as r or the r -value) shows the strength and direction of a linear relationship between two variables. The r -value is always between -1 and $+1$. The closer the correlation coefficient is to -1 or $+1$, the stronger the relationship between the two variables, with 0 indicating no relationship and -1 or $+1$ indicating a perfect correlation. On a scatter plot, the closer the data points cluster around the best-fit line, the stronger the correlation coefficient. A perfect correlation would be a straight line of data points that does not vary from the best-fit line. A correlation of -1 or $+1$ thus allows one to infer a value of Y from any given value of X perfectly. A correlation of 0 , on the other hand, means that knowing the value of X tells you nothing about the value of Y .

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- LARGE SHEET OF BLANK GRAPH PAPER
- VISUAL AID 4.1
"Strength and Direction of Correlations"
- VISUAL AID 4.2
"Comparing Correlation Strength"
- VISUAL AID 4.3
"Scoring Guide: Analyzing and Interpreting Data (AID)"
- ITEM-SPECIFIC SCORING GUIDE:
Activity 4, Build Understanding Item 2

FOR EACH GROUP OF FOUR STUDENTS

- SCATTER PLOT CARDS
(7 CARDS)

FOR EACH STUDENT

- DOT STICKER
- SCORING GUIDE:
Analyzing and Interpreting Data (AID)
(OPTIONAL)

Display the sheet of blank graph paper on the wall where students can add to it during the procedure. Label the x-axis "Average Quality of Sleep" and the y-axis "Average Mood."

When previewing the graphs on the Scatter Plot cards, please note that all data points except for those on Card B are simulated to match the given r -values.

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (20 MIN)

1 Familiarize students with scatter plots, using class data.

- Have each student estimate their average quality of sleep for the last 5 days, using a scale of 0 to 10 (0 = very low-quality sleep and 10 = very high-quality sleep). Explain that quality of sleep refers to a combination of how quickly you fall asleep, how long and deeply you sleep without interruptions, and how rested you feel after you wake up. Have students record their answers in their science notebooks.
- Have each student estimate their average mood for the last 5 days, using a scale of 0 to 10 (0 = very low/bad to 10 = very high/good). Have them record their answers in their science notebooks.
- Review the basic concept of a scatter plot by using the sheet of graph paper posted on the wall with the x-axis labeled “Average Quality of Sleep” and the y-axis labeled “Average Mood.” Explain that a scatter plot is a type of graph. Emphasize that in a scatter plot, each dot represents an individual data point (in this instance, data for an individual student). **It may be helpful to talk through the process for plotting a dot for your own data point as an example for students. Model where the dot would appear on the graph by posting it in the correct coordinates.**
- Hand out one dot sticker to each student. Have students write their initials on their dot stickers and have them place their dot stickers on the class graph at the correct coordinates for their average sleep quality and mood rating. Have students look at the graph of the class data and share what they observe. Research shows a strong association between average sleep quality and mood, so it is likely that there will be some patterns in the data, depending on the size of your class and individual data points. There will likely be a general trend of less sleep associated with poorer mood, and vice versa. If you are conducting the activity in more than one class, consider compiling the graphs to share with your classes once they’ve all had a chance to respond.
- Have students read the Introduction in the Student Book in pairs or in small groups. Alternatively, read the Introduction aloud, using a storytelling approach. You may want to review Figure 4.1 with students to highlight the difference between associations and non-associations. The upper graphs show associations where X and Y change together, while the lower graphs do not because Y remains constant or lacks a clear pattern. Emphasize that a pattern in X alone does not indicate an association. **Facilitate the engagement of students with learning disabilities and neurodiverse**

learners by providing targeted support. Students who need more time processing language (such as students with dyslexia) can be provided with the Introduction in advance of the day's activity.

- Review the terms *association* and *correlation* that are presented in the Introduction. Ask students to look again at their class graph for sleep and mood data. Discuss the following questions by asking, **Does the data show a correlation between the two variables (sleep quality and mood)?** Students' responses will vary depending on your class data, but you can expect that they will recognize an association between better sleep quality and improved mood. However, a linear correlation is less likely to be easily seen, especially with data from just one class. Use this as an opportunity to distinguish between the two related terms.
- Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by adding the term *correlation* to the word wall and providing an example as needed. For more information on a Word Wall, see [Appendix 1: Literacy Strategies](#).

PROCEDURE SUPPORT (45 MIN)

2 Support students as they describe correlation data.

- In Procedure Step 1, distribute a set of Scatter Plot cards to each group of four. Students will likely be able to arrange the cards simply based on the patterns in the data, but they may need more support with the specific language to describe the correlations. Circle around the room and listen to student conversations to determine if support is necessary. It may help to ask probing questions that help students notice patterns in the data, such as *Do you notice anything about how close together the data points are? Does it seem like there's any pattern at all in the data points? Are the data points generally going up or down?* Check that students are ordering the cards from strongest negative to strongest positive so they can easily compare answers in Procedure Step 4.
- Once students have completed Steps 2 and 3, have a brief class discussion about what they noticed about how best-fit lines and correlation coefficients can be helpful in analyzing correlation data. Encourage students to look for patterns and to develop a conceptual understanding of how these two tools help to interpret correlations. Students should notice that with the best-fit line, closer clustering of the data points around the line indicates a stronger correlation. They should also notice that the closer the correlation coefficient is to 1, the stronger the correlation. Additionally, a negative slope corresponds with a negative r -value and a positive slope with a positive r -value. However the r -value is not otherwise related to the slope of the line (i.e., a larger or smaller slope does not correspond to a larger or smaller r -value).
- Students don't need a deep understanding of the statistical concepts in this activity or know how to calculate them for this unit. However, it may be helpful to explain that the best-fit line and the value of the correlation coefficient are not arbitrary but are calculated using statistics.

Sample Student Response, Procedure Step 3

- a *If the r -value is positive, it is a positive correlation. If it is negative, it's a negative correlation.*
 - b *If the r -value is closer to 1, it is strong; if it is closer to 0, it is weak; and if it is 0, there is no correlation.*
- Once students have completed Procedure Step 4, have one group share the order in which they placed their Scatter Plot cards. Ask if any groups disagree and, if so, have them explain why they disagree. It may be helpful to review that correlation coefficients are used to indicate the strength of correlations with 0 being no correlation, +1 a perfect positive correlation, and -1 a perfect negative correlation. Display Visual Aid 4.1, “Strength and Direction of Correlations,” to support this discussion.
 - The correct order for the Scatter Plot cards (from strongest negative to strongest positive) is shown in the following sample response.

Sample Student Response, Procedure Step 4

CARD B	<i>Internet Searches for “I have a headache” in the US vs. % of American Children with Asthma Attacks</i>
CARD C	<i>Screen Time Score (higher = more) vs. Sleep Quality Score (higher = better)</i>
CARD G	<i>Perceived Stress Level Rating vs. Happiness Rating</i>
CARD E	<i>Age in Years vs. Life Satisfaction Rating</i>
CARD A	<i>Sleep Quality Rating vs. Well-Being Rating</i>
CARD F	<i>Closeness of Friend vs. Time Spent with Friend</i>
CARD D	<i>Self-Reported Online Friend Count vs. Actual Online Friend Count</i>

- Mention to students that while correlations are typically between two continuous variables (e.g., between -1 and +1) with many possible measurements in between, associations can also occur between other kinds of variables. Review conditions in which there might be an association between two variables that are not continuous. For example, one variable might be a condition that is yes or no, which is a binary variable—whether or not a person is wearing a jacket. Wearing a jacket (or not) has an association with how cold you feel, which is a continuous variable.
- 3 Review the possible connections between correlation and cause-and-effect relationships.**
- In Part B, students are first asked to consider causality in an everyday example of two variables that have a strong correlation (shark attacks vs. ice-cream sales). Students should easily see that there is no direct cause and effect because there is no reasonable mechanism for it. Use this example to support student understanding that there can be very strong correlations where there is no cause-and-effect relationship. Circulate and listen to group conversations to be sure students are able to easily answer the questions for Step 5. If needed, go through the questions individually with students. It may be helpful for students to refer to Figure 4.2 in Procedure Step 1 when they are trying to describe the correlation.

Sample Student Response, Procedure Step 5

- a *The two variables being investigated are the amount of ice cream sold and the number of shark attacks.*
 - b *There is a strong positive correlation between the two variables because the data points are close together and are both increasing at about the same rate. The more ice cream sold, the higher the number of shark attacks.*
 - c *There is probably not a direct cause-and-effect relationship because there is no reasonable logical connection between the two variables.*
- In Procedure Step 6, students further analyze the correlation. Review with students that they are trying to come up with an alternative explanation for why the two variables (ice-cream sales and shark attacks) are correlated. Students are not looking for a separate cause of shark attacks alone but rather a reason for why both variables increase *together*. If students are struggling, prompt them to think about what external factor might influence both variables in a way that creates the observed pattern.

Sample Student Response, Procedure Step 6

- a *Association*
The two variables do tend to change together.
 - b *Timing*
We do not know from the graph which thing (shark attack or ice-cream sales) happened first.
 - c *Mechanism*
There is no logical reason for ice-cream sales to lead to shark attacks.
 - d *Alternative Explanations*
One possible explanation is that hot weather might cause more people to buy ice cream and more people to go swimming in the ocean where they might get attacked by a shark. So, both are caused by a third variable, the weather, or perhaps the time of year when the weather is warm.
- If students need additional support, consider rephrasing the questions about causation. For example:
 Association
 If X goes up/down, does Y go up/down?
 Timing
 Does the data tell you when X or Y happened?
 Mechanism
 Can you think of a way that X might cause Y?
 Alternative Explanations
 Can you think of another reason why X and Y might increase/decrease together?
 - Ask, Does a correlation always means that there is a cause-and-effect relationship between two variables? Students' responses should indicate that they understand that there are correlations with no direct cause-and-effect relationship between the two variables. Students may cite the

example of shark attacks and ice-cream sales and how the four questions about causation were helpful for determining if a cause-and-effect relationship was likely. Students should realize that the questions help them to further evaluate the possibility of a cause-and-effect relationship but do not necessarily give them a definitive answer.

4 Facilitate a discussion about what can and cannot be concluded from an association between two variables.

- As groups complete Steps 7 and 8, support their conversations as needed. If students are having trouble selecting appropriate cards, guide them toward cards that are fairly easy to interpret, such as Card A (Sleep Quality Rating and Well-Being Rating) for a likely cause-and-effect relationship and Card B (Internet Searches and Asthma Attacks) for two variables that are not likely to have a cause-and-effect relationship. Preselecting the cards for students can facilitate the engagement of students with learning disabilities and neurodiverse learners by providing targeted support. Students will probably select cards A, C, D, F, or G as likely cause-and-effect relationships.
- The following sample student responses are shown for Card C and Card B.

Sample Student Response, Procedure Step 7

CARD C *Screen time score and sleep quality score probably has a cause-and-effect relationship.*

- a *Association: As screen time goes up, sleep scores tend to go down.*
- b *Timing: We do not know anything about the timing of changes in these two variables.*
- c *Mechanism: If you are spending more hours using devices with screens, you might be sleeping less, which would lower your sleep score.*
- d *Alternative Explanations: One possible explanation is that people might have a lot of work to do that has to be done on a computer, so they don't have time to sleep, and they also spend more time in front of a screen, but it's not cause and effect. It's a third variable, time working, that causes both.*

Sample Student Response, Procedure Step 8

CARD B *Internet searches for having a headache and percent of children having asthma attacks probably does not have a cause-and-effect relationship.*

- a *Association: As online searches for headaches go up, asthma attacks go down.*
- b *Timing: We do not know anything about the timing for this correlation.*
- c *Mechanism: We don't know of any reasonable mechanism that could explain this correlation.*
- d *Alternative Explanations: We think this correlation is just due to chance because there are not that many data points..*

SYNTHESIS OF IDEAS (30 MIN)

5 Reinforce the main concepts related to correlation.

- Have a brief class discussion about what can be learned from the strength of a correlation. Review Visual Aid 4.2, “Comparing Correlation Strengths,” and point out that weaker correlations are more likely to be due to chance than stronger correlations. When data points vary widely, as seen with Medication 1, the correlation is weaker and more likely to be random. Let students know that this is even more noticeable in smaller studies where there are fewer data points (such as on Card B). In contrast, when data points are more consistent, as with Medication 3, the correlation is stronger and less likely to be due to chance.
- Students should realize from the correlations they have analyzed in Part B that a stronger correlation does not necessarily indicate a greater likelihood of a cause-and-effect relationship. Beginning in Activity 6, students will learn more about small sample sizes and confounding variables, which can often lead to strong correlations between two variables that do not have a cause-and-effect relationship.

6 Use the Analyzing and Interpreting Data (AID) Scoring Guide to assess Build Understanding item 2.

- Build Understanding item 2 is an Analyzing and Interpreting Data assessment item. This first opportunity should be used to introduce your students to the optional Scoring Guide: Analyzing and Interpreting Data (AID). As this is the first opportunity for students to review the Scoring Guide, you may wish to have them work in pairs or small groups to discuss and/or write their responses, using the Scoring Guide to help develop their responses. See [Appendix 2: Assessment Resource](#) at the end of the Teacher’s Edition for more guidance and information on using the Scoring Guide with your students.
- Do not share the item-specific version of the Scoring Guide (Item-Specific Scoring Guide: Activity 4, Build Understanding Item 2) with students as it provides specific information on how to respond to the item prompt. Review the Item-Specific Scoring Guide to support scoring this specific item.
- Visual Aid 4.3, “Scoring Guide: Analyzing and Interpreting Data (AID),” can be used to prepare students for Build Understanding item 2. Point out the scoring levels (0–4) and review the criteria for each score. Explain that the scores are based on the quality of students’ responses and reflect student growth over time. The scores do not correspond to letter grades. A Level 4 response is complete and correct. A Level 3 response is almost complete and mostly correct, but possibly missing minor details or containing small errors. At first, many students will write Level 2 responses, and they should strive to achieve Level 3 or Level 4 responses. Let students know that you would like them to improve by at least one level as they progress through the unit. As a class, discuss what a Level 4 response to Build Understanding item 2 would include. You may develop a Level

4 exemplar as a class or share with students the Level 4 response from the provided sample responses. To help students better understand the three levels, discuss how they are different and ask students for ideas about how to improve from Level 2 to Level 3 and from Level 3 to Level 4.

- For some students, you may wish to support a specific level of growth—this can be particularly helpful if students have an Individualized Educational Plan (IEP), a 504 plan, or other specific educational goals. Growth from a Level 1 to a Level 2 may indicate significant progress for a student and should be recognized as such. Additionally, assessments can be a good opportunity to have students evaluate one another's work and provide initial feedback for revisions prior to submitting their responses to you.
- Sample responses for Levels 1–4 are provided in the Build Understanding section. Review these responses to get an idea of what is expected for each level, alongside the Item-Specific Scoring Guide. See [Appendix 2: Assessment Resource](#) at the end of the Teacher's Edition for more guidance and information on using the Scoring Guides and assessment system with your students.

7 Conclude the activity by revisiting the class-generated scatter plot comparing sleep quality and mood.

- Connections to Everyday Life item 5 can be used as a class or small-group discussion prompt or to collect written responses. Have the class revisit the scatter plot generated at the beginning of the activity. Depending on the class data, there may or may not be a clear association between sleep quality and mood. If there is no visible association in the class scatter plot, mention that many well-designed studies have shown that there is a strong positive correlation between quality of sleep and mood. One example is the study that provided the results shown on Card A in the activity. As appropriate for your class, revisit the idea of timing, mechanism, and possible alternative explanations as they might relate to this correlation. Tie this discussion to the data in Connections to Everyday Life item 5 showing an association between hours of sleep and academic performance scores.
- When students reflect on what they learned while investigating correlations, they should be able to explain the importance of having a larger body of evidence to determine cause-and-effect relationships, not just correlations. Explain that in Activity 5, students will investigate this type of evidence for the four proposed well-being strategies for Salas High School.
- Finish the activity by revisiting the Guiding Question, *What can be learned from an association between two variables?* Use the responses to this question to formatively assess students' understanding of the key concepts and process skills related to correlations. Students should recognize that an association may be a weak indicator of some possible cause-and-effect relationship but that it is not by itself strong evidence for causation.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

- ① Examine the data in Figure 4.4.

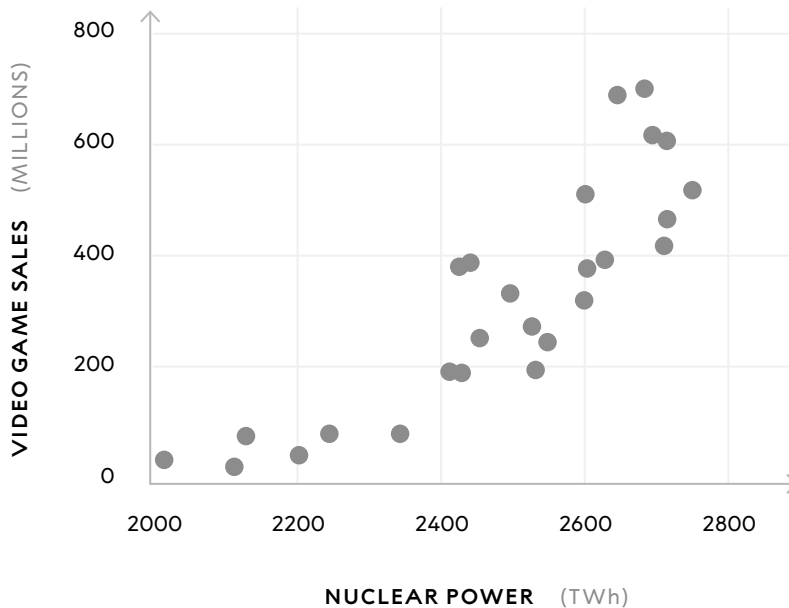


FIGURE 4.4
Video Game Sales vs.
Nuclear Energy Production
1990–2015

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

- a** Is there a correlation between these two variables? If so, describe it.

Yes, there is a strong positive correlation between these two variables.

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

I don't think there is a direct cause-and-effect relationship between these two variables because there is no logical reason for how video game sales and nuclear energy production could be affecting each other (mechanism). An alternative explanation is that as the world population has also increased, more people are buying video games and more nuclear energy is being produced, but one didn't cause the other to happen.

- ② AID Assessment

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.

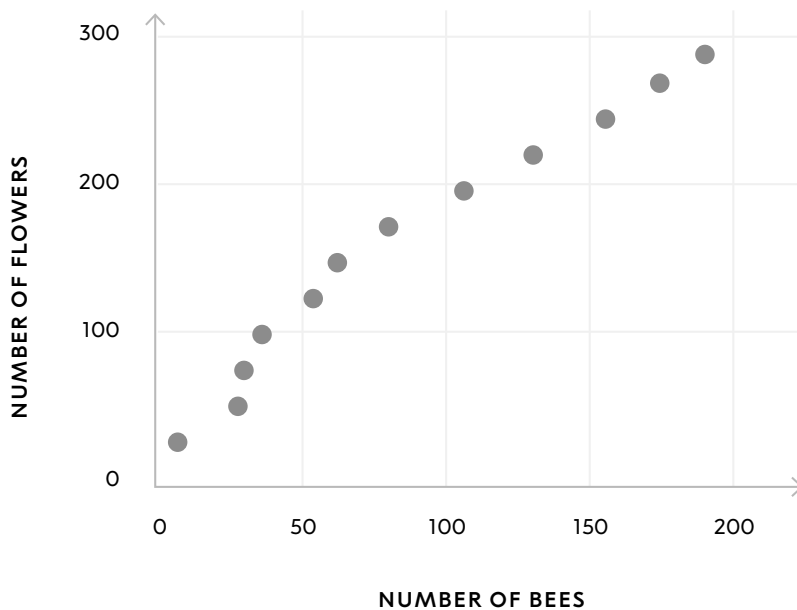


FIGURE 4.5
Flowers vs. Bees

Answer the following questions:

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

Level 4 response

- The number of bees and number of flowers show a strong positive correlation. When one increases, the other increases.*
- Yes, given the strong correlation, knowing the number of bees would help predict the number of flowers in the meadow. If there were fewer bees, you would predict fewer flowers, and vice versa.*
- No, you cannot determine that there is a cause-and-effect relationship with just the correlation between the two variables, even if the correlation is very strong. The correlation is just one piece of evidence. You would need more information about other indicators, like timing and mechanism. You would also need to rule out alternative explanations for the correlation.*

- d** Yes, I do think that there is a cause-and-effect relationship. I think that if there are more bees, they will pollinate more flowers, causing more flower seeds and therefore more flowers (X causes Y). Although, if there were somehow more flowers first, it might be possible that they would attract more bees (Y causes X), maybe if a person planted the flowers or spread seeds to cause more flowers to grow. Also, bees use pollen as food, so if there are more flowers to feed the bees, you would expect more bees to grow and reproduce. I am supporting my answer with the background knowledge that bees help pollinate flowers when they go from flower to flower to gather the pollen that they use as food.

Level 3 response

- a** The number of bees and number of flowers show a strong positive correlation.
- b** Yes, the strong correlation suggests that you could predict the number of flowers in the meadow if you knew the number of bees.
- c** No, you need more evidence about things like timing.
- d** Yes, I think there is a cause-and-effect relationship because the correlation is so strong, and the bees and flowers live together in the meadow. I've seen bees flying around and landing on flowers at the park, and I know that lots of plants and animals that live in the same habitat affect each other, so there might be a cause-and-effect relationship there.

Level 2 response

- a** There is a strong correlation.
- b** I predict there will be more flowers because bees carry pollen.
- c** No, I can't predict because I would need to see more information.
- d** I think there is a cause-and-effect relationship because bees pollinate flowers and make them grow.

Level 1 response

- a** There is a correlation.
- b** I can predict the number of flowers.
- c** Yes, correlations always show cause and effect.
- d** Bees and flowers live together.

- 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.**

Jenine's result ($r = 0.20$) is more likely to be from random chance because the correlation is weaker. A lower r -value means there isn't a strong pattern between height and playing sports. Cy's correlation ($r = 0.40$) is stronger, so it's less likely to be random.

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

Yes, it's possible. Since they both only studied 30 kids, that's a small group, and random patterns can show up just by chance. If they tested more students, they might find that the correlations change or even disappear.

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

They should collect data from more kids, maybe from multiple schools, not just their own class. They could also check if their results stay the same in different groups to see if the patterns are real or just random.

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

- a What do you think this phrase means?**

"Correlation does not equal causation" means just because two things happen together, it doesn't mean that one causes the other. For example, if two things both increase at the same time, like more ice-cream sales and more shark attacks, that doesn't mean buying ice cream causes shark attacks.

- 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**

If the timing is off, like if the effect happens before the cause, then it's not actually causation.

- **the mechanism for the possible cause and effect**

If there is no likely mechanism to explain how one thing would lead to the other, it is probably not a cause-and-effect relationship.

- **if alternative explanations exist**

Lastly, correlation tells you nothing about whether an alternative explanation could be possible for the effect.

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!”

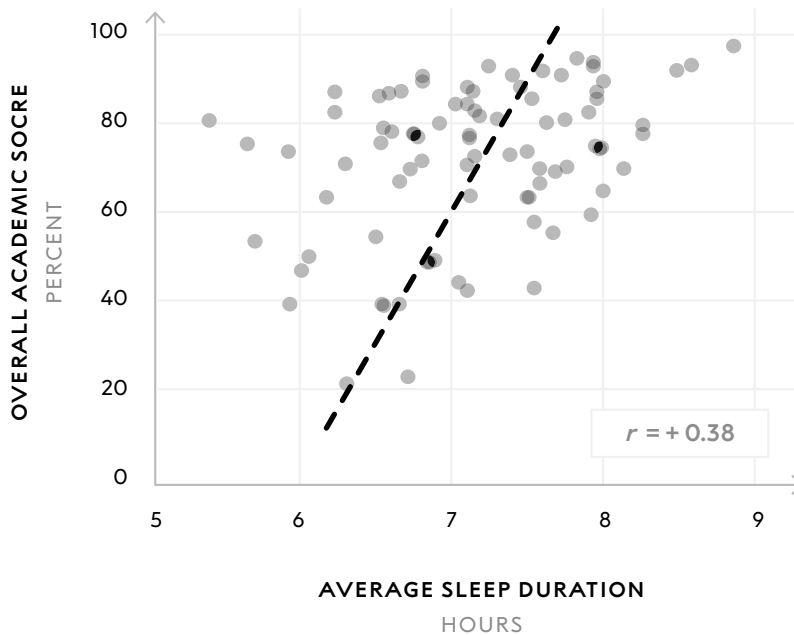


FIGURE 4.6
Sleep vs. Academic Performance

- 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.

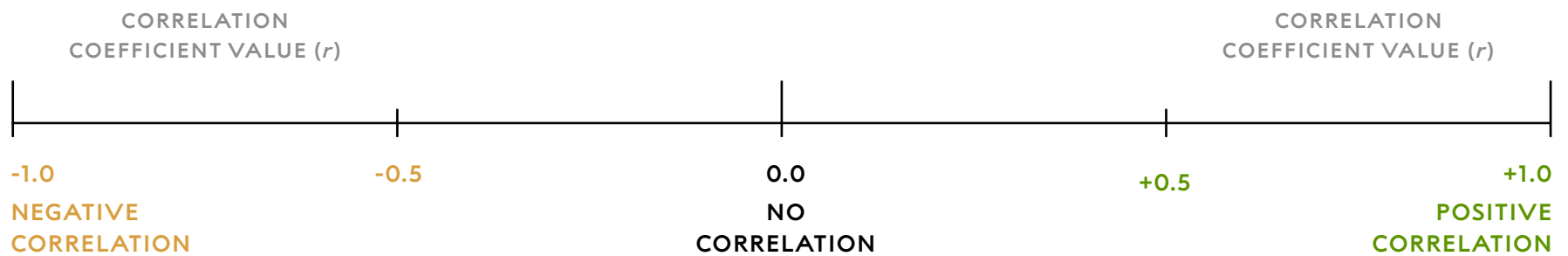
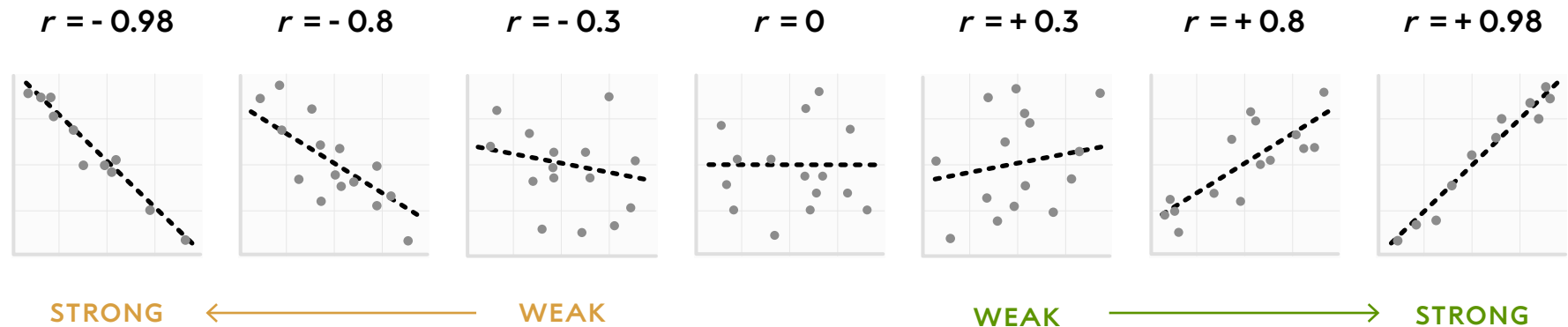
No, I don’t think my friend is right. The data does show that there is a correlation, so it shows that students who sleep more tend to have better grades, but that doesn’t prove that sleep is the reason. We can’t tell anything about timing from this data (if sleep could be affecting grades or the other way around). There might be some kind of mechanism, like getting more sleep means you can think more clearly, but it could also be that people who sleep more also study more or they’re healthier, so they don’t miss as much school. I would still study!

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

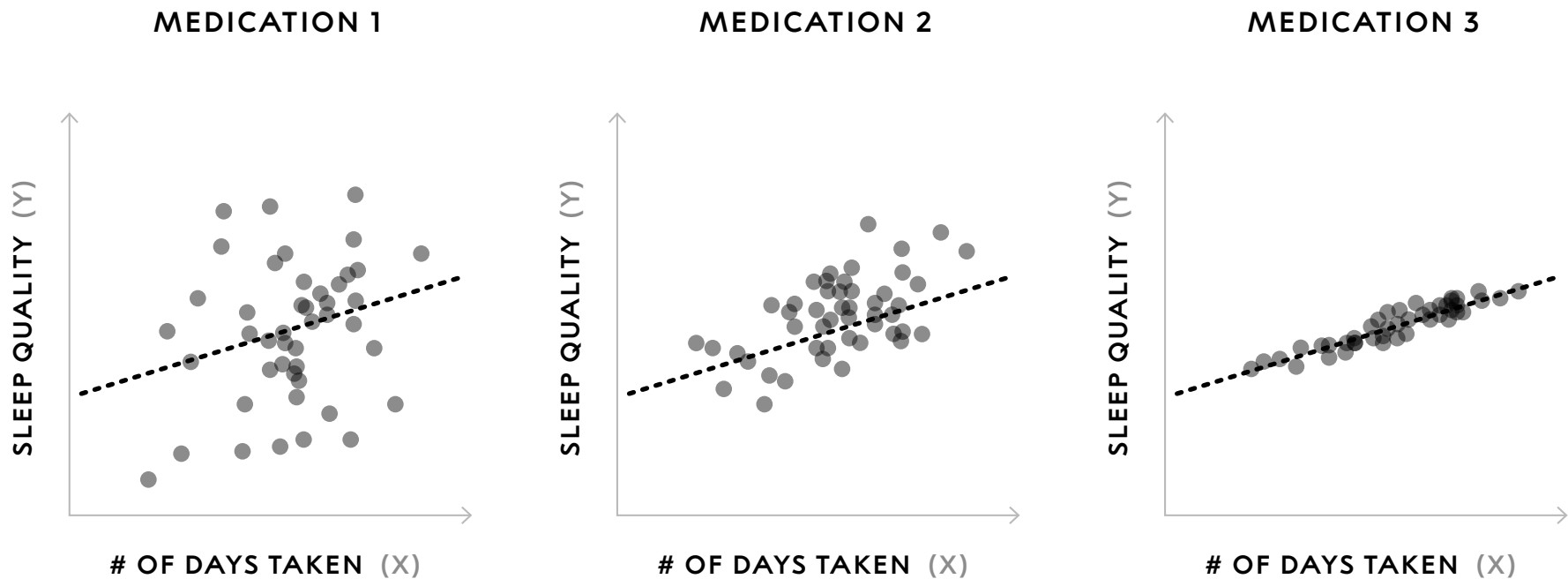
To know if sleep actually causes better grades, I’d want to see if other studies showed the same correlation or see if an experiment could be done to directly test if different amounts of sleep affect academic performance. We could also test other things, like how much they study or if they eat healthy to see if those things were causing it.

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● DATA POINT ---- BEST-FIT LINE



Which medication shows a correlation that is more likely to be from chance?

Which medication shows the strongest correlation between the number of days it is taken and sleep quality?

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.

WHAT TO LOOK FOR:

- Response describes patterns and trends in data.
- Response interprets patterns and trends to describe possible causal relationships.

LEVEL	GENERAL DESCRIPTION
Level 4 Complete and correct	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data and interprets them completely and correctly to identify and describe relationships. When appropriate, the student: • makes distinctions between causation and correlation. • states how biases and errors may affect interpretation of the data. • states how study design impacts data interpretation.
Level 3 Almost there	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data BUT incorrectly and/or incompletely interprets them to identify and describe relationships.

LEVEL	GENERAL DESCRIPTION
Level 2 On the way	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes, BUT does not interpret, patterns and relationships.
Level 1 Getting started	The student attempts to analyze the data BUT does not use appropriate tools, techniques and/or reasoning to identify and describe patterns and relationships.
Level 0 Missing or off task	The student's analysis is missing, illegible, or irrelevant to the goal of the investigation.
X	The student had no opportunity to respond.

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.

WHAT TO LOOK FOR:

- Response describes patterns and trends in data.
- Response interprets patterns and trends to describe possible causal relationships.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 4 Complete and correct	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data and interprets them completely and correctly to identify and describe relationships. When appropriate, the student: • makes distinctions between causation and correlation. • states how biases and errors may affect interpretation of the data. • states how study design impacts data interpretation.	The student response: • describes the correlation as positive and strong. • describes patterns in the data that lead to predictions of increased bees = increased flowers (and/or less bees = less flowers). • thoroughly describes sound reasoning for why causation cannot be determined with certainty, including discussion of timing, mechanisms, and/or alternative explanations. • provides a thoroughly reasoned response for a cause-and-effect relationship (or not). Background knowledge is not required, as long as reasoning is logical and well explained.

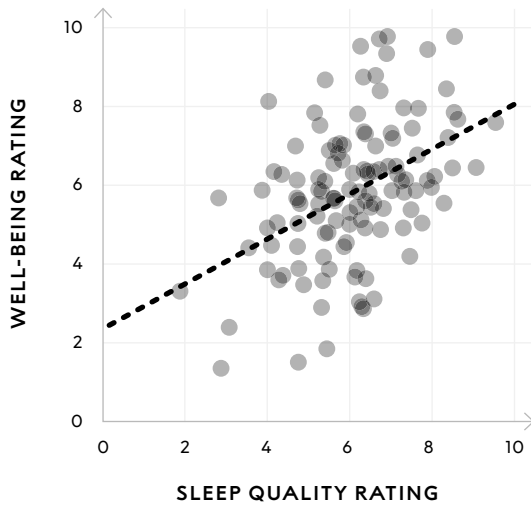
LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 3 Almost there	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data BUT incorrectly and/or incompletely interprets them to identify and describe relationships.	The student response: - describes the correlation as positive and strong. - describes patterns in the data that lead to predictions of increased bees = increased flowers (and/or less bees = less flowers). The student response may have minor errors or limited responses related to: - describing reasoning for why causation cannot be determined with certainty. - providing a reasoned response for a cause-and-effect relationship (or not). Background knowledge is not required, as long as reasoning is logical.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 2 On the way	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes, BUT does not interpret, patterns and relationships.	The student response: - describes the correlation as <i>either</i> positive or strong. - describes a prediction but may have inaccuracies or lack detail. The student response may have errors or limited responses/reasoning for: - determining causation with certainty. - a cause-and-effect relationship (or not). Background knowledge is not required, as long as reasoning is logical.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 1 Getting started	The student attempts to analyze the data BUT does not use appropriate tools, techniques, and/or reasoning to identify and describe patterns and relationships.	The student response: - states that there is no correlation, does not describe the correlation, or incorrectly describes the correlation. - describes a prediction that is illogical or incorporates background knowledge. The student response may have significant errors or very limited responses/reasoning for: - determining causation with certainty. - a cause-and-effect relationship (or not). Background knowledge is not required, as long as reasoning is logical.
Level 0 Missing or off task	The student's analysis is missing, illegible, or irrelevant to the goal of the investigation.	
X	The student had no opportunity to respond.	

A

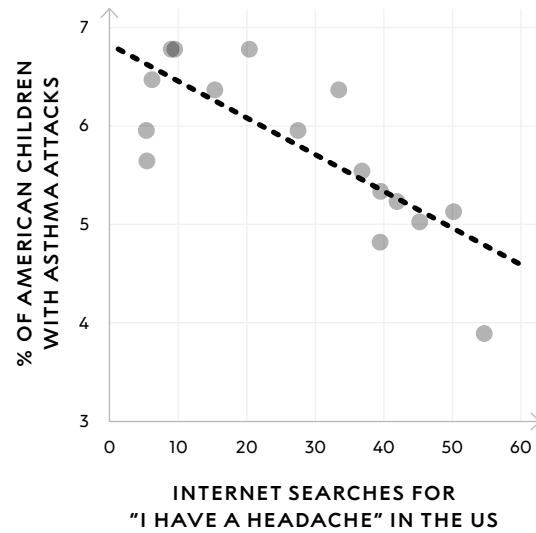
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SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 4: Investigating Evidence for Causation, Activity 4

B

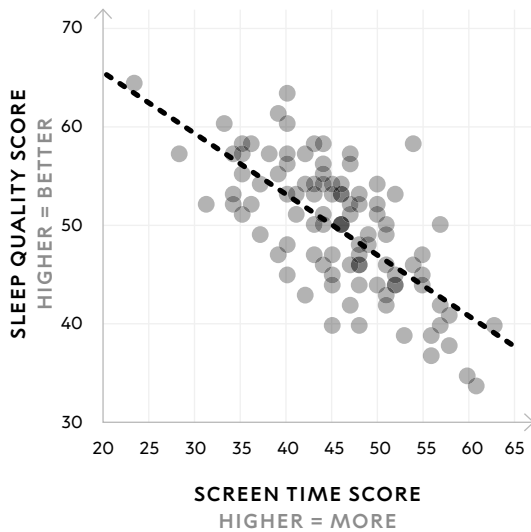
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SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 4: Investigating Evidence for Causation, Activity 4

C

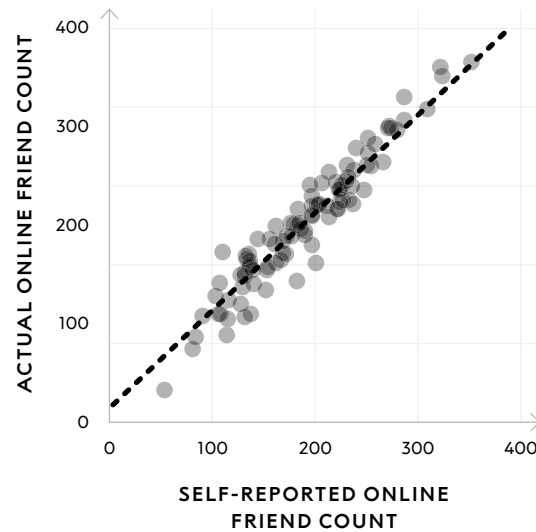
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SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 4: Investigating Evidence for Causation, Activity 4

D

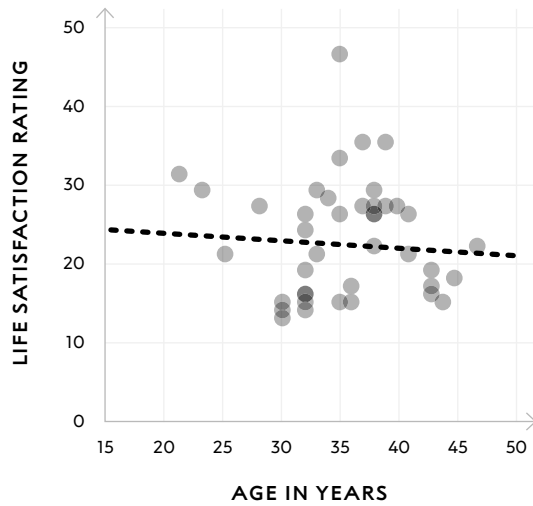
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SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 4: Investigating Evidence for Causation, Activity 4

E

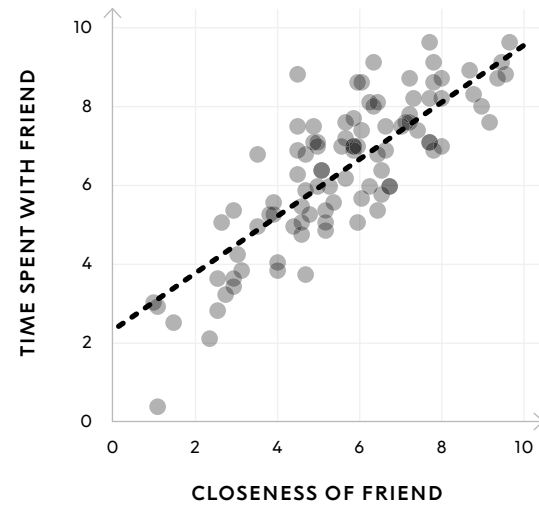
$$r = -0.05$$



SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 4: Investigating Evidence for Causation, Activity 4

F

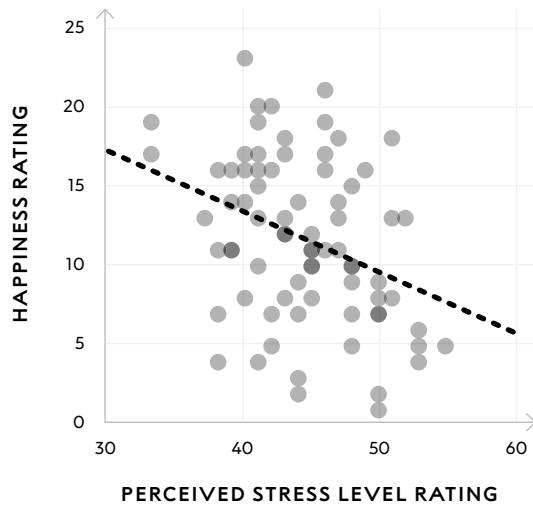
$$r = +0.83$$



SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 4: Investigating Evidence for Causation, Activity 4

G

$$r = -0.37$$



SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 4: Investigating Evidence for Causation, Activity 4



ACTIVITY 5

Evidence of Well-Being

INVESTIGATION

ACTIVITY 5

Evidence of Well-Being

ACTIVITY SUMMARY

Students use the indicators of causation to analyze the strength of a set of evidence for one of the four proposed strategies to improve well-being at Salas High School. Each group evaluates the strengths and weaknesses of three pieces of evidence for a strategy and considers alternative explanations. Then, using a classroom jigsaw approach, students discuss the evidence and collaboratively arrange the strategies from weakest to strongest evidence.

ACTIVITY TYPE
INVESTIGATION

NUMBER OF
40-50 MINUTE
CLASS PERIODS
1-2

KEY CONCEPTS & PROCESS SKILLS

- 1 Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.
- 2 Indicators of causation include the timing of events, observed associations between variables, and plausible mechanisms for the possible cause and effect.
- 3 A likely alternative explanation for an effect reduces the probability that the cause being investigated is the correct one.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:

Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (*Science and Engineering Practice: Analyzing and Interpreting Data*)

CONCEPTUAL
TOOLS



MATERIALS & ADVANCE PREPARATION

FOR EACH STUDENT

- STUDENT SHEET 5.1
(a, b, c, or d)
“Evaluating Indicators
of Causation”
- STUDENT SHEET 1.2
“Unit Concepts
and Skills”
(OPTIONAL)

In Part A, each student in a group of four will receive the same version of Student Sheet 5.1 (a, b, c, or d). Before the activity, decide which group will receive which version.

When previewing the graphs on Student Sheets 5.1a, 5.1c, and 5.1d, please note that all data points are simulated to match the given r -values.

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (10 MIN)

1 Review key concepts about causal reasoning.

- Have students read the Introduction in the Student Book, either as a class or individually. Support students, particularly emerging multilingual learners, in sensemaking and language acquisition as they read the text. Circulate around the room and check in with students as they use the strategy to decode scientific ideas and construct meaning as they read.
- At this point in the unit, students should be familiar with some of the bigger concepts in the unit including cause and effect, correlation, correlation coefficient, indicator of causation questions, and alternative explanations. Although this activity does not introduce any new content, it allows students to look further into the role of evidence in determining causation.
- Depending on your student population, you may want to conduct a word sort before starting the activity to make sure students have an understanding of the major themes they will need to complete this activity. This quick formative assessment presents two lists of words. In each list, one word is not related to the others, and another word encompasses the remaining words. The following two word sorts can be used to support a review of basic causation ideas. For more information on a word sort, see [Appendix 1: Literacy Strategies](#).

LIST 1

correlation
reasoning
causation
opinion
evidence

LIST 2

timing
assumption
association
causal reasoning
alternate explanations
mechanism

- In each list, look for a relationship among a list of five or six words or phrases related to a topic.
- Cross out the one word or phrase that does not belong.
- Highlight any word or phrase that includes all the other words.
- Explain how the highlighted word or phrase is related to all the other words or phrases in the list. (There may be more than one correct answer to a single word sort.)

Sample Student Response

LIST 1

correlation
reasoning
causation
~~opinion~~
evidence

Causation requires more than just a correlation; it is supported by evidence and reasoning.

LIST 2

timing
~~assumption~~
association
causal reasoning
alternate explanations
mechanism

Timing, mechanism, association, and alternative explanations are used in causal reasoning.

- Review the idea from the Introduction that when experiments aren't an option, scientists use different types of evidence—such as associations, timing, and mechanisms—to study cause and effect. Emphasize that scientists consider alternative explanations not just for correlations but also for timing and mechanisms. Let students know that they will practice this by analyzing evidence for each of the four well-being strategies Salas High School is considering.

PROCEDURE SUPPORT (20 MIN)

2 Students evaluate a set of Evidence Statements related to one well-being strategy.

- In Procedure Step 1, provide four copies of Student Sheet 5.1 (a, b, c, or d), “Evaluating Indicators of Causation,” to each group (so each group member in a group gets the same student sheet). Each version of the student sheet focuses on one of the four proposed strategies for Salas High School. Let students know that they will be evaluating data from peer-reviewed scientific journals for all four strategies. Distribute the strategies as evenly as possible among groups and inform students that each group is responsible for becoming an expert on the evidence for their assigned strategy. **For emerging multilingual learners and other diverse learners, it may be helpful to provide the student sheets in advance, have groups read the text aloud, or both.**
- Before starting the activity, you may want to review the following ideas to help students assign a rating from 0 to 5 for the strength of each piece of evidence for their strategy:
 - The possible cause should occur before the possible effect.
 - Stronger correlations provide better evidence because they reduce the likelihood that the association is due to chance. However, even a strong correlation does not prove causation.
 - A reasonable mechanism strengthens the evidence more than a mechanism that is unlikely or unclear.
 - Alternative explanations are important in avoiding incorrect conclusions. Students should think about other possible reasons for the observed timing, correlation, or mechanism that could influence their ratings.
- In Procedure Steps 2–3, students work in their groups to complete their student sheets. Remind students that their ratings for the strength of evidence for each study should be based on the available information, even if the information is incomplete. Scientists often make evaluations with partial data. A rating of 0 means the evidence is irrelevant, while a rating of 5 means it is extremely compelling. Encourage students to use the numbers in between the range. The exact ratings for group members don’t have to match, and there is no single correct answer. The goal is to practice evaluating evidence strength.
- If students find it difficult to choose a number to rate the strength of evidence, encourage them to reread the Evidence Statements and ask them the questions related to indicators of causation: *Does the possible cause come before the effect? How strong is the correlation? Is there a reasonable mechanism?* You can also ask, *What are alternative explanations?*
- **For those students who may need extra support identifying the indicators of causation for each piece of evidence, help them highlight key terms in the Evidence Statements, such as *after* for timing or *many times* for association. When considering possible mechanisms, encourage students to focus on statements that include relevant scientific concepts, as these can help explain how one variable might cause a change in another.**

3 Address misconceptions about alternative explanations.

- Before students move on to Part B, remind them to record any alternative explanations for one or more of the Evidence Statements. These should be possible explanations for one Evidence Statement, not alternative factors of well-being or explanations that cover all three Evidence Statements. Responses will vary, but one sample student response for each strategy is shown at the end of this activity.
- A common misconception about alternative explanations is that they are alternative causes for an *effect*, but they can also be alternative reasons for the *evidence*. For example, when considering how a bad mood may be caused by poor sleep or by being hungry, being hungry is an alternative cause for a bad mood. However, it is not an alternative explanation for the association between sleep quality and mood (unless hunger affects both sleep quality and mood separately). Ask, **What is another possible explanation for the evidence?** Students should see that answering this question illustrates that they should be looking for alternative explanations for the evidence, not alternative causes for the effect.

4 Use a jigsaw classroom approach to help students consider all the available evidence.

- In Part B, move students into new groups, making sure each new group has at least one “expert” representing each strategy. Students then compare the strength of the overall evidence for each strategy in their new groups.
- In Procedure Step 6, some groups may want to simply take the average of their group members’ evidence ratings and arrange the student sheets based on those numbers, without any discussion. Encourage groups to go further by pointing out that group members may have used different criteria or expectations when rating their evidence. Therefore, students should explain and compare their thinking in evaluating the evidence. Point out that there is no one correct way to arrange the student sheets. Groups may come up with different sequences, and this is acceptable. Remind students that this process may result in a final order that does not match their previous ratings.
- The goal of this activity is for students to practice evaluating evidence and recognize the difficulties in doing so. The following sample student response shows only one possible sequence. Reasons for this sequence include the sample sizes used and the likelihood of alternative explanations.

Sample Student Response, Procedure Step 6

Strongest overall evidence

Gratitude Writing (3.5)
Quality Sleep (3.0)
Pet Therapy (3.0)

Weakest overall evidence

Green Spaces (2.75)

SYNTHESIS OF IDEAS (10 MIN)

5 Discuss the complexities of evaluating evidence to support causation.

- This activity asked students to apply what they have learned to novel questions and contexts. Ask, **What were some of the difficulties in evaluating the evidence for causation?** Student responses may include the idea that they were missing some background knowledge about these topics or that they were missing some details about study designs. Follow this with a question about the Salas High School scenario. Ask, **How does what you've learned influence your thoughts about the choice of the four strategies?** Students' responses should indicate that the strategies with stronger evidence are more likely to be effective treatments for well-being at Salas High School.
- An important takeaway from the activity is that evidence should not be evaluated simply by counting how many pieces of evidence there are, or whether there is at least one piece of evidence for each indicator of causation (timing, association, mechanism). Instead, each piece of evidence must be evaluated on its own merit, and then the multiple lines of evidence can be brought together. An example of this is when all three indicators of causation are present, yet each piece of evidence is very weak, and there are many possible alternative explanations.
- Build Understanding item 3 engages students in metacognition about why alternative explanations reduce the strength of evidence. This helps students understand the important function of looking for alternative explanations. A prompt that asks students to reflect on which well-being strategy would be most effective for their own lives is provided in Connections to Everyday Life item 4.
- You may wish to revisit optional Student Sheet 1.2, "Unit Concepts and Skills," to help students formally organize the ideas introduced in the unit so far. Students can place the headings of the main ideas related to correlation and causal reasoning into the organizer and add examples from their classroom experiences. See the end of Activity 1 in the Teacher's Edition for a sample student response.
- Foreshadow Activity 6 by letting students know they will be reading about other techniques that help make research findings stronger by focusing on the quality, variety, and consistency of the evidence.
- To conclude the activity, evaluate whether your students are able to answer the Guiding Question, *How do scientists use evidence to evaluate causation?* Use this as a chance to revisit and summarize the key concepts and process skills of the activity.

SAMPLE STUDENT RESPONSES

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?

After learning about indicators for causation, I feel more confident in recommending strategies that have clear timing and mechanisms, like getting more sleep or spending more time in green spaces. The science behind sleep and its impact on well-being makes sense, and I can see how it works right away. Knowing that being in a green space might affect your nervous system to calm you is good evidence, too. On the other hand, green spaces did not show that strong of a correlation. Most importantly, when looking for alternative explanations, I realized that lots of other things, like personality or stress levels, can make it really hard to figure out how well the strategy works on its own.

- 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?

In everyday situations and research, people use observations to understand what causes something to happen. The questions about causation help us figure out if one thing can cause another, and the answers are useful in both cases. However, research uses larger groups, precise measurements, and more reliable methods. Research also looks at more complex situations. In everyday life, we often rely on personal experience and assumptions because we don't need to be as careful when figuring things out.

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

They reduce the strength of the evidence because if another explanation could explain the result, then we can't be sure if the cause we are investigating was the reason for it.

CONNECTIONS TO EVERYDAY LIFE

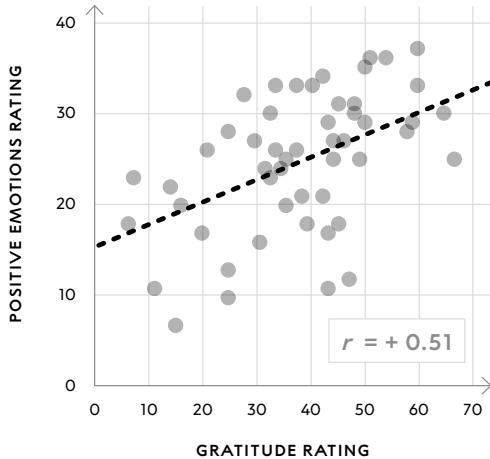
- ④ After learning about each of the four well-being strategies and considering what you know about yourself, which one do you think would be most effective for improving your own well-being? Explain why you believe it would work best for you.

I believe more sleep would work best for me. I know I feel tired all the time, and I've noticed that when I don't get enough sleep, I'm more moody and less focused. If I could improve my sleep schedule, I think I'd be more energetic and in a better mood during the day. I've read that sleep helps with mental health, so I think it could really help me.

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Well-Being Strategy: Gratitude Writing**CAUSE-AND-EFFECT CLAIM:** Gratitude increases positive emotions.

EVIDENCE STATEMENT	TYPE OF INDICATOR FOR CAUSATION	STRENGTH OF EVIDENCE (0–5)
Study 1 A study of 77 romantic couples showed that when one partner recorded a video to express their gratitude and the other partner watched it, couples felt a stronger connection to each other. Social connection is closely linked to many aspects of well-being.		
Study 2 In a study with 132 college students, one group was asked to write once a week about things they were grateful for, while the other group wrote about any events. Afterward, the students in the gratitude group reported feeling more satisfied with their lives, had a more positive outlook on the future, and exercised more than those in the other group.		
Study 3 The scatter plot shows the correlation from a study of 201 college students on gratitude and positive emotions. 		

What is an alternative explanation for one or more of the Evidence Statements described above?

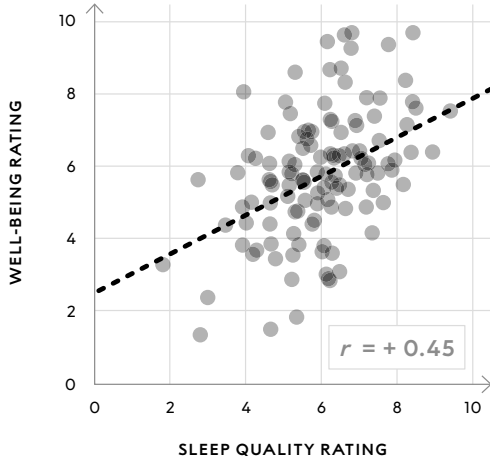
Well-Being Strategy: Pet Therapy**CAUSE-AND-EFFECT CLAIM:** Time with pets decreases stress and makes people happier.

EVIDENCE STATEMENT	TYPE OF INDICATOR FOR CAUSATION	STRENGTH OF EVIDENCE (0–5)
Study 1 Using a Social Stress Test, researchers tested 99 children with pet dogs, both with and without their dogs present. Having a dog present was associated with more positive emotions compared to those who did the test without a dog present.		
Study 2 In a study with 20 dog owners, spending 25 minutes with their dogs increased levels of oxytocin, a hormone linked to feelings of relaxation and happiness.		
Study 3 An analysis of 27 scientific studies looked at the effects of therapy dogs on people with disabilities. It found that one-third of the studies showed improved well-being after receiving a therapy dog, two-thirds showed no change, and almost none showed negative effects.		

What is an alternative explanation for one or more of the Evidence Statements described above?

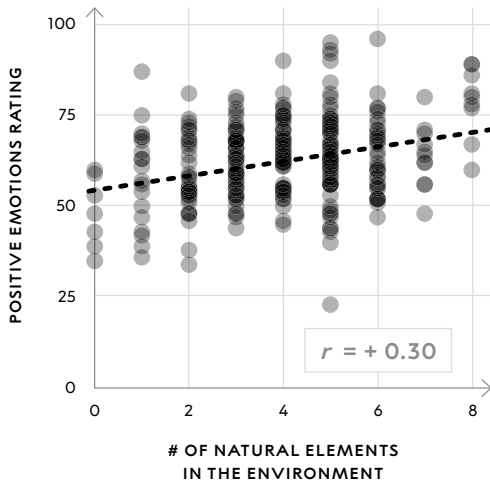
Well-Being Strategy: 😊 Quality Sleep

CAUSE-AND-EFFECT CLAIM: Better sleep improves mood and leads to higher alertness.

EVIDENCE STATEMENT	TYPE OF INDICATOR FOR CAUSATION	STRENGTH OF EVIDENCE (0–5)
Study 1 Researchers had 34 teenagers sleep in a lab dormitory for 9 nights and get either 5 hours, 7.5 hours, or 10 hours of sleep per night. The group that got only 5 hours of sleep reported feeling more angry, confused, and depressed compared to before the study.		
Study 2 A study of 488 adults in Australia found a correlation between sleep quality and overall well-being. 		
Study 3 A review of multiple studies suggests that poor sleep can reduce how well the immune system functions, making people more vulnerable to illnesses.		

What is an alternative explanation for one or more of the Evidence Statements described above?

Well-Being Strategy: Green Spaces**CAUSE-AND-EFFECT CLAIM:** Time in green spaces lowers stress and improves mood.

EVIDENCE STATEMENT	TYPE OF INDICATOR FOR CAUSATION	STRENGTH OF EVIDENCE (0–5)
Study 1 Researchers purposely stressed out 46 college students and then had them look at pictures of either natural green spaces or urban areas. The students who viewed the nature images showed stronger activation of their parasympathetic nervous system, which helps calm the body (including lowering heart rate and slowing breathing).		
Study 2 The scatter plot shows the relationship between positive emotions and the number of natural elements in a person's surroundings (such as trees, plants, or flowers). The data comes from 51 college students who were randomly surveyed a total of 1,120 times at different times of the day. 		
Study 3 In the Netherlands, researchers added live plants to green walls to four elementary classrooms and tested students' attention and well-being before, two months, and three months after the plants were added. Students in classrooms with green walls scored better on attention tests than those without them.		

What is an alternative explanation for one or more of the Evidence Statements described above?

Well-Being Strategy: Gratitude Writing**CAUSE-AND-EFFECT CLAIM:** Gratitude increases positive emotions.

EVIDENCE STATEMENT	TYPE OF INDICATOR FOR CAUSATION	STRENGTH OF EVIDENCE (0–5)
Study 1 A study of 77 romantic couples showed that when one partner recorded a video to express their gratitude and the other partner watched it, couples felt a stronger connection to each other. Social connection is closely linked to many aspects of well-being.	<i>mechanism</i>	3
Study 2 In a study with 132 college students, one group was asked to write once a week about things they were grateful for, while the other group wrote about any events. Afterward, the students in the gratitude group reported feeling more satisfied with their lives, had a more positive outlook on the future, and exercised more than those in the other group.	<i>timing</i>	4
Study 3 The scatter plot shows the correlation from a study of 201 college students on gratitude and positive emotions. 	<i>association</i>	3

What is an alternative explanation for one or more of the Evidence Statements described above?

For Study 3, maybe having a higher well-being causes someone to have more things to be grateful for, and not the other way around.

Well-Being Strategy: Pet Therapy**CAUSE-AND-EFFECT CLAIM:** Time with pets decreases stress and makes people happier.

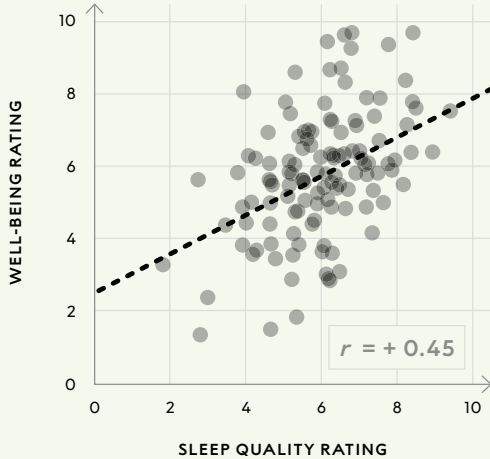
EVIDENCE STATEMENT	TYPE OF INDICATOR FOR CAUSATION	STRENGTH OF EVIDENCE (0–5)
Study 1 Using a Social Stress Test, researchers tested 99 children with pet dogs, both with and without their dogs present. Having a dog present was associated with more positive emotions compared to those who did the test without a dog present.	association	3
Study 2 In a study with 20 dog owners, spending 25 minutes with their dogs increased levels of oxytocin, a hormone linked to feelings of relaxation and happiness.	mechanism	4
Study 3 An analysis of 27 scientific studies looked at the effects of therapy dogs on people with disabilities. It found that one-third of the studies showed improved well-being after receiving a therapy dog, two-thirds showed no change, and almost none showed negative effects.	timing	2

What is an alternative explanation for one or more of the Evidence Statements described above?

For Study 3, people who were already feeling more optimistic may have been more likely to get therapy dogs. This could mean that their positive feelings were due to other factors, not to getting therapy dogs.

Well-Being Strategy: 😊 Quality Sleep

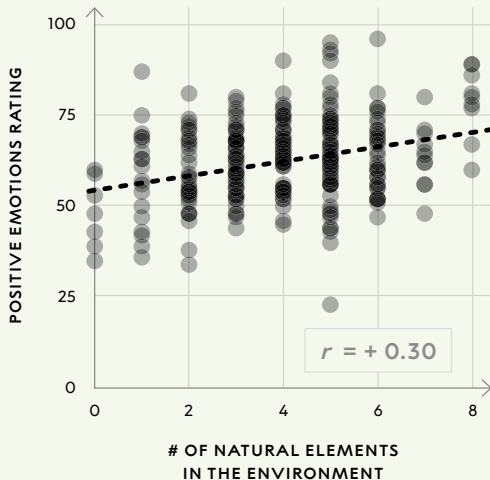
CAUSE-AND-EFFECT CLAIM: Better sleep improves mood and leads to higher alertness.

EVIDENCE STATEMENT	TYPE OF INDICATOR FOR CAUSATION	STRENGTH OF EVIDENCE (0–5)
Study 1 Researchers had 34 teenagers sleep in a lab dormitory for 9 nights and get either 5 hours, 7.5 hours, or 10 hours of sleep per night. The group that got only 5 hours of sleep reported feeling more angry, confused, and depressed compared to before the study.	timing	4
Study 2 A study of 488 adults in Australia found a correlation between sleep quality and overall well-being. 	association	3
Study 3 A review of multiple studies suggests that poor sleep can reduce how well the immune system functions, making people more vulnerable to illnesses.	mechanism	2

What is an alternative explanation for one or more of the Evidence Statements described above?

For Study 2, it's possible that higher well-being is due to lower stress levels, rather than to better sleep. In other words, people with lower stress levels may feel better and sleep better, which could explain the results.

Well-Being Strategy: Green Spaces**CAUSE-AND-EFFECT CLAIM:** Time in green spaces lowers stress and improves mood.

EVIDENCE STATEMENT	TYPE OF INDICATOR FOR CAUSATION	STRENGTH OF EVIDENCE (0–5)
Study 1 Researchers purposely stressed out 46 college students and then had them look at pictures of either natural green spaces or urban areas. The students who viewed the nature images showed stronger activation of their parasympathetic nervous system, which helps calm the body (including lowering heart rate and slowing breathing).	<i>mechanism</i>	4
Study 2 The scatter plot shows the relationship between positive emotions and the number of natural elements in a person's surroundings (such as trees, plants, or flowers). The data comes from 51 college students who were randomly surveyed a total of 1,120 times at different times of the day. 	<i>association</i>	3
Study 3 In the Netherlands, researchers added live plants to green walls to four elementary classrooms and tested students' attention and well-being before, two months, and three months after the plants were added. Students in classrooms with green walls scored better on attention tests than those without them.	<i>timing</i>	1

What is an alternative explanation for one or more of the Evidence Statements described above?

For Study 2, maybe the students who had more natural things around them were in places with friends. This could mean it was the time with friends that gave them more positive emotions instead of being near natural things.



ACTIVITY 6

Understanding Well-Being Through Research

READING

ACTIVITY 6

Understanding Well-Being Through Research

ACTIVITY SUMMARY

Students read about the landmark Harvard Study of Adult Development that began in 1938 and continues today. The researchers conducted a long-term observational study to track patterns of happiness and well-being among a group of 19-year-old students for the rest of their lives. The study's design exemplifies some of the causal reasoning approaches students have been investigating in this unit, such as reducing the likelihood of alternative explanations. Students learn how scientists design studies and analyze data to be more confident in their findings. Students engage in a literacy strategy to support reading comprehension.

ACTIVITY TYPE
READING

NUMBER OF
40-50 MINUTE
CLASS PERIODS
1-2

KEY CONCEPTS & PROCESS SKILLS

- 1 Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations.
- 2 Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.
- 3 A likely alternative explanation for an effect reduces the probability that the cause being investigated is the correct one.

CONCEPTUAL
TOOLS



VOCABULARY DEVELOPMENT

confound

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

sample size

the number of individuals participating or items included in a study

effect size

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

TEACHER BACKGROUND INFORMATION

Harvard Study of Adult Development

The Harvard Study of Adult Development is one of the longest-running studies of adult life. It began in the 1930s and continues today. It originally gathered data from two groups of men: one group of Harvard sophomores and a second group of men from low-income neighborhoods in Boston. The goal of the study was to understand the factors that contribute to healthy aging and well-being. Over the decades, the study expanded to include the wives and children of the original participants, making the research more inclusive and diverse. This expansion helped researchers test whether the connections they observed between social relationships and well-being also applied to people with different socioeconomic backgrounds, genders, and ethnicities. The study has shown that meaningful and supportive social connections and satisfying relationships are associated with long-term happiness and health, regardless of income, gender, or location. The study is recognized for its rigorous design, which includes longitudinal data collection, large sample sizes, and attention to confounding factors.

Social Connection and Well-being

The Harvard Study of Adult Development's finding that social connection predicts well-being has been supported by many other studies. Although the Harvard Study didn't account for factors such as race, studies have consistently found that strong social connections are a major predictor of happiness for people of all racial, economic, and cultural backgrounds. Research in psychology, public health, and sociology consistently shows that strong, supportive relationships are associated with better mental health, greater life satisfaction, and even improved physical health outcomes. Observational studies have found that people with high-quality social connections tend to experience lower rates of depression and anxiety, as well as better immune and cardiovascular health. For example, a meta-analysis, which combines data from multiple studies, published in *PLOS Medicine* found that individuals with higher levels of social support are more likely to live longer, even after accounting for factors such as income, education, and health behaviors.

Additionally, experimental studies have provided evidence for a cause-and-effect relationship between social connection and well-being. Randomized controlled trials, which students will learn more about in Activities 7 and 8, show that improving social connections through activities or support programs leads to better mental health and overall well-being. These studies offer stronger evidence that social ties can directly influence happiness, stress, and physical health, supporting the findings from the Harvard Study.

Observational Studies

An observational study is a type of study in which scientists observe subjects without changing or controlling any variables. Unlike experiments, researchers do not assign treatments; instead, they analyze naturally occurring behaviors or conditions. There are different types of observational studies: cross-sectional studies in which data is collected at one point in time (such as a survey on hours of social media use and happiness level); cohort studies in which a group of people is followed over time to track factors such as exercise and heart health; and case-control studies in which researchers compare people with a condition (such as lung cancer) to those without the condition to identify potential causes, such as smoking.

While observational studies can show correlations between variables, they cannot prove causation because other factors (confounds) could influence the results. For observational studies to yield reliable results, they need a large and diverse sample size to minimize the chance that results are due to random differences. Observational studies are helpful when experiments are not possible or ethical, such as studying the long-term effects of smoking. They are also good for examining real-world behaviors and studying long-term effects. However, since researchers do not have as much control over all variables, observational studies have a higher risk of confounds; therefore, these studies cannot conclusively establish direct cause-and-effect relationships.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 6.1
“Read, Think, and
Take Note Guidelines”
- VISUAL AID 6.2
“Study Design Elements
and Analysis Methods”

FOR EACH STUDENT

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

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (10 MIN)

1 Introduce the reading as an example of an observational study.

- Have students read the Introduction. Reading the Introduction aloud can better support comprehension for many students, including neurodiverse students and emerging multilingual learners who often have more highly developed listening and oral skills than reading comprehension skills. Alternatively, students can read the Introduction independently.
- Discuss the key idea that causation is not always simple. This is especially true for complex topics such as well-being where many factors can contribute to someone's level of well-being. Emphasize that studying cause-and-effect relationships related to human behavior can be especially challenging since it is complex and influenced by many factors. For example, if someone's mood improves after drinking coffee and then exercising outside on a beautiful day, multiple factors could be responsible for their mood change. The caffeine, physical activity, or pleasant weather—or a combination of these factors—might have contributed to the person's improved mood.
- In this activity, students will read about the Harvard Study of Adult Development, a famous observational study. Students may not be aware that research studies fall into different categories, such as observational studies (e.g., case studies, correlational studies, and longitudinal studies) and experimental studies (e.g., randomized controlled trials and clinical trials). While you don't need to explain all these categories, it may be helpful to clarify that this activity is about an observational study. In an observational study, researchers observe subjects without controlling or changing any variables; instead, they analyze existing behaviors or conditions. Observational studies are useful for understanding long-term effects of real-world behaviors.
- Explain to students that observational studies, such as the one they will read about, can identify correlations between variables but cannot fully prove causation because many additional factors could be influencing the results. However, by using careful study design and analysis, the researchers were able to uncover important relationships between variables, making the findings informative and valuable. Let students know that they will learn about these methods in the reading.

PROCEDURE SUPPORT (20 MIN)

2 Review the Read, Think, and Take Note Guidelines to support students' reading comprehension.

- Review the Read, Think, and Take Note Guidelines to support students in completing the reading. The Read, Think, and Take Note strategy provides an opportunity for students to record their thoughts, reactions, and questions on sticky notes as they read. The notes serve to make concrete the thoughts arising in their minds and then serve as prompts to generate conversation or write explanations. You can use Visual Aid 6.1, "Read, Think, and Take Note Guidelines," to review this literacy strategy. If your students are unfamiliar with the strategy, it can be helpful to demonstrate with a short passage of simple text, such as the Introduction to the activity. For more information about the Read, Think, and Take Note strategy, see [Appendix 1: Literacy Strategies](#).

3 Use a Directed Activity Related to Text (DART) strategy to support students' synthesis of key concepts in the reading.

- In Procedure Step 2, hand out Student Sheet 6.1, "DART: Harvard Study of Adult Development." To help synthesize the information in the reading, have students work in pairs to complete Student Sheet 6.1. For more information on a Directed Activity Related to Text (DART), see [Appendix 1: Literacy Strategies](#). The DART strategy helps students summarize the concepts related to scientific methods for studying causation. A sample student response to Student Sheet 6.1 can be found at the end of this activity.
- As students work through Student Sheet 6.1, it may help to review the terms in the left-hand column of the table. For students who need extra support, you may also want to complete a row of the student sheet as a class to model the task.

4 Review the key concept of a confound that is introduced in the reading.

- The key concept of a confound can be further explained by discussing the example provided in the reading about the number of shark attacks vs. the number of ice-cream sales. This example was also used in Activity 4, Procedure Step 5 in the Student Book. Remind students of the scatter plot in Figure 4.3 and ask, **When you looked at the two variables, was there a correlation?** Students should recall that yes, there was a strong positive correlation between the two variables because the data points are close together and are both increasing at about the same rate—the more ice cream sold, the higher the number of shark attacks. Then ask, **Was there a direct cause-and-effect relationship—did the ice-cream sales cause the shark attacks to happen?** Students should say that no, there is probably not a direct cause-and-effect relationship because there is no reasonable, logical connection between the two variables. Ask, **What other variable could be related to both sharks and ice-cream sales?** Students should recognize that weather, or the season, is a third variable affecting both factors. Warm weather increases ice-cream sales and brings more people to the ocean where shark attacks might occur. Explain that in this case, weather distorts the relationship between the tested variables, making it a confound. While students have explored confounds in this unit through alternative explanations, this activity formally introduces the term.

- Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by adding new vocabulary for the unit to the word wall. Record the terms *sample size*, *confound*, and *effect size* to the word wall. Provide additional examples for each term as needed. For more information on a Word Wall, see [Appendix 1: Literacy Strategies](#).

SYNTHESIS OF IDEAS (20 MIN)

5 Review how research methods can increase confidence in results.

- Ask students to share their responses to Student Sheet 6.1. For each term, have students provide an example from the Harvard Study and explain how that design element or analysis method can help strengthen a study's findings. Use the sample responses for the student sheet to help clarify key concepts and guide students in applying them to the specific study. For example, highlight that the original sample size of 268 at the start of the study grew to 1,300. This increase in the number of participants helped ensure that the results were not due to chance. In Activity 7, students will further explore how sample size directly impacts the reliability of results. For now, it is enough to discuss how the increased sample size strengthens the evidence for association.
- Display Visual Aid 6.2, "Study Design Elements and Analysis Methods," to review the key aspects of research studies that can strengthen a study's findings: large effect size, large sample size, consistency across settings, and reduction of confounds.
- You may wish to evaluate if your students are able to identify the essential ideas of the activity by reviewing their answers to Build Understanding item 1.
- Finish the activity by revisiting the Guiding Question, *What study designs and analysis methods increase confidence in results?* Use responses to this question to formatively assess students' understanding of the key concepts and process skills related to the ideas of researching complex correlations.

EXTENSION (50 MIN)

6 Use the Extension as an opportunity for advanced learning.

The World Happiness Report is an annual publication that ranks countries based on happiness levels using data from global surveys. Have students choose a topic from an online chapter of the 2025 World Happiness Report titled *Connecting with others: How social connections improve the happiness of young adults*. This chapter specifically focuses on social connection in young adults. After reading, students can create or compare charts or infographics based on the report's data, or reflect personally on the topic they chose. For example, they could create a visual comparing happiness trends across countries, analyze how social network density affects well-being, or write a reflection on how the empathy gap influences their own views on social connections. Encourage students to share their findings with the class through a presentation, discussion, website, or video.

SAMPLE STUDENT RESPONSES

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.

The study was strong because it had a large sample size, meaning that many people participated in the study, which made the results more reliable. The study also found the same results for different groups of people, like men and women or rich and poor. This showed that the connection between good social relationships and happiness was consistent across different settings. Researchers also checked for confounds that could affect the results to make sure that social relationships were really the reason for the better chance of happiness. Lastly, the effect size for social connection was much larger than for other factors, showing that good relationships had the biggest impact on happiness and health.

- 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?

The results from the Harvard Study made me think that social connection should be a big part of whichever strategy we recommend for Salas High School. For example, in the school garden, students could work in teams, forming connections while learning about gardening. In gratitude writing, having students exchange their thoughts with others could spread positivity and foster strong connections. If a bunch of students are spending time with a dog, then a school therapy dog could also increase social connection by bringing people together. The exception is the sleeping strategy. I'm not sure how to make a later school start time a social event.

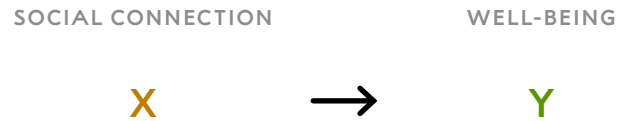
- ③ The Harvard Study reported a correlation between social connection and well being. Which of the following reasons could explain this association? (Choose all that apply.)

- 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 cause and effect between X, Y, and Z. Label and explain your diagram(s).

All three explanations could explain the association, either independently or in combination.

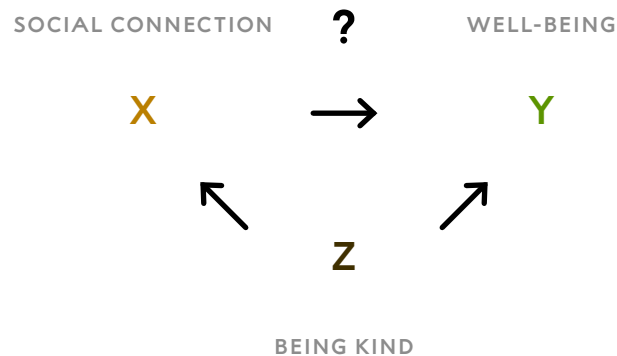
- a When people have strong social connections, they have more support, feel less lonely, and experience more positive emotions. This could improve their overall well-being by reducing stress and increasing happiness.



- b If someone is happy and feels good about themselves, they might be more outgoing and social. This could lead to making more friends and having stronger relationships.



- c When people are kind to others, it can help them build friendships and stronger social connections. At the same time, doing kind things for others can also make someone feel happier and improve their sense of well-being.



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?

One strategy I could try is improving my social skills. I would like to practice speaking more in class or talking to people I don't know very well. This would help me get better at making new friends. Another strategy I could try is changing negative thoughts about social situations into positive ones. If I try to think more positively about being with other people, I might feel more comfortable and willing to connect with others.

- 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?

One way to use social media to promote positive connections is by following and interacting with friends and family. You could use it to keep in touch, share updates, and support each other, such as liking their posts or sending encouraging comments. Another example is joining groups or online communities where people share common interests or hobbies, which can make you feel connected to others who understand you.

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STUDY DESIGN ELEMENT OR ANALYSIS METHOD	EXAMPLE FROM READING	HOW DOES IT STRENGTHEN A STUDY'S FINDING?
effect size		
sample size		
consistency across settings		
accounting for confounds		

STUDY DESIGN ELEMENT OR ANALYSIS METHOD	EXAMPLE FROM READING	HOW DOES IT STRENGTHEN A STUDY'S FINDING?
effect size	<i>Social connection had a larger effect on happiness than wealth.</i>	<i>It shows which factors have the strongest impact on outcomes.</i>
sample size	<i>The study started with 268 participants and later grew to 1,300.</i>	<i>A larger sample (more people) makes the results more reliable by reducing the chance of inaccurate results.</i>
consistency across settings	<i>The study added participants from different backgrounds (low-income neighborhoods and women).</i>	<i>It strengthens the findings by making sure that the results apply to a wide range of people and situations.</i>
accounting for confounds	<i>They compared results for different subgroups (such as wealth, gender) to check if the results were the same.</i>	<i>It helps make sure that the result is due to what you are studying (for example, social connection) and not some other factor.</i>

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.

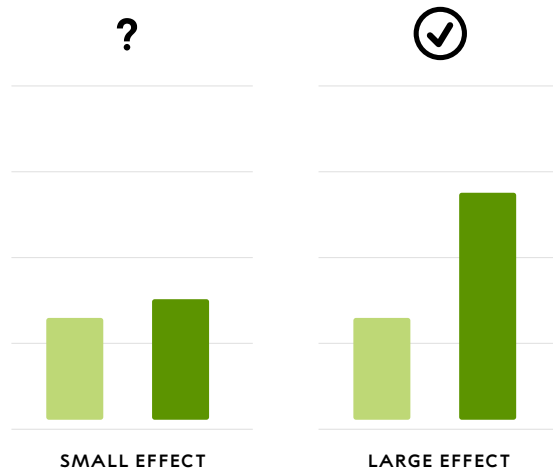
As you read, use a sticky note from time to time to:

- 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.

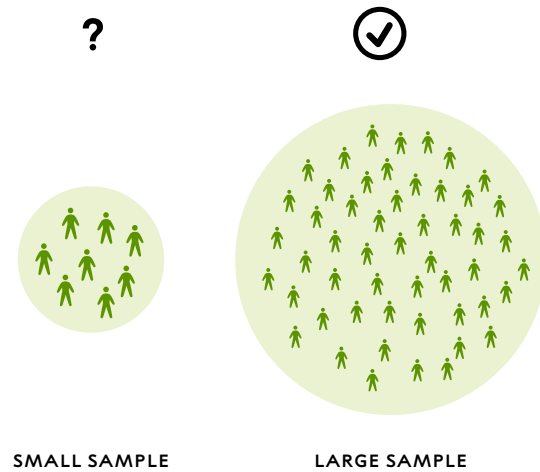
After writing a thought or question on a sticky note, place it next to the word, phrase, sentence, diagram, drawing, or paragraph in the reading that prompted your note.

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

Effect Size



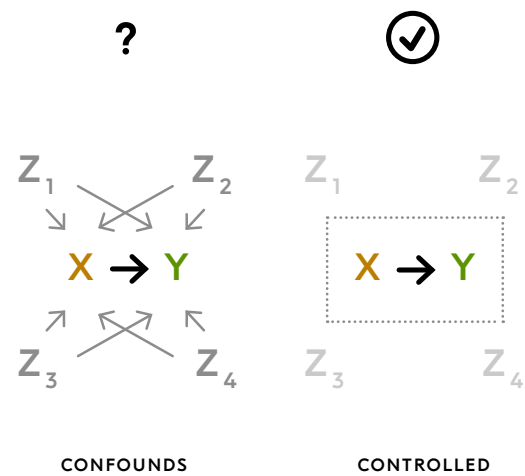
Sample size



Consistency across settings



Reduction of confounds





ACTIVITY 7

Improving Experimental Design

COMPUTER SIMULATION

ACTIVITY 7

Improving Experimental Design

ACTIVITY SUMMARY

Students use a computer simulation to see how adjustments to experimental design affect the reliability and interpretation of the results. First, they manipulate sample size to understand how results can vary widely even with the same experimental design. Then, they apply their understanding of sample size to explore different treatments and methods for assigning participants to experimental and control groups. As students progress, they explore how reliable results depend on large sample sizes and reducing confounds, which prepares them to design their own randomized controlled trial in Activity 8.

ACTIVITY TYPE
COMPUTER
SIMULATION

NUMBER OF
40-50 MINUTE
CLASS PERIODS
1-2

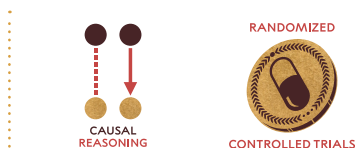
KEY CONCEPTS & PROCESS SKILLS

- 1 Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations.
- 2 Randomized controlled trials (RCTs) are the most reliable method for identifying cause-and-effect relationships because they reduce the likelihood that alternative factors are influencing the effect.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:

Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (*Science and Engineering Practice: Analyzing and Interpreting Data*)

CONCEPTUAL
TOOLS



VOCABULARY DEVELOPMENT

control group

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

experimental group

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

treatment

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

TEACHER BACKGROUND INFORMATION

Random Sampling

Random sampling, also known as random selection, is a method in which a smaller group is chosen from a larger group in a way that gives every member an equal chance of being selected—like drawing names from a hat. This helps ensure that the sample represents the whole population fairly and without bias. However, if the population is very diverse and the sample size is small, the results may not be accurate. In a small sample, each individual has a greater impact on the overall average, which can lead to an unrepresentative outcome just by chance.

Random sampling of people is often more challenging than conducting controlled experiments in fields such as chemistry and physics where researchers directly manipulate variables instead of relying on participant selection. In human studies, selecting participants is not always truly random because it depends on who is willing to participate and how they are recruited. For example, national opinion polls try to gather a representative sample that mimics random selection, but this is becoming more difficult in recent years because fewer people have been agreeing to participate. Those who do participate tend to differ from the general population—they may be less busy, older, or more trusting of institutions such as polls—which makes the sample less representative of the general population.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 7.1
"Random Sampling"
(OPTIONAL)
- VISUAL AID 7.2
"Comparing Trials"
- VISUAL AID 7.3
"Example Results at
Different Sample Sizes"
(OPTIONAL)
- VISUAL AID 7.4
"Scoring Guide: Analyzing
and Interpreting Data
(AID)"
- ITEM-SPECIFIC
SCORING GUIDE:
Activity 7, Build
Understanding item 3

FOR EACH PAIR OF STUDENTS

- COMPUTER WITH
INTERNET ACCESS

FOR EACH STUDENT

- STUDENT SHEET 7.1
"Comparison of
Study Designs"
- SCORING GUIDE:
Analyzing and
Interpreting Data (AID)
(OPTIONAL)

Review the [Dapple Experiments simulation](#) before class so you are familiar with how it functions and are prepared to answer questions.

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (10 MIN)

1 Prepare students to explore a computer simulation about experimental study design.

- In Activity 6, students learned about key characteristics of observational studies. In this activity, students will be introduced to another type of study that can provide better evidence for a cause-and-effect relationship between variables. Students will explore the key elements of randomized controlled trials (RCTs) as they review how sample size and confounds can affect study results. At this point, do not define RCTs for students, as the goal is to allow them to discover this on their own as they work through the simulation. In Activity 8, students will receive a formal definition.
- Have students share examples of games they've played that they think improved their moods. Ask, **Why do you think those games improved your mood?** Ask students to describe any evidence they have—perhaps they felt more relaxed, had fun, or connected with friends while playing. Some students may also mention that games served as a distraction from other tasks they could have or should have been doing. Ask, **How would you design a study to determine how playing a game affects mood?** At this point, allow for all responses. Let students know that they will be using the Dapple Experiments simulation to investigate how playing a game affects well-being. Their goal is to design a study to answer the research question: *Does playing Dapple increase well-being for kids in Salas?*

PROCEDURE SUPPORT (40 MIN)

2 Students begin to explore experimental study design in Part A.

- The fictional scenario presented in Procedure Step 1 can be shared with the class in multiple ways. Read the scenario aloud to the class or have individual students read it aloud while others follow along with the text (either as a whole class or in small groups). **Reading the scenario aloud can better support comprehension for many students, including neurodiverse students and emerging multilingual learners who often have more highly developed listening and oral skills than reading comprehension skills. Alternatively, students can read the scenario independently.**

- Support students as they work through Procedure Steps 2–4. The simulation is designed to get students thinking about what information they need to evaluate a study with a focus on sample size and effect size.
- Support students, particularly emerging multilingual learners, in sensemaking and language acquisition as they read the text in the simulation. Circulate around the room and check in with students as they use the strategy to decode scientific ideas and construct meaning as they progress through the simulation screens.
- After Procedure Step 4, you may want to point out that each trial run in the simulation uses random sampling, meaning that even if the same sample size is used, different people are randomly selected to participate each time. You may wish to display optional Visual Aid 7.1, “Random Sampling,” to explain this concept.
- When students have completed Part A, review their responses to Procedure Step 5. Ask, **Why aren’t the results of the eight trials in Part A the same, even though they had identical study designs?** Students should recognize that each trial is an independent event, and therefore, the results will vary. Students may also notice that the variation in results is influenced by both the small sample sizes and random sampling, which means that different people are selected for each trial. If students don’t identify this on their own, don’t explain it yet as they will continue to explore how sample size impacts effect size in Part B of the simulation.

Sample Student Response, Procedure Step 5

The results are different because each trial is separate, and the people chosen are random. The numbers vary so much because each person is different and has their own individual well-being level. We only tested six individuals in each trial, so it is hard to know whether it worked or not.

TEACHER’S NOTE: If students have completed Unit 3, Scientific Uncertainty and Probabilistic Reasoning, in the *Scientific Thinking for All: A Toolkit* curriculum, they may recognize that random errors are responsible for variability (noise) in the results in Parts A and B of the simulation. Random sampling combined with a low sample size increases the potential for random error due to greater variability between the sample and the population. Likewise in Unit 3, students explore how larger sample size and averaging reduce uncertainty from random errors. Connect students’ inquiry in this activity to the concepts of signal and noise from the other unit.

3 In Part B, students use the Effect Sizes for Different Sample Sizes graph in the simulation to see how sample size affects the trial results.

- Before students start Part B, help them interpret the Effect Sizes for Different Sample Sizes graph shown in the lower section of the simulation by displaying Visual Aid 7.2, “Comparing Trials.” Ask, **Which sample size, A or B, shows more consistent results?** Students should see that Sample Size B shows more consistent results because the arrows are closer to one another, are similar in length, and are going in the same direction.

- Review what the arrows represent in the simulation by using the following descriptions:
 - arrows: a single trial
 - arrow location on the x-axis: the sample size of that trial
 - tail of an arrow: the average well-being level of participants in the control group
 - tip of an arrow: the average well-being level of participants in the experimental group
 - length of an arrow: the effect size, which is the same as that shown in the corresponding bar graph in the upper right of the simulation
 - arrow color: blue shows that the Dapple players had higher well-being on average; red shows that the non-players in the control group had lower well-being on average
- Students can explore the results at each sample size in any order but will need to run trials at every sample size in the graph (from 6 to 120) to see how the reliability of results slowly improves with more samples. Encourage students to repeat trials multiple times at each sample size to find a pattern.
- After completing the graph by running trials with a sample size of up to 120, students will be able to select the Run 25 Trials At A Time button. This allows them to see 25 trials at every sample size, helping them to better estimate the smallest sample size where the results become consistent and reveal the true effect size of playing Dapple. The true effect size is the actual strength of a relationship or difference in the population, not just what a small number of trials finds. Share with students that the true effect size can be estimated from the average arrow length at the sample size where the results become consistent across trials..
- After Procedure Step 7, ask students to share their responses about the sample size and true effect size where the trial results become consistent. Students may have different ideas about what is consistent enough, depending on how precise an estimate of the effect size they want. Emphasize that there is not a correct answer. Answers will vary but generally, the more precise and certain students want to be about the results, the bigger the sample size needed. Students may suggest a sample size between 72 and 114 as the point where results become reliable and recognize that the true effect size is 1.5 points on the 10-point well-being scale.

Student Sample Response, Procedure Step 7

The smallest sample size that gives reliable results is 102, because that's when the blue lines are similar lengths, which is about 1.5, so this is probably the true effect size.

- Facilitate a class discussion about what the Results Across Dapple Trials graph suggests. Ask, **Why do you think that smaller sample sizes result in more varied and less reliable results than a large sample size?** Students should understand that this happens because some individuals are very different from the average in a population (i.e., they are statistical outliers). In a small sample, these individuals have a stronger influence on the results; in a larger sample, the effects of individual differences are balanced out.

4 In Part C, students explore six possible study designs and choose the best one.

- There are 12 possible configurations for the study designs (2 treatments x 2 controls x 3 methods of assignment). While students do not need to do all the combinations, they should explore at least 6 and understand that there are additional possibilities.
 - In Procedure Step 11, hand out Student Sheet 7.1, “Comparison of Study Designs.” Results for Procedure Step 12 will vary from group to group because the simulation does not yield identical results across trials. However, if students choose adequate sample sizes, the same study design should give similar results across trials. A sample student response to Student Sheet 7.1 is shown at the end of this activity. A few of the more notable results students should notice include the following:
 - The experimental group that plays the game once results in little or no effect size since the treatment may not be long enough to make a difference.
 - There are three confounding variables.
 - 1 Assigning groups by neighborhood places the control group in a southern area with many parks and the experimental group in a northern area without parks. This confound results in lower well-being in the experimental group because of less exposure to green spaces, not because of the game.
 - 2 Assigning groups by grade places middle school students in the control group and high school students in the experimental group. This confound is less obvious, making it a good example of a hidden confound. Students will only recognize it as a confound if they compare a study design with grade-based assignment to one with random assignment (the coin flip) and see that assignment by grade level inflates the difference in well-being (implying that middle schoolers in Salas have lower well-being than high schoolers).
 - 3 The control group with the condition “sits on the sidelines” creates a confound by lowering non-players’ well-being simply because they don’t get to play, which could distort the true effect size.
 - The study design with the biggest effect size has the following settings:
 - The experimental group plays the game once a day for a week.
 - The control group sits on the sidelines.
 - Group assignment is based on grade.
- However, as just described, both “sitting on the sidelines” and “assignment by grade” are confounds that can falsely increase the effect size.
- Larger effect sizes or results opposite to the true effect may also arise from small sample sizes, which can be pulled to extremes by outliers.
 - In Procedure Step 13, students will be asked to label their best study design with a star. The best study design has the following settings to avoid confounds and false results from low sample size:
 - Sample size: 120
 - Experimental group: Plays the game once a day for a week
 - Control group: Gather in same size groups without playing Dapple
 - Assignment to group by coin flip

5 Optional: Support students' inquiry into the error bars displayed on the graphs.

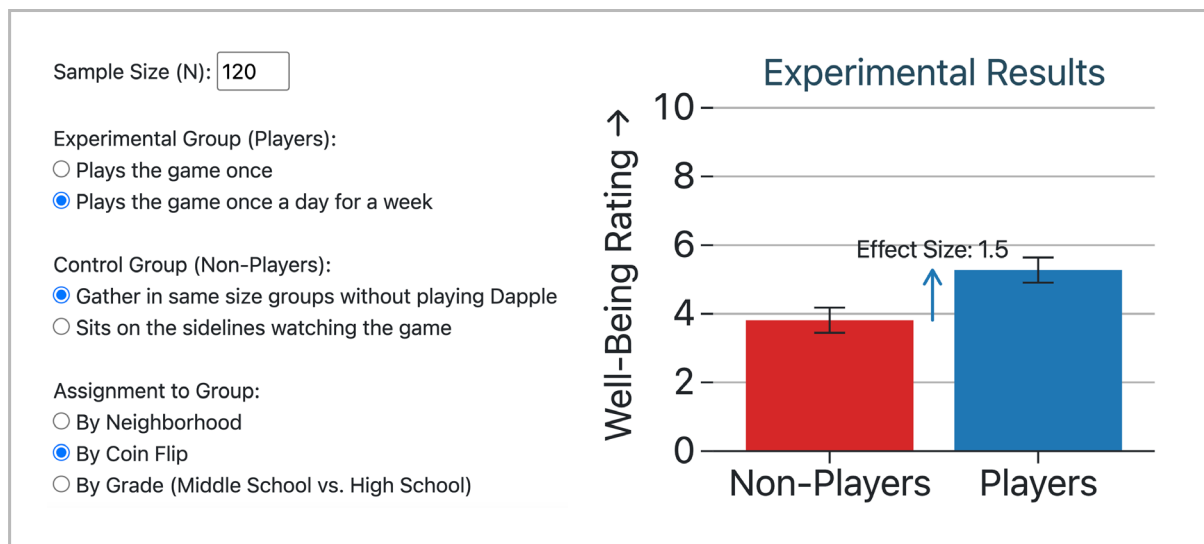
- The error bars in the simulation represent standard error, a statistic that estimates the variation across multiple samples of a population. Smaller standard errors occur from lower variation in a data set and larger sample sizes. While students don't need a formal understanding of standard error, the Error Bar toggle in the simulation allows them to explore how variation impacts the size of the error bars and confidence in the true effect size.
- In Part C, the error bars indicate whether differences between groups might be due to chance. If the bars overlap, the difference could be random. If they do not overlap, the difference is less likely to be due to chance. Use optional Visual Aid 7.3, "Example Results at Different Sample Sizes," to show that larger sample sizes have smaller error bars because extreme values tend to average out at large sample sizes.

SYNTHESIS OF IDEAS (10 MIN)

6 Facilitate a discussion about the best study design for studying the effects that playing Dapple has on well-being.

- Have a few students share with the class what they thought was their best study design and have them explain their reasoning.
- In Procedure Step 14, facilitate a discussion to review the strengths and weaknesses of the different study designs. Ask the following questions to guide the discussion and check students' understanding:
 - **What is the best sample size for the investigation?** Students should recall from Parts A and B that larger sample sizes produce more consistent results by minimizing the impact of individual outliers, leading to more reliable findings.
 - **Which control condition was better—having kids gather in the same size groups somewhere else and not play or sitting on the sidelines watching?** Students should recognize that having kids gathering somewhere else and not playing is the better control condition. Sitting on the sidelines could introduce a confound, as frustration and boredom from being unable to talk or do anything else might affect results.
 - **What was the best way to assign participants to the experimental and control groups?** Students should identify random assignment by coin flip as the best method. This approach prevents confounds related to factors such as neighborhood or grade level.
 - **Was it better to have kids play the game once or once a day for a week?** Students should find that playing daily for a week produced a stronger effect, while playing only once was too weak a treatment to show a noticeable impact in the experimental group.

- Why do scientists repeat experiments many times with different people and how does this help scientists be more confident in identifying a cause-and-effect relationship? Students should recognize that scientists repeat experiments with different people to ensure that the results are not just due to random chance. If the results are consistent across multiple trials, scientists can be more confident that the observed effect is real and not a fluke.
- Help students summarize what they have discovered about study design by reviewing the elements that contributed to the best design. The optimal study design settings and the true effect size are shown in the following screenshot from the simulation.



- Revisit the research question that began the activity, *Does playing Dapple increase well-being for kids in Salas?* If playing Dapple does increase well-being for kids, by how much? Students should respond that yes, the results show an increase in well-being from playing Dapple. Ask students to reflect on how the best study design impacted their confidence in this conclusion. Students should recognize that the best study design produced more reliable results by trying to avoid confounds and by using a large enough sample size to accurately measure the effect size.

7 Review student responses to Build Understanding items 1 and 2.

- Students can complete Build Understanding items 1 and 2 individually, in pairs, or in small groups. It is important to be sure that students' responses to item 1 indicate that they understand that larger sample sizes increase confidence by reducing random variation but do not eliminate confounds, so accuracy is not guaranteed. For item 2, responses should show that confounds create uncertainty about whether the treatment or another factor caused the effect. It may help to discuss that in Part C of the simulation, assigning groups by neighborhood may have made the control group seem to have higher well-being, not because they didn't play the game, but because they had more access to parks.
- Optional: If you discussed error bars with your students in Teaching Step 5, ask them how error bars and sample sizes are related. Show optional Visual Aid 7.3, "Example Results at Different Sample

Sizes,” again. Students should explain that larger sample sizes result in smaller error bars because they produce more consistent and reliable results, which leads to a narrower range of possible true values for the effect and increases confidence in the findings.

8 Assess student growth, using the Analyzing and Interpreting Data (AID) Scoring Guide for Build Understanding item 3.

- Remind students of the Analyzing and Interpreting Data Scoring Guide. You may wish to project Visual Aid 7.4, “Scoring Guide: Analyzing and Interpreting Data (AID),” for your students to review each level and clarify your expectations.
- Do not share the item-specific version of the Scoring Guide (Item-Specific Scoring Guide: Activity 7, Build Understanding Item 3) with students as it provides specific information on how to respond to the item prompt.
- Remind students that you expect to see them demonstrate growth in their understanding and explanation of analyzing and interpreting data and that they may want to review their responses to the assessment in Activity 4 (Build Understanding item 2). You may also want to let students know that they will have one more opportunity in the unit to be assessed (Activity 9, Build Understanding item 2).
- Sample responses for Levels 1–4 are provided in the Build Understanding section that follows. Review these responses to get an idea of what is expected for each level alongside the Item-Specific Scoring Guide. See [Appendix 2: Assessment Resource](#) at the end of the Teacher’s Guide for more guidance and information on using the Scoring Guides and assessment system with your students.
- Depending on your students, you may want to have them provide feedback on one another’s work for revision prior to turning in their work to you for scoring. Alternatively, consider having students turn in a rough draft to you for feedback and revision.

9 Revisit the Guiding Question for the activity.

Finish the activity by revisiting the Guiding Question, *How do changes in study design affect the results?* Use responses to this question to formatively assess students’ understanding of the key concepts and process skills related to experimental design such as sample size, effect size, and confounds.

SAMPLE STUDENT RESPONSES

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.

A bigger sample size would increase my confidence in the results because it helps reduce the random differences that can happen when only a few people are involved.

- b Does having a really big sample size guarantee that your results will be accurate? Why or why not?

A really big sample size doesn't guarantee accurate results because it does not get rid of confounds, other factors that could still affect the results.

- 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.

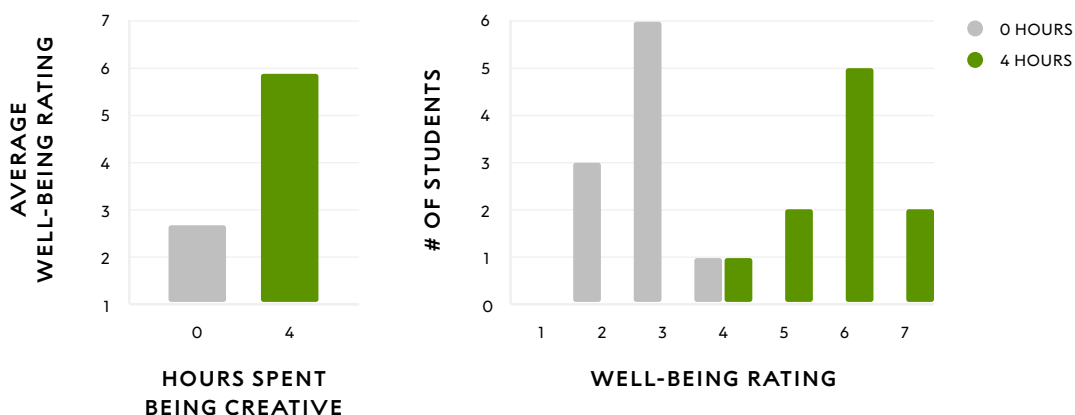
Confounding variables make it harder to interpret results because you can't tell if the difference between experimental and control groups is because of the treatment or because of the confounding variable. For example, when we studied the game in Part C of the simulation, the parks were a confound if you chose the groups by neighborhood. The control group could have had higher well-being than the experimental group, not because of the game but because they lived near the park and had more time to spend in green spaces.

- ③ AID Assessment

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 7.2.

FIGURE 7.3

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



- Does the data support the class's idea that creativity improves well-being? Why or why not?
- What elements of the study design could be improved? Explain how changing these elements would improve your confidence in the study results.
- 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?

Level 4 response

- The data does support their idea because almost all the students who spent time being creative rated their well-being much higher than those who didn't spend time being creative.*
- There are several elements that could be improved to increase my confidence in the study results. The sample size is small, and a bigger sample size would improve the study because if the results are similar with a bigger sample size, it's less likely that the results are from chance. Also, they didn't assign people randomly to groups, which means that students might have chosen something they prefer to do, and that could have affected their well-being. Third, they didn't get the participants' well-being ratings before the experiment, so they don't have any way to know if there is really an effect. Maybe the people with higher ratings already had high ratings (and vice versa).*
- Yes, I would change the study design by assigning people randomly to groups. I would also want a bigger sample size, but my class isn't very big, so I might see if I could get people from a couple of other classes to participate. I would also want to know what their well-being rating was before they started, so I could see if there really is an effect.*

Level 3 response

- a *The data does support their idea because the students who spent time being creative had a higher well-being.*
- b *There are elements that could be improved in the study design to increase confidence in the results. The sample sizes were small in both studies, and they didn't assign people randomly. This means their results might not be accurate.*
- c *I would assign people to groups randomly.*

Level 2 response

- a *The data does support their idea that being creative improves well-being.*
- b *The sample size was small, and they didn't assign people randomly.*
- c *More people.*

Level 1 response

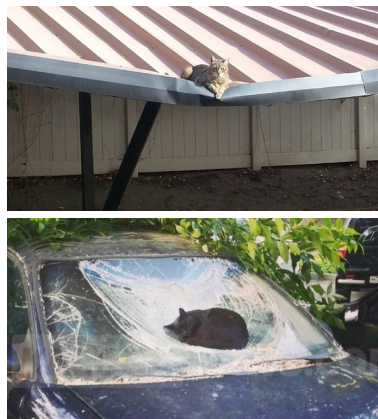
- a *The data supports being creative.*
- b *There was a small sample size.*
- c *I would change it.*

CONNECTIONS TO EVERYDAY LIFE

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



This keeps happening. Cats must be heavy!



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.

This meme doesn't show causation because the sample size is too small, and there is an alternative explanation. There are only three cats, and that's not enough to prove an association exists. Just because the cats are settled into those crushed spots doesn't mean that they caused them. There isn't a likely mechanism for how the cats could have caused the damage. Also, we don't know the timing, so an alternative explanation is that the structures were already crushed before the cats sat there. So, we can't say the cats caused the damage based on just these three examples.

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

It may be difficult if you have to take time to recruit and collect data from all the participants, and the researcher has limited time. Or if participants need to be paid, and there is limited money. Or if you want to study a specific demographic or disease, and there are not many people who fit the criteria for the study. Or if it requires an unpleasant treatment, and not many people are willing to try it even if it might ultimately help them.

REFERENCES

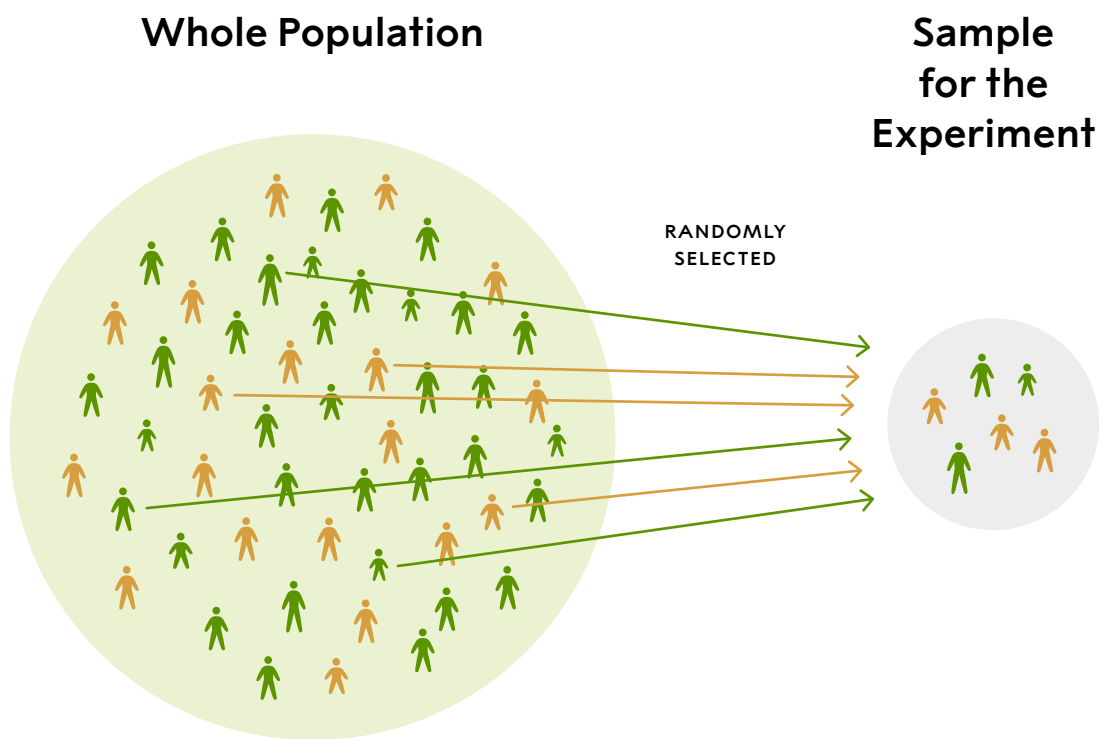
Fuller, S. [@Fuller_Si]. "This keeps happening. How heavy are cats?" X, April 30, 2021, https://x.com/fuller_si/status/1388106214324662272?mx=2

STUDY DESIGN	SAMPLE SIZE	EXPERIMENT GROUPS		ASSIGNMENT TO GROUP BY circle one	RESULTS draw bar chart	INTERPRETATION circle one of the bold words
		EXPERIMENTAL circle one	CONTROL circle one			
1		ONCE	NOT PLAYING	NEIGHBORHOOD		Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.
		ONCE A DAY FOR A WEEK	SIDELINES: WATCHING	COIN FLIP GRADE		
2		ONCE	NOT PLAYING	NEIGHBORHOOD		Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.
		ONCE A DAY FOR A WEEK	SIDELINES: WATCHING	COIN FLIP GRADE		
3		ONCE	NOT PLAYING	NEIGHBORHOOD		Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.
		ONCE A DAY FOR A WEEK	SIDELINES: WATCHING	COIN FLIP GRADE		

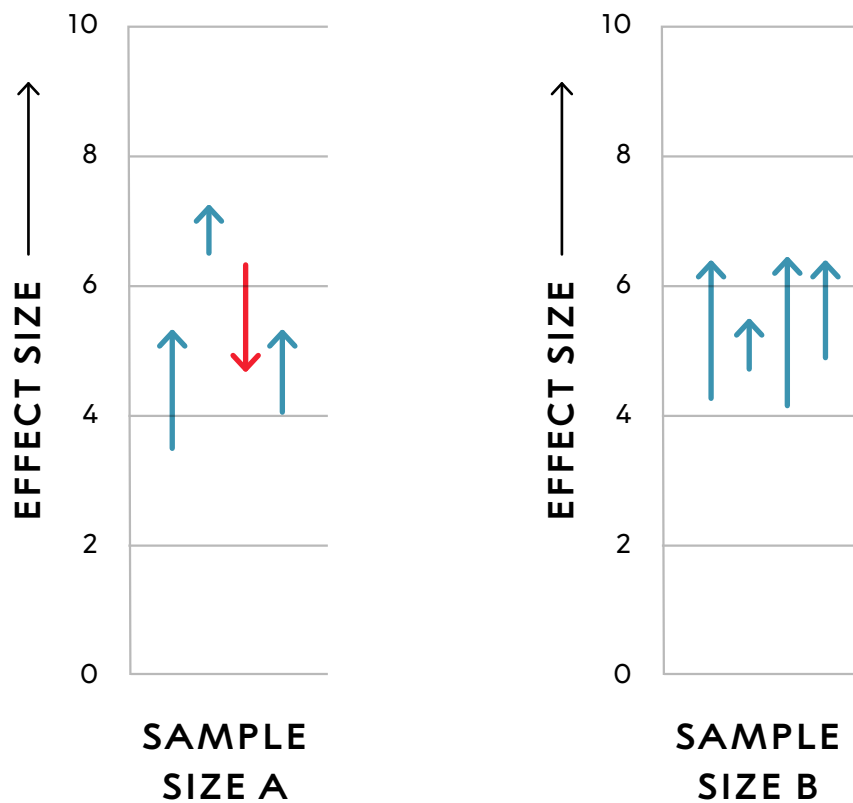
STUDY DESIGN	SAMPLE SIZE	EXPERIMENT GROUPS		ASSIGNMENT TO GROUP BY circle one	RESULTS draw bar chart	INTERPRETATION circle one of the bold words
		EXPERIMENTAL circle one	CONTROL circle one			
4		ONCE	NOT PLAYING	NEIGHBORHOOD		Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.
		ONCE A DAY FOR A WEEK	SIDELINES: WATCHING	COIN FLIP GRADE		
5		ONCE	NOT PLAYING	NEIGHBORHOOD		Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.
		ONCE A DAY FOR A WEEK	SIDELINES: WATCHING	COIN FLIP GRADE		
6		ONCE	NOT PLAYING	NEIGHBORHOOD		Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.
		ONCE A DAY FOR A WEEK	SIDELINES: WATCHING	COIN FLIP GRADE		

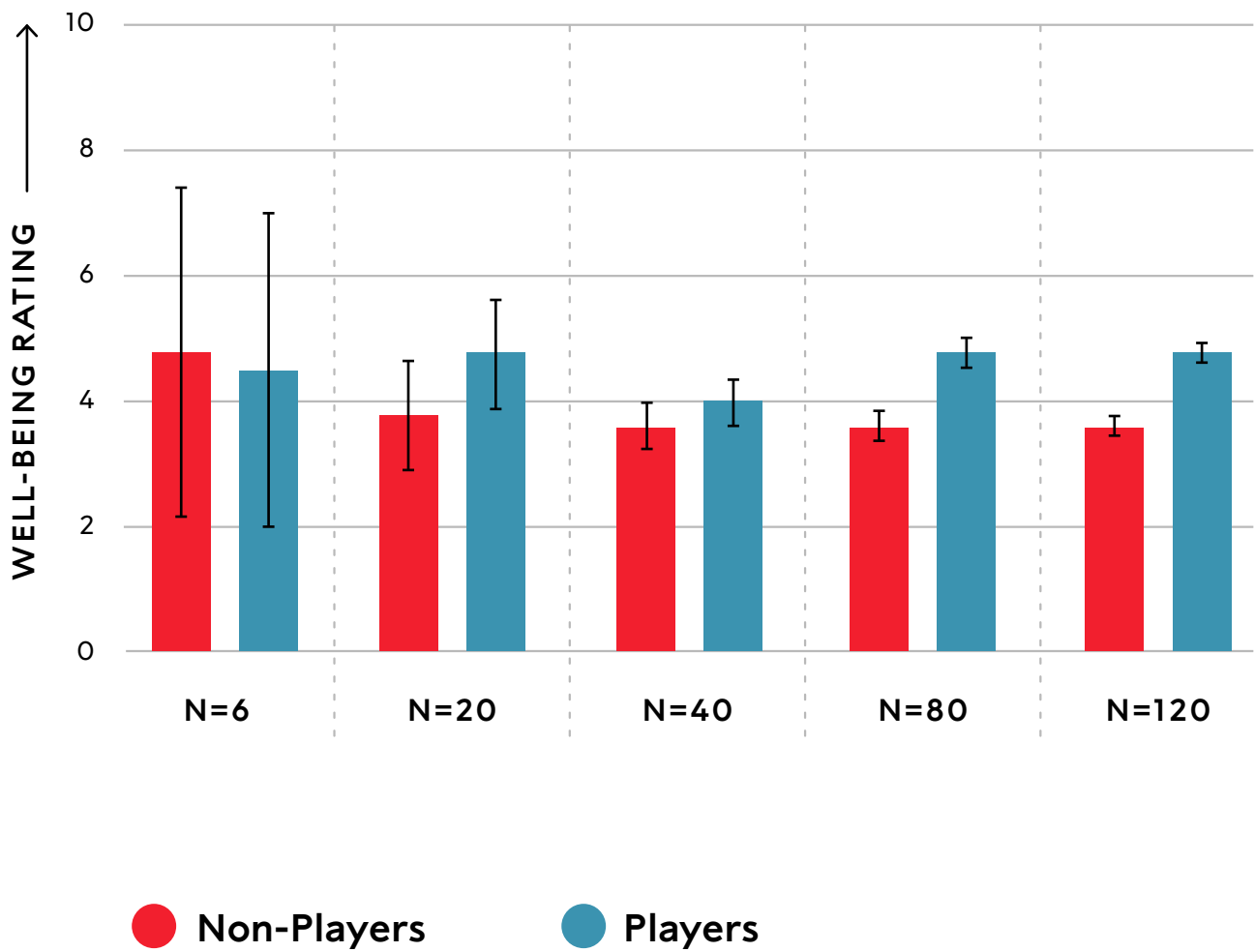
STUDY DESIGN	SAMPLE SIZE	EXPERIMENT GROUPS		ASSIGNMENT TO GROUP BY circle one	RESULTS draw bar chart	INTERPRETATION circle one of the bold words
		EXPERIMENTAL circle one	CONTROL circle one			
1	50	ONCE ONCE A DAY FOR A WEEK	NOT PLAYING SIDELINES: WATCHING	<i>confound</i> ↓ NEIGHBORHOOD COIN FLIP GRADE	WELL-BEING RATING NON-PLAYERS PLAYERS	Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.
2	120	ONCE ONCE A DAY FOR A WEEK	NOT PLAYING SIDELINES: WATCHING	<i>confound</i> ↓ NEIGHBORHOOD COIN FLIP GRADE	WELL-BEING RATING NON-PLAYERS PLAYERS	Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.
3	80	ONCE ONCE A DAY FOR A WEEK	NOT PLAYING SIDELINES: WATCHING ↑ <i>confound</i>	NEIGHBORHOOD COIN FLIP GRADE	WELL-BEING RATING NON-PLAYERS PLAYERS	Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.

STUDY DESIGN	SAMPLE SIZE	EXPERIMENT GROUPS		ASSIGNMENT TO GROUP BY circle one	RESULTS draw bar chart	INTERPRETATION circle one of the bold words
		EXPERIMENTAL circle one	CONTROL circle one			
4	8	ONCE ONCE A DAY FOR A WEEK	NOT PLAYING SIDELINES: WATCHING	NEIGHBORHOOD COIN FLIP GRADE	WELL-BEING RATING NON-PLAYERS PLAYERS	Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.
5	120	ONCE ONCE A DAY FOR A WEEK	NOT PLAYING SIDELINES: WATCHING ↑ confound	NEIGHBORHOOD COIN FLIP GRADE ↑ confound	WELL-BEING RATING NON-PLAYERS PLAYERS	Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.
★ 6	120	ONCE ONCE A DAY FOR A WEEK	NOT PLAYING SIDELINES: WATCHING	NEIGHBORHOOD COIN FLIP GRADE	WELL-BEING RATING NON-PLAYERS PLAYERS	Experimental group had LOWER EQUAL HIGHER well-being compared to the control group.



Which sample size, A or B,
shows more consistent results?





WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.

WHAT TO LOOK FOR:

- Response describes patterns and trends in data.
- Response interprets patterns and trends to describe possible causal relationships.

LEVEL	GENERAL DESCRIPTION
Level 4 Complete and correct	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data and interprets them completely and correctly to identify and describe relationships. When appropriate, the student: • makes distinctions between causation and correlation. • states how biases and errors may affect interpretation of the data. • states how study design impacts data interpretation.
Level 3 Almost there	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data BUT incorrectly and/or incompletely interprets them to identify and describe relationships.

LEVEL	GENERAL DESCRIPTION
Level 2 On the way	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes, BUT does not interpret, patterns and relationships.
Level 1 Getting started	The student attempts to analyze the data BUT does not use appropriate tools, techniques and/or reasoning to identify and describe patterns and relationships.
Level 0 Missing or off task	The student's analysis is missing, illegible, or irrelevant to the goal of the investigation.
X	The student had no opportunity to respond.

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.

WHAT TO LOOK FOR:

- Response describes patterns and trends in data.
- Response interprets patterns and trends to describe possible causal relationships.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 4 Complete and correct	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data and interprets them completely and correctly to identify and describe relationships. When appropriate, the student: • makes distinctions between causation and correlation. • states how biases and errors may affect interpretation of the data. • states how study design impacts data interpretation.	The student response: • describes the data as supportive and provides thorough reasoning. • lists and explains at least three limitations for the study. • lists and explains at least two changes they would make to the study design.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 3 Almost there	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data BUT incorrectly and/or incompletely interprets them to identify and describe relationships.	The student response: • describes the data as supportive and provides reasoning. • lists and explains at least two limitations for the study. • lists and explains at least one change they would make to the study design. The student response may have minor errors or limited responses related to: • reasoning. • limitations for studies.
Level 2 On the way	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes, BUT does not interpret, patterns and relationships.	The student response: • describes the data as supportive but provides limited or no reasoning. • lists at least two limitations but may not explain limitations. • lists at least one change they would make to the study design but may not explain. The student response may have several minor errors.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 1 Getting started	The student attempts to analyze the data BUT does not use appropriate tools, techniques, and/or reasoning to identify and describe patterns and relationships.	The student response: • describes the data as supportive but provides illogical or no reasoning. • lists at least one limitation but may not explain. • states if they would change the study or not but may not list or explain changes. The student response may have several errors.
Level 0 Missing or off task	The student's analysis is missing, illegible, or irrelevant to the goal of the investigation.	
X	The student had no opportunity to respond.	



ACTIVITY 8

Testing a Well-Being Strategy

LABORATORY

ACTIVITY 8

Testing a Well-Being Strategy

ACTIVITY SUMMARY

Students choose one of the four well-being strategies under consideration for Salas High School to test out in their classroom. First, they choose a strategy to investigate with a randomized controlled trial, and then they work as a class to generate a study design for a randomized control trial that can be conducted in the classroom. They run the experiment in their classroom and analyze the results. Finally, students compare their study design and results to those of a study on the same strategy published in a peer-reviewed scientific journal.

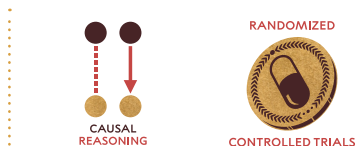
ACTIVITY TYPE
LABORATORY

NUMBER OF
40-50 MINUTE
CLASS PERIODS
2-3

KEY CONCEPTS & PROCESS SKILLS

- 1 Some effects are difficult to identify due to insufficient evidence, multiple causes, delayed effects, or confounding factors.
- 2 Incorrect conclusions about causation can happen when the result is due to an alternative explanation, such as chance or a confound. Careful study design and analysis can reduce the likelihood of the occurrence of alternative explanations.
- 3 Randomized controlled trials (RCTs) are the most reliable method for identifying cause-and-effect relationships because they reduce the likelihood that alternative factors are influencing the effect.

CONCEPTUAL
TOOLS



VOCABULARY DEVELOPMENT

randomized controlled trial (RCT)

an experiment in which participants are randomly assigned to an experimental group or a control group

TEACHER BACKGROUND INFORMATION

Randomized Controlled Trials

Randomized controlled trials (RCTs) are the gold standard in science for establishing strong evidence for causation. RCTs are designed to isolate the hypothesized causal variable to see if the hypothesized effect is different when the causal variable changes. They accomplish this through two essential features: first, a comparison between an experimental and a control group and second, randomized assignment of participants to the experimental or control group.

The purpose of randomized assignment is to prevent systematic differences between individuals assigned to the two groups. If not randomized, such differences can create confounding variables, which can lead to incorrect results. Without randomized assignment, there is a greater risk that pre-existing differences between the two groups (e.g., demographic, personality, or health-related factors) may affect the outcome, leading to biased results and incorrect conclusions about the effect of the independent variable. The purpose of a control group is to have a group against which to compare the experimental group. This allows researchers to be confident that any changes in the experimental group are due to the treatment and not to some other unconsidered variable (a confound, also referred to as a confounding variable).

Randomized Assignment

Some methods of assignment to groups in an experiment can create obvious confounds, but even a seemingly fair method of assignment can give rise to confounds. For example, assigning participants to a group by last name may lead to an overrepresentation of students of Arab descent in one group, because they are more likely to have names beginning with A, or an overrepresentation of students of Irish descent in the group with names beginning with O' or M. Due to this, scientists often use random number generators to randomize assignments. A common misconception is that random assignment is the same as random sampling (also referred to as random selection), which takes a sample representative of the larger population. However, random assignment only ensures that participants are evenly distributed between selected groups, not that the sample reflects the larger population. For more details about random sampling, see Teacher Background Information in Activity 7.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER — VISUAL AID 8.1 “Sample RCT Procedure” (OPTIONAL) — 8 SETS OF RCT SUMMARY CARDS (4 CARDS)	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”
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Review the suggestions in Teaching Step 3 that follows when students choose a classroom RCT for the activity. Some activities may not be appropriate for a classroom, so check in advance with school administrators and determine if there are any possible restrictions.

Prepare the RCT Summary cards in advance by copying sets of all 4 cards. While cards for all 4 well-being strategies are provided, only the card set for the class’s chosen well-being strategy will be handed out to each group in Part B, Procedure Step 10. Set aside the remaining 3 card sets as they will be used in Activity 10.

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (10 MIN)

1 Review the main concepts related to a randomized controlled trial (RCT).

- In Activity 7, students informally investigated the elements of a good study design through their exploration of the simulation. The Introduction for this activity builds on that by formally introducing the term *randomized controlled trial*, which was the type of study on which Activity 7 was based. Have students read the Introduction and clarify any questions they have about the definition of that term. Support students, particularly emerging multilingual learners, in sensemaking and language acquisition as they read the text. Circulate around the room and check in with students as they read to support them as they decode scientific ideas and construct meaning.
- Review why randomized controlled trials are a powerful way to study cause and effect. Remind students that correlations only show an association between two things but don't prove that one causes the other. Ask, **How do RCTs provide stronger evidence for cause and effect than studies that only identify correlations?** Students should be able to think back to Activity 7 and articulate that controlling for variables and randomly assigning people into groups reduces the chances of an alternative explanation for the experiment results, while a correlation does not. If the importance of RCTs in scientific research doesn't come up in the class discussion, bring up the following points:
 - Controlling for variables: RCTs help rule out alternative explanations for the results, keeping everything the same between the control group and the experimental group except for the treatment. Controlling all the other variables reduces the chance that the outcome is from a confound. Correlations only observe the two variables of interest, they don't control for other factors.
 - Randomized assignment: Assigning participants to groups randomly also reduces the chance of possible confounds by distributing any differences into both the control group and the experimental group.
 - If an effect appears in both groups, it may be due to a confound rather than the treatment itself; but if it appears only in the experimental group, it is more likely caused by the treatment.
- Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by adding to the word wall. Record the term *randomized controlled trial (RCT)* and provide an example as needed. For more information on a Word Wall, see [Appendix 1: Literacy Strategies](#).

PROCEDURE SUPPORT (40 MIN)

2 Facilitate the selection of one of the four well-being strategies to investigate as a class.

- Read the fictional scenario in Procedure Step 1 aloud with the class. Reading the scenario aloud can better support comprehension for many students, including neurodiverse students and emerging multilingual learners who often have more highly developed listening and oral skills than reading comprehension skills. Alternatively, students can read the scenario independently.
- In Procedure Step 2, help the class choose which of the four well-being strategies they will investigate. One suggested way to select the strategy is to begin by having students brainstorm in small groups. Ask, **Which of the strategies is the most interesting and practical to do in a classroom?** Have students talk amongst themselves as they consider all four strategies. Then, have students share their ideas with the class. Students' responses will vary depending on your school setting. After students share their ideas, narrow down the choice by either consensus or vote.

3 Groups brainstorm and select a treatment for the class to test.

- In Procedure Steps 3–4, support student ideation of a study design. As students consider ideas in their small groups, circulate around the room and encourage students to think concretely about the elements of the study they imagine. It may help to inform students that the descriptions for each well-being strategy (in Procedure Step 2) are examples of treatments—for instance, a school garden, regular visits to a park, or adding more plants around campus are all examples of treatment ideas for the Green Spaces strategy. Students should be able to describe a treatment and how they would decide who will be in which group. At this stage, do not share (or ask about) the suggested control conditions listed for each treatment, as students will work through this in Procedure Step 5 when they are in their small groups. The following ideas for treatments can be offered for inspiration.

Gratitude Writing

1 EXPERIMENTAL GROUP

Write three things for which you are grateful.

CONTROL GROUP

Write three things that have happened recently.

2 EXPERIMENTAL GROUP

Write a letter to someone in the class for whom you are grateful and give it to them.

CONTROL GROUP

Write a letter to a friend about something general and give it to them.

3 EXPERIMENTAL GROUP

Write an email to someone not in your class for whom you are grateful and send it to them.

CONTROL GROUP

Play a computer or phone game or work on homework.

School Therapy Dog

1 EXPERIMENTAL GROUP

Watch a video of cute dogs for 10 minutes.

CONTROL GROUP

Play a computer game or work on homework.

2 EXPERIMENTAL GROUP

Have someone bring in a friendly dog for students to play with.

CONTROL GROUP

Students are not allowed to play with the dog, but they may watch.

NOTE: This could create a confound as students who are not allowed to touch the dog may be disappointed.

School Garden

1 EXPERIMENTAL GROUP

Go outside to the area of the school grounds with the most nature and sit there for 10 minutes.

CONTROL GROUP

Remain inside the classroom.

2 EXPERIMENTAL GROUP

Watch a nature video for 10 minutes.

CONTROL GROUP

Watch a video of a cityscape.

3 EXPERIMENTAL GROUP

Examine a plant, interesting branch, or shoebox filled with natural objects for 8 minutes.

CONTROL GROUP

Examine a box with simple human-made objects.

Later School Start Time

1 EXPERIMENTAL GROUP

Half the students in the class go to bed earlier than they normally would for 1 night. The next day, follow up with data collection on mood and alertness, using self-reported ratings from 1 to 5.

CONTROL GROUP

The other half of the class goes to bed when they normally do.

2 EXPERIMENTAL GROUP

Allow a 15-minute nap on desks, with lights dimmed.

CONTROL GROUP

Spend the time quietly doing homework or playing on their computers.

- Once students have discussed and brainstormed treatment ideas in their small groups, have groups share their ideas with the class. As a class, evaluate the options and agree on one treatment to test. Help students choose a treatment that is a version of the strategy, could easily be done in the classroom, and is likely to have an effect.

Sample Group Response, Procedure Step 4

Our group was thinking that for the experimental group for gratitude writing, we could have students write a letter to a friend and give it to them. Another idea for a treatment is to have students just write in a journal about things they are grateful for.

- For students with learning disabilities and neurodiverse learners, provide targeted support. Adapt the selection of the strategy to best suit the needs of your particular students. Consider providing the suggested lists of treatments to choose from, or select one yourself. Students who need more time processing language (such as students with dyslexia) can be provided with these suggestions in advance of the day's activity.

4 Groups propose study designs for the classroom RCT.

- In Procedure Step 4, hand out Student Sheet 8.1, “Experimental Design of RCTs.” Once the class agrees on a general idea for a treatment, each group designs a study to test its effects.
- In Procedure Step 5, you might want to quickly review the following design elements to help students before they create their study designs:

Hypothesis

The class should come to a consensus on the hypothesis—what they think the results will show.

Sample Size

The sample size is usually the size of the class, with students as participants.

NOTE: If you are running this activity in multiple classes, you may wish to combine the data from all your classes to obtain a larger sample size.

Method of Assignment to Group

Assignment should be random (e.g., by coin flip). Some students might suggest nonrandom methods of assignment, such as by choice or by class. Encourage students to consider weaknesses of this method and to recall the simulation from Activity 7 in which this was addressed.

Experimental Group

Although the class should have come to a consensus on a general treatment in Procedure Step 4, students may develop more details in order to make it easier or more likely to show an effect. Encourage students to consider details that may impact the results of the experiment. For instance, the duration of the treatment (such as watching a 30-second pet video vs. a 5-minute pet video) and the intensity of the treatment (such as writing 1 thing vs. 10 things you are grateful for) can

both influence outcomes.

Control Group

Encourage students to consider whether their control might give rise to confounds. It may not be possible to come up with a control that eliminates all possible confounds, and this is acceptable. The point is to get students to come up with the best control they can.

Measurement of Effect

The most straightforward way to measure an effect is with a self-reporting rating scale from 0 to 10. For example, the scale might include a prompt such as *What is your mood?* with responses identified as 0 = terrible mood, 5 = neutral mood, 10 = excellent mood. Some students might begin to consider how they will analyze and average their data; if not, these details can be addressed later as a class in Procedure Step 6.

Possible Confounds

Noticing confounds may help students improve other aspects of their study designs: adjusting treatments, control groups, and/or method of assignment to the control and experimental groups.

- Have students record their design ideas in the “Group Proposal” column on the student sheet.

5 The class combines the best ideas into one experimental design, performs the classroom RCT, and analyzes the data.

- In Procedure Step 6, hold a class discussion to review each group’s study design proposal from Student Sheet 8.1. Come to consensus on the RCT procedures the class will conduct by combining the best elements from their designs. At this point, you may need to address specific details in the experimental procedures that students have not yet addressed (such as treatment duration or how measurements will be made). Have students record the consensus study design in the “Classroom RCT” column on the student sheet. To ensure that all participants are doing the same thing during the experiment, consider writing the treatment procedure on the board for students to follow.
- Depending on your students, you may want to provide an advance copy of the finalized procedure and conduct the experiment the next day so students can preread it. Alternatively, you may want to have students write a more detailed procedure for the chosen classroom RCT idea on the back of the student sheet. A sample procedure is shown on optional Visual Aid 8.1, “Sample RCT Procedure.”
- In Procedure Step 7, groups conduct and record the data from the class experiment. Analysis and results will vary depending on the RCT the class designs. The following tables show an example of class data for one possible RCT.

Example of Class Data, Procedure Step 7

CONTROL GROUP

Mood Rating (0 to 10)

STUDENT	BEFORE	AFTER	DIFFERENCE (POST - PRE)
1	5	5	0
2	4	8	4
3	6	5	-1
4	4	4	0
5	5	6	1
6	5	5	0
7	5	6	1
8	6	6	0
9	5	5	0
10	5	4	-1
Average Difference =			0.40

EXPERIMENTAL GROUP

Mood Rating (0 to 10)

STUDENT	BEFORE	AFTER	DIFFERENCE (POST - PRE)
1	5	7	2
2	4	4	0
3	3	5	2
4	5	6	1
5	5	8	3
6	4	9	5
7	5	7	2
8	6	5	-1
9	5	6	1
Average Difference =			1.67

- As students interpret the results, facilitate a discussion about whether the results support their hypotheses. Students may find that the difference between the two groups may be small, since the treatment is not very strong. If there is no difference between groups, or if the difference is in the opposite of the expected direction, discuss the possible reasons for this. Ask, **Why do you think the hypothesis was not supported, and do you think this means that the well-being strategy is ineffective?** Student responses may vary. Students may feel that the hypothesis was wrong, the treatment duration or the treatment intensity was too low, the sample size was too small to detect a real effect, or the strategy itself was not very effective. Remind students that a negative result for a single experiment does not necessarily mean that the strategy is not effective; it just means that more investigation is needed.

6 In Part B, compare groups' results with a summary of a published RCT.

- In Procedure Step 10, give each group the RCT Summary card that matches the well-being strategy your class chose to investigate. Point out that the information in the summary is from a peer-reviewed scientific journal. **Support students, particularly emerging multilingual learners, in sensemaking and language acquisition as they read the text. Circulate around the room and check in with students as they decode the scientific ideas and construct meaning as they read.**

- Support students as they work in pairs to complete the “Published RCT” column of the table on Student Sheet 8.1. A sample completed student sheet is shown at the end of this activity.
- For Procedure Steps 12 and 13, students should come up with similar observations when they compare the classroom RCT to the published RCT. Ask, **What are the differences between the classroom RCT and the published RCT, and what are the possible reasons for these differences?** Students are likely to observe that the published RCT had the following differences:
 - a larger sample size
 - stronger or different treatments
 - control groups with fewer possible confounds
 - potentially a wider array of effect measurements

Students are likely to suggest that these differences may be due to a longer time frame, a larger sample size, and/or more resources for the published RCTs. This makes it likely that the published RCTs are more reliable and have fewer confounds. Responses will vary, but one sample response follows:

Sample Student Response, Procedure Step 13

Our classroom RCT for gratitude writing was much shorter than the published study—ours lasted just 1 day, while theirs went on for 10 weeks. That could matter because happiness might change over time. Also, the published study had 129 college students, but we only had 29 sophomores from the same school. A bigger sample with lots of different people might make the results more reliable. Another big difference was the control groups. In the published study, people wrote about annoying things, which could have made them feel worse. Our control group just wrote journal entries, so they weren’t focused on negative things. That could explain why our results were different.

SYNTHESIS OF IDEAS (20 MIN)

7 Connect what students have learned in this activity with their previous knowledge about evidence for cause and effect.

- Have students reflect on both the RCT they created and the RCT summary from the published study. Remind students that asking about alternative explanations is one of the questions about causation that can help to evaluate cause-and-effect relationships. Ask, **How do RCTs prevent alternative explanations?** Students should respond in a way that shows they understand that by design, the only difference between the experimental and control groups is the treatment itself. Review how this is done through random assignment, which helps balance out other factors that could influence the results, and by using control groups to compare outcomes. By keeping all other conditions the same, RCTs make it more likely that any differences in results are caused by the treatment rather than by other variables.

- Another major point that helps explain why RCTs provide such reliable evidence is because they address the other three questions about causation previously brought up in this unit. Ask, **Do RCTs offer evidence to answer the other three questions about causation?** Students should be able to recall that the three questions relate to indicators of causation: timing, association, and mechanism. Students should respond that, yes, RCTs do provide evidence that supports the indicators, at least for timing and association, but possibly not for mechanism. You may want to go through the indicators individually and emphasize the following points:

- **Timing**

By controlling when the treatment changes and when the effect is measured, RCTs control timing.

- **Association**

If the results for the experimental and control groups in an RCT are different, that shows an association between the treatment and the effect.

- **Mechanism**

RCTs do *not* generally offer evidence about mechanisms, unless the possible mechanisms are also measured or changed.

- Finish the activity by revisiting the Guiding Question, *How do you design a randomized controlled trial?* Use responses to this question to formatively assess students' understanding of the key concepts and process skills related to the design of these kinds of experiments.

EXTENSION (10 MIN)

8 Use the Extension as an opportunity for advanced learning.

Students should be able to connect the structure of the RCT they ran in their class to the structure of an RCT used to test a new medication. All RCTs should include the components discussed in this activity. Have students choose a medication or treatment they are interested in. It can be something recently approved by the FDA, such as GLP-1 medications, a new gene therapy for sickle cell anemia, the mRNA-based COVID-19 vaccine, or groundbreaking medications approved years ago, such as penicillin, aspirin, or oxycontin. Students may also choose to research and present how these medications have impacted health and well-being over time or how they could impact health and well-being in the future.

For this extension, you may need to explain the term *placebo*, which is commonly used in RCTs that test medications. A placebo is a treatment that looks the same as the real medication but has no actual effect, such as a sugar pill. A placebo is used to prevent participants from knowing whether they're in the control group or the experimental group. The placebo effect occurs when the treatment has no real effect, and participants feel better simply because they believe they are receiving a treatment. This can create a potential confound.

SAMPLE STUDENT RESPONSES

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.

One way we could improve our study is by testing more people in different places. Our class only had 29 students, so the sample size was small. If we included more teenagers from different schools and backgrounds, the results would be more reliable. Another improvement would be testing people separately or in different rooms. Since we only had one room, the control group could see what the experimental group was doing, which might have influenced their responses. Also, we could have measured well-being in more ways and over a longer time. Instead of just asking about mood, we could have also measured stress levels or even heart rate to get a physical measure. Lastly, tracking results over one week instead of just one day could show if the effect lasts or is stronger.

- 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 only 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

RCTs are stronger than correlation studies because of the way they are designed.

- a **Timing:** *In a correlation study, two things might change together, but you don't know which one came first. In an RCT, researchers make sure the possible cause happens before measuring the effect (timing).*
- b **Association:** *Both types of studies show associations but in different ways—correlation studies show it by measuring the strength of a relationship, while RCTs compare differences between groups.*
- c **Mechanism:** *While RCTs can confirm whether a treatment causes an effect, they don't always explain the mechanism, so we might not fully understand why the effect happens. Correlation studies can suggest ideas, but RCTs give stronger evidence of cause and effect.*
- d **Alternative explanations:** *RCTs use random assignment and control conditions to make the treatment the only difference between groups. This helps rule out alternative explanations, like a hidden factor causing the results.*

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.

I would recommend they take Medicine B, which was tested using a randomized controlled trial (RCT) because it's a better way to know if it's effective. Correlation only shows that two things are related, but it doesn't prove that one causes the other.

- 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?

It is important to make sure the medicine actually works and is safe. Just because people take the medicine and feel better doesn't mean the medicine caused it. An RCT makes sure the medicine is tested in a way that shows cause and effect, not just a coincidence.

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

So you know if people in the experimental group (the ones who get the medicine) improve more than people in the control group. Sometimes people get better without medicine, or because they think they got medicine.

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

It helps make sure the two groups are as similar as possible. If people got to pick their group, or if one group had more sick people in it than the other, it could mess up the results.

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Well-Being Strategy: _____

Treatment: _____

STUDY DESIGN	GROUP PROPOSAL	CLASSROOM RCT	PUBLISHED RCT
a Hypothesis			
b Sample Size			
c Method of Assignment to Group			
d Experimental Group			
e Control Group			
f Measurement of Effect			
g Possible Confounds			
Results			

Well-Being Strategy: Gratitude WritingTreatment: Letter to a classmate

STUDY DESIGN	GROUP PROPOSAL	CLASSROOM RCT	PUBLISHED RCT
a Hypothesis	<i>Writing about things you're grateful for will cheer up people.</i>	<i>People who write gratitude letters will be happier and have more life satisfaction.</i>	<i>Participants who write in a gratitude journal for 10 weeks will be happier than those who write about annoyances.</i>
b Sample Size	<i>30 kids in our class</i>	<i>The 29 students here today: 15 girls and 14 boys, all sophomores</i>	<i>129 college students</i>
c Method of Assignment to Group	<i>by choice</i>	<i>by coin flip</i>	<i>random assignment</i>
d Experimental Group	<i>Write 3 things you were grateful for this week.</i>	<i>Write a gratitude letter to someone in the class and read it to them.</i>	<i>Once a week, wrote 5 things they were grateful for.</i>
e Control Group	<i>Write three things that happened this week.</i>	<i>Write a journal entry just for yourself.</i>	<i>Once a week, wrote 5 things that were annoying to them.</i>
f Measurement of Effect	<i>Ask people their mood.</i>	<i>Ask people to rate their mood on a scale from 1 to 5 (1 = miserable, 5 = great).</i>	<i>Rating questions about gratitude, emotion, life satisfaction, and expected life satisfaction.</i>
g Possible Confounds	<i>Maybe people who are already happy might be more likely to choose the gratitude group.</i>	<i>Maybe writing to yourself is more frustrating than writing to someone else.</i>	<i>Writing about something annoying could make you less happy and less grateful.</i>
Results		<i>Students who wrote gratitude letters wound up in a better mood than those who didn't.</i>	<i>Participants who wrote in a gratitude journal for 10 weeks were happier than those who wrote about annoyances.</i>

Well-Being Strategy: Pet TherapyTreatment: Cute animal video

STUDY DESIGN	GROUP PROPOSAL	CLASSROOM RCT	PUBLISHED RCT
a Hypothesis	<i>Seeing animals will cheer up people.</i>	<i>People who watch the animal videos will be in a better mood than people who did their homework.</i>	<i>Participants who spend time with dogs will be less stressed and homesick than those who don't.</i>
b Sample Size	<i>30 kids in our class</i>	<i>The 29 students here today: 15 girls and 14 boys, all sophomores</i>	<i>163 American college students</i>
c Method of Assignment to Group	<i>by choice</i>	<i>by coin flip</i>	<i>random assignment</i>
d Experimental Group	<i>Watch a 5-minute cute animal video.</i>	<i>Watch cute animal videos for 10 minutes.</i>	<i>Spent 20 minutes with a therapy dog.</i>
e Control Group	<i>Watch whatever videos they want for 5 minutes.</i>	<i>10 minutes of quiet homework time.</i>	<i>Spent 20 minutes studying as usual.</i>
f Measurement of Effect	<i>Ask people their mood before and after.</i>	<i>Ask people to rate their mood on a scale from 1 to 5 (1 = miserable, 5 = great).</i>	<i>Self-reported stress, homesickness, and a sense of belonging before and after.</i>
g Possible Confounds	<i>Maybe people in the control group watched something else that was more fun.</i>	<i>Maybe doing the homework is stressful and makes people less happy.</i>	<i>Maybe just getting a break from normal schoolwork is relaxing.</i>
Results		<i>Watching the video was associated with a better mood than doing homework.</i>	<i>Participants who played with dogs decreased stress and homesickness and felt an increased sense of belonging.</i>

Well-Being Strategy: Quality SleepTreatment: Taking a nap

STUDY DESIGN	GROUP PROPOSAL	CLASSROOM RCT	PUBLISHED RCT
a Hypothesis	<i>Sleeping more will make people feel more alert and happier.</i>	<i>People who nap will be in a better mood and more alert.</i>	<i>Participants who nap will be more patient and attentive, with better well-being.</i>
b Sample Size	<i>30 kids in our class</i>	<i>The 29 students here today: 15 girls and 14 boys, all sophomores</i>	<i>452 low-income urban workers in Chennai, India.</i>
c Method of Assignment to Group	<i>by choice</i>	<i>by coin flip</i>	<i>random assignment</i>
d Experimental Group	<i>Sleep 1 extra hour.</i>	<i>Nap on a desk for 15 minutes.</i>	<i>Took a 30-minute nap during the day in a quiet office once a day for 3 weeks.</i>
e Control Group	<i>Go to sleep 1 hour later than usual.</i>	<i>Work quietly for 15 minutes.</i>	<i>Did not take a nap in a quiet office.</i>
f Measurement of Effect	<i>Ask people their mood.</i>	<i>Ask people to rate their mood on a scale from 0 to 10 (0 = miserable, 10 = great).</i>	<i>Questionnaire about well-being and a data-entry task to measure attention.</i>
g Possible Confounds	<i>Maybe people in the control group spent their extra time awake and reading stressful news.</i>	<i>Maybe doing the work is stressful and makes people less happy.</i>	<i>Perhaps access to the quiet office, rather than the nap, made the experimental group feel special and relaxed.</i>
Results		<i>People who took naps wound up in a better mood than those who did work.</i>	<i>Participants who napped reported higher well-being and showed more patience and attentiveness.</i>

Well-Being Strategy: Green SpacesTreatment: Watching a nature video

STUDY DESIGN	GROUP PROPOSAL	CLASSROOM RCT	PUBLISHED RCT
a Hypothesis	<i>Taking a hike will leave people feeling more peaceful and happy.</i>	<i>People who just watched a nature video will be in a better mood than people who watched a city video.</i>	<i>Participants who walk through nature will have more positive emotions and be better able to reflect than city walkers.</i>
b Sample Size	<i>30 kids in our class</i>	<i>The 29 students here today: 15 girls and 14 boys, all sophomores</i>	<i>76 college students</i>
c Method of Assignment to Group	<i>by choice</i>	<i>by coin flip</i>	<i>random assignment</i>
d Experimental Group	<i>Take a hike in the woods.</i>	<i>Watch a nature video.</i>	<i>Walked through a nature preserve.</i>
e Control Group	<i>Walk around campus.</i>	<i>Watch a city video.</i>	<i>Walked through a quiet urban setting.</i>
f Measurement of Effect	<i>Ask people their mood.</i>	<i>Ask people to rate their mood on a scale from 0 to 10 (0 = miserable, 10 = great).</i>	<i>Rating questions about positive emotions, ability to reflect, connection to nature.</i>
g Possible Confounds	<i>Maybe people in the control group have bad memories from campus, but the woods are a new place.</i>	<i>Maybe watching the city video is stressful because of all the cars and noise.</i>	<i>The urban walk could have stressed out participants with all the cars and noise.</i>
Results		<i>Watching the nature video was associated with a better mood than watching the city video.</i>	<i>Participants who walked in nature had more positive emotions and greater ability to reflect than urban walkers.</i>

Experiment Protocol: Testing the effects of gratitude letters on well-being

Materials Needed

- PAPER OR DIGITAL DOCUMENT FOR WRITING
- PENS OR PENCILS (if writing by hand)
- PRE-EXPERIMENT AND POST-EXPERIMENT MOOD-RATING SURVEYS
- COIN FOR RANDOM GROUP ASSIGNMENT

Procedure

1 Assign Participants to Groups

- The 29 students in class today (15 girls, 14 boys, all sophomores) will participate.
- Each student will flip a coin:
 - Heads = assigned to the gratitude-letter group (experimental group)
 - Tails = assigned to the journal-writing group (control group)

2 Pre-Experiment Mood Rating

Before starting the activity, all participants use the pre-experiment mood-rating survey to rate their mood on a scale from 1 to 5:

- 1 = MISERABLE
- 2 = NOT GREAT
- 3 = NEUTRAL
- 4 = PRETTY GOOD
- 5 = GREAT

Participants should be honest in their mood ratings.

3 Writing Task

- Experimental Group (gratitude letter):
 - Write a letter to another participant in the class expressing appreciation for them.
 - Read the letter aloud to the person.
- Control Group (journal entry):
 - Write a journal entry about anything on their mind.
 - The entry will not be shared with anyone.

4 Post-Experiment Mood Rating

After completing the writing task, all participants will use the post-experiment mood-rating survey to record their mood on the same scale as in Step 2.

5 Data Collection and Analysis

- Participants' pre-experiment and post-experiment mood ratings will be compared.
- The class will look for differences in mood changes between the experimental group (gratitude letter) and the control group (journal writing).
- Calculate and graph the difference in scores for each group, using the following:

$$\text{SCORE DIFFERENCE} = \text{AVERAGE POST-TREATMENT MOOD RATING} - \text{AVERAGE PRE-TREATMENT MOOD RATING}$$



RCT SUMMARY

Gratitude Writing

STUDY DESIGN

- **Participants:** 129 college students
- **Assignment randomly into 2 groups:**
 - Experimental Group:** Once a week, participants wrote 5 things they were grateful for.
 - Control Group:** Once a week, participants wrote 5 things that were annoying to them.
- **Measurement:** After 10 weeks, all participants answered questions about their gratitude, emotions, life satisfaction, and expected life satisfaction.

STUDY RESULTS

Compared to the control group, participants in the experimental group reported 1) higher gratitude levels, 2) higher life satisfaction overall, 3) higher expected life satisfaction for the upcoming week, and 4) more positive emotions.



RCT SUMMARY

Pet Therapy

STUDY DESIGN

- **Participants:** Sample size of 163 college students from the United States.
- **Assignment randomly into 2 groups:**
 - Experimental Group:** Participants had 20 minutes interacting with a trained therapy dog.
 - Control Group:** Participants had 20 minutes of studying.
- **Measurement:** All participants completed a survey before and after the 20 minutes. Afterward, they rated their stress, homesickness, and sense of belonging at school.

STUDY RESULTS

Participants in the control group showed no change in their stress levels. However, participants in the experimental group reported 1) less stress and homesickness and 2) a stronger sense of belonging at school after spending time with a therapy dog.



RCT SUMMARY

Quality Sleep

STUDY DESIGN

- **Participants:** 452 adults from a low-income urban area in Chennai, India, who slept an average of only 5.6 hours a night, even though they spent nearly 8 hours in bed.
- **Assignment randomly into 2 groups:**
 - Experimental Group:** Participants took a 30-minute nap during the day in a quiet office once a day for 3 weeks.
 - Control Group:** Participants did not take a nap.
- **Measurement:** Participants completed questionnaires about their physical and mental well-being. To measure attention, researchers observed how focused participants were while doing a data-entry task at work. Participants also answered survey questions about their level of patience.

STUDY RESULTS

Participants in the experimental group who took naps had significantly better 1) psychological well-being, 2) patience, and 3) attention at work as compared with participants in the control group who did not take naps.



RCT SUMMARY

Green Spaces

STUDY DESIGN

- **Participants:** 76 college students in a town in the Midwestern United States.
- **Assignment randomly into 2 groups:**
 - Experimental Group:** Participants took a 10-minute walk through a nature preserve with woods and a river and stopped at a creek in the woods.
 - Control Group:** Participants took a 10-minute walk through an urban area with cars and buildings, ending at a quiet concrete area next to a parking lot.
- **Measurement:** Both groups were asked to think about a small problem in their lives (such as finding time to study for a test) and not talk to one another during the 10-minute walk. After the walk, all participants completed a survey to rate their emotions, ability to reflect, and connection to nature.

STUDY RESULTS

On average, participants in the experimental group reported 1) slightly more positive emotions, 2) a better ability to reflect, and 3) a stronger connection to nature as compared with participants in the control group who were not in nature.



ACTIVITY 9

Evaluating Randomized Controlled Trials

DATA ANALYSIS

ACTIVITY 9

Evaluating Randomized Controlled Trials

ACTIVITY SUMMARY

Groups analyze short summaries of peer-reviewed randomized controlled trials (RCTs) related to the four well-being strategies being considered for Salas High School. Students examine key characteristics of each study, such as effect size, consistency across different settings, and sample size, to assess their confidence in the results. This prepares students for the final activity in which they will examine the data they have collected over the course of the unit to help them determine the best well-being strategy for Salas High School.

ACTIVITY TYPE
DATA ANALYSIS

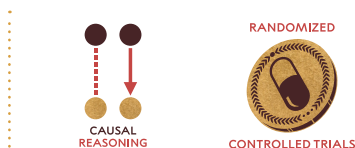
NUMBER OF
40-50 MINUTE
CLASS PERIODS
2

KEY CONCEPTS & PROCESS SKILLS

- 1 Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.
- 2 Randomized controlled trials (RCTs) are the most reliable method for identifying cause-and-effect relationships because they reduce the likelihood that alternative factors are influencing the effect.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:

Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. (Science and Engineering Practice: Analyzing and Interpreting Data)

CONCEPTUAL
TOOLS

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 1.3
“Proposed Well-Being Strategies for Salas High School”
(OPTIONAL)
- VISUAL AID 6.2
“Study Design Elements and Analysis Methods”
(OPTIONAL)
- VISUAL AID 9.1
“Scoring Guide: Analyzing and Interpreting Data (AID)”
- ITEM-SPECIFIC SCORING GUIDE:
Activity 9, Build Understanding Item 2

FOR EACH STUDENT

- STUDENT SHEET 9.1
“Comparing RCTs Related to the Well-Being Strategies”
- STUDENT SHEET 1.2
“Unit Concepts and Skills”
(OPTIONAL)
- SCORING GUIDE:
Analyzing and Interpreting Data (AID)
(OPTIONAL)

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (10 MIN)

1 Remind students of the key features of a well-designed study.

- Let students know that after designing and testing their own randomized controlled trial (RCT) for one of the proposed well-being strategies, they will now evaluate data from published RCTs for all four strategies. This will help them decide which strategy Salas High School should choose. Emphasize that using the published RCT evidence to make this decision depends on understanding what makes a research study strong and reliable.
- Have students read the Introduction in the Student Book, either as a class or individually. For students who need more reading support, consider having students share the reading responsibilities within a group of four. One pair completes the first paragraph and shares the information with the other pair who then completes the second paragraph. Then the group of four works together to summarize both paragraphs.
- Ask, **What are the design elements that can make you more sure that the results are accurate?** Encourage students to consider the progression of what they have learned about RCTs in the previous activities and from the Introduction they just read. Students should be able to answer this question by offering the main ideas from previous Activities 6–8. As students respond to the prompt, make a list on the board for students to refer to during the activity. Alternatively, you may wish to display optional Visual Aid 6.2, “Study Design Elements and Analysis Methods” as you review the concepts. Make sure the following main ideas are included:
 - A large sample size makes it less likely that the results are from random chance.
 - Testing a variety of groups and settings provides a way to determine if the results are consistent.
 - Controlling as many variables as possible makes it more likely that the result is not from a variable other than the one you are testing. It helps to prevent confounds.
 - A larger effect size shows a stronger association between variables, indicating it is less likely that the results happened by chance.
 - Your target group is the group you want to learn about. If you test a different group, the results might not be the same for your target group (the results may not apply to who you want to study or treat).

PROCEDURE SUPPORT (30 MIN)

2 Introduce students to the studies they will analyze.

- Have students read the fictional scenario presented in Procedure Step 1. Reading the scenario aloud can better support comprehension for many students, including neurodiverse students and emerging multilingual learners who often have more highly developed listening and oral skills than reading comprehension skills. Alternatively, students can read the scenario independently.
- If it would be helpful for your students, consider reviewing the list of four possible strategies to improve well-being shown on optional Visual Aid 1.3, “Proposed Well-Being Strategies for Salas High School,” to remind students of the strategies that the Salas High School Task Force is considering.
- In Procedure Step 2, assign a different RCT study (A, B, C, or D) to each student in a group of four. Let students know that these four RCT studies correspond to one of the well-being strategies being considered by Salas High School. Have students rearrange their groups so they are sitting with three other students who were assigned to the same RCT study. Each student in these new groups will become an expert on one of the four RCT studies.
- Facilitate the engagement of students with learning disabilities and neurodiverse learners by providing targeted support for the text in the studies. Consider how to best adapt the activity to meet the needs of your particular students. Students who need more time processing language (such as students with dyslexia) can be provided with the four study summaries in advance of the day’s activity.

3 Jigsaw groups to compare across RCT studies.

- In Procedure Step 3, hand out Student Sheet 9.1, “Comparing RCTs Related to the Well-Being Strategies.” Students work in their expert groups to read and complete Section 1 on Student Sheet 9.1 for their assigned RCT. For students who need more support reading the RCTs, have students divide into pairs and preread them. They can describe the RCT summary by using whatever modality is most comfortable, such as verbal (story) or visual (drawing). If there is time, students could find a generic picture on the Internet that matches each description. Alternatively, you can model the process of analyzing the text and work through Student Sheet 9.1 together as a class. Consider providing an example to help students recognize each study design element or analysis method listed in the first column of the Student Sheet.
- In Procedure Step 4, after expert groups have worked together to analyze their RCTs, students will return to their original groups. Each original group should now have at least one expert for each of the four RCT studies so group members can share one another’s findings as they complete Section 1 for all four studies on Student Sheet 9.1. This “jigsaw” approach increases students’ access to the information as they analyze the four RCT studies.
- In Procedure Step 5, students work together in their original groups to complete Section 2 of Student Sheet 9.1. It may be helpful to revisit the list of design elements that you compiled and

posted from Teaching Step 1 or optional Visual Aid 6.2, “Study Design Elements and Analysis Methods.” Remind students that these elements of a research study are helpful when reviewing the RCTs and can lead to more confidence in the results.

- After students have completed Procedure Step 5, let them know that they have not yet considered alternative explanations for the findings from confounds. Ask, **Based on how the studies were designed, what are possible confounds that could have affected the results?** When leading the discussion, allow students to brainstorm potential confounds and alternative explanations. Have the class work together to complete Section 3 of the student sheet. If needed, ask the following questions to help students identify potential confounds. Ask, **In the gratitude-writing study, do you think seeing someone important to them might have improved the experimental group’s well-being instead of the letter itself?** Students should respond in a way that shows they understand how another factor besides the treatment (e.g., interacting with an important person) could have affected the well-being of the experimental group. Continue with similar questioning for the remaining studies.

SYNTHESIS OF IDEAS (10 MIN)

4 Facilitate a discussion about the strengths and limitations of the studies.

- After completing Procedure Step 7, have groups briefly share and justify the ratings they gave for each study’s findings. Ask, **Which study did your group find most convincing and why?** Student responses may include reasons such as large sample size, target group, fewer confounds, large effect size, etc. A sample student response for Student Sheet 9.1 can be found at the end of this activity.
- When discussing the strengths and weaknesses of the studies, address the misconception that studies must include all the study design elements and analysis methods that students identified in this activity (large sample size, matching target group, consistency across settings, and large effect size). Emphasize that studies with limitations can still provide valuable evidence; depending on how those limitations affect the study results or the researchers’ conclusions, the evidence from the study may still be useful.
- Another key point to discuss with students is the amount of evidence provided by the RCT studies in this activity. Ask, **Is one RCT enough evidence to convince you that a strategy works?** Have students explain why or why not. Students should respond that one study is not convincing, unless it was a very large experiment run over a long time. Even if a study is well designed and well conducted, there is a threshold amount of data that makes people sure of the results. That threshold, as previously discussed, depends on the decision being made from the results.

5 Assess student growth, using the Analyzing and Interpreting Data Scoring Guide for Build Understanding item 2.

- Remind students of the Analyzing and Interpreting Data Scoring Guide. You may wish to project Visual Aid 9.1, “Scoring Guide: Analyzing and Interpreting Data (AID),” for your students to review each level and clarify your expectations.
- Do not share the item-specific version of the Scoring Guide (Item-Specific Scoring Guide: Activity 9, Build Understanding Item 2) with students as it provides specific information on how to respond to the item prompt. Review the Item-Specific Scoring Guide to support scoring this specific item.
- Remind students that you expect to see them demonstrate growth in their understanding and explanation of causal reasoning. They may want to review their responses to the assessment from Activity 4 (Build Understanding Item 2) and/or Activity 7 (Build Understanding Item 3).
- Sample responses for Levels 1–4 are provided in the Build Understanding section that follows. Review these responses to get an idea of what is expected for each level alongside the Item-Specific Scoring Guide. See [Appendix 2: Assessment Resource](#) at the end of the Teacher’s Guide for more guidance and information on using the Scoring Guides and assessment system with your students.
- Depending on your students, you may want to have them provide feedback on one another’s work for revision prior to turning in their work to you for scoring. Alternatively, consider having students turn in a rough draft to you for feedback and revision.

6 Revisit some of the key concepts of the unit that have been introduced.

- You may wish to revisit optional Student Sheet 1.2, “Unit Concepts and Skills,” to help students formally organize the ideas introduced in the unit so far. This is the final opportunity for students to summarize their learning on the student sheet. Students can place the headings of the main ideas related to randomized controlled trials into the organizer and add examples from their classroom experiences in Activities 7–9. See the end of Activity 1 in the Teacher’s Edition for a sample student response.
- Let students know that in Activity 10, the final activity of the unit, they will be able to apply their analysis from this activity. They will compare multiple lines of evidence from different studies to help choose which of the four well-being strategies to recommend to Salas High School.
- Finish the activity by revisiting the Guiding Question, *How can randomized controlled trials be evaluated?* Use responses to this question to formatively assess the student’s understanding of key concepts and process skills related to study designs for randomized controlled trials such as sample size, effect size, and random assignment of participants into groups.

SAMPLE STUDENT RESPONSES

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.

Answers may vary depending on which study design elements students found most relevant. One sample response is given below:

- a *We thought that RCT D: Green Spaces had the most convincing evidence. This is because it had a pretty large effect on both a physical and mental measurement of stress and a pretty large sample size (120 participants). Also, it did not have as many confounds as the other studies, even though they tested college students and not high school students. Because of all this, we rated the evidence 4.5 for how strong it was in showing that videos of green spaces can reduce stress.*
- b *We thought RCT B: Pet Therapy had the least convincing evidence for its conclusion. Cortisol is a good indicator of stress, so the results suggest that time with a dog can help prevent stress. However, they only measured cortisol levels, not how stressed students actually felt. Also, the sample was small, especially the control group, which only had 19 students. This makes it harder to rule out random chance. Lastly, the study only included students aged 8–10 from a few schools in the United Kingdom, so the results might not apply to older students or other students in other areas. Overall, we rated the evidence 3 for whether it showed that time with dogs can prevent stress.*

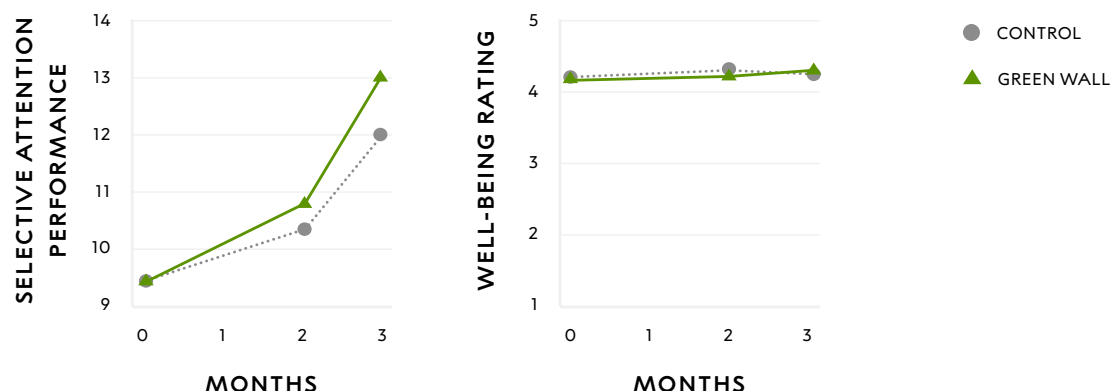
② AID ASSESSMENT

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.

FIGURE 9.5

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



- Does the data support the claim that access to green spaces improves well-being? Why or why not?
- What are the main limitations of this study? Explain how the limitations affect your confidence in the study results.
- 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.

Level 4 response

- This data does not support the claim that access to green spaces improves well-being, because the well-being scores remained about the same during the experiment, which means that there was no effect for this experiment.*
- This study was only performed in four classrooms, so the sample size is small. Also, the well-being ratings were pretty high before the study. If the sample size was larger and included classrooms where the well-being scores started lower, the study might have gotten different results. Researchers also only tested elementary school students in their classrooms, so there could be different results with different age groups, in different settings, or with different types of green spaces.*
- I would still recommend the green spaces strategy for Salas High School. The evidence from the RCT with the nature videos is very strong. The limitations in the study for green walls are pretty significant. When you add the evidence together, overall I still think there is a cause-and-effect relationship between green spaces and well-being.*

Level 3 response

- This data does not support the claim that access to green spaces improves well-being because the well-being scores did not change.*

- b** *The sample size is small. Also, the well-being ratings were pretty high before the study. They also only tested elementary school students in their classrooms. I am less confident in the results.*
- c** *I would still recommend the green spaces strategy for Salas High School. The evidence from the RCT with the nature videos is very strong. I still think there is a cause-and-effect relationship between green spaces and well-being.*

Level 2 response

- a** *The well-being scores did not change.*
- b** *The sample size is small.*
- c** *I would still recommend the green spaces. The other evidence is good.*

Level 1 response

- a** *It doesn't.*
- b** *They had lots of limitations.*
- c** *I think green spaces is a good idea.*

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?**

One claim I've seen is that drinking a lot of water every day can improve your skin. To test this, I could ask a lot of people (sample size), not just a few friends, about their experience with drinking more water and if they noticed a difference in their skin. I'd also ask people from different places, like at school, home, and even online, to see if the results are the same everywhere (consistency across settings). Finally, I'd look at how noticeable the difference was in their skin to see if there was a big improvement (effect size). If lots of people from different places say it worked and the difference in their skin is easy to see, it would make the claim seem more likely to be true.

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SECTION 1 Study Information	RCT A Gratitude Writing	RCT B Pet Therapy	RCT C Sleep Quality	RCT D Green Spaces
Control groups vs. Experimental group(s) (describe each)				
Well-being variable(s) that were measured (list the variables)				
Main conclusion(s) of the study (describe each)				

CONTINUED

SECTION 2 Study Design Elements and Analysis Methods	RCT A Gratitude Writing	RCT B Pet Therapy	RCT C Sleep Quality	RCT D Green Spaces
Sample Size Number of participants in each group				
Target group of the study Age of the participants				
Consistency across settings Types of people and locations included in the study				
Effect size Size of the difference between the groups				

CONTINUED

SECTION 3 Evaluation	RCT A Gratitude Writing	RCT B Pet Therapy	RCT C Sleep Quality	RCT D Green Spaces
What is an alternative explanation for the results? HINT: Is there a possible confound or inadequate sample size?				
On a scale of 0–5, how well does the evidence support the study's conclusion(s)?				

SECTION 1 Study Information	RCT A Gratitude Writing	RCT B Pet Therapy	RCT C Sleep Quality	RCT D Green Spaces
Control groups vs. Experimental group(s) (describe each)	CONTROL GROUP <i>1 week of writing about memories</i> EXPERIMENTAL GROUP <i>1 week writing a gratitude letter and giving it to someone</i>	CONTROL GROUP <i>normal class</i> EXPERIMENTAL GROUP 1 <i>20 minutes with a dog</i> EXPERIMENTAL GROUP 2 <i>20 minutes stretching or listening to a story</i>	CONTROL GROUP <i>8 hours of sleep each night for 12 nights</i> EXPERIMENTAL GROUP <i>4 hours of sleep each night for 12 nights</i>	CONTROL GROUP <i>shopping mall video</i> EXPERIMENTAL GROUP 1 <i>nature video</i> EXPERIMENTAL GROUP 2 <i>traffic video</i>
Well-being variable(s) that were measured (list the variables)	<i>happiness score (based on positive emotion, sense of connection, and how meaningful their lives felt)</i>	<i>stress by measuring cortisol levels</i>	<i>optimism-sociability levels (how friendly, energetic, motivated someone feels)</i>	<i>heart signal (related to blood pressure) and self-rated feelings (fear, anger, sadness)</i>
Main conclusion(s) of the study (describe each)	<i>Writing a gratitude letter and giving it to someone can increase happiness for up to one month.</i>	<i>Spending time with dogs can keep stress levels down compared to no time with dogs or relaxation techniques.</i>	<i>Not enough sleep can decrease how social or optimistic someone feels (which includes how friendly, energetic, creative someone is feeling).</i>	<i>Watching nature videos helps people recover from stress more quickly and completely compared to watching videos of traffic or malls. This may happen because of the way the nervous system reacts to nature.</i>

CONTINUED

SECTION 2 Study Design Elements and Analysis Methods	RCT A Gratitude Writing	RCT B Pet Therapy	RCT C Sleep Quality	RCT D Green Spaces
Sample Size Number of participants in each group	CONTROL GROUP 70 EXPERIMENTAL GROUP 80	CONTROL GROUP 19 EXPERIMENTAL GROUP 1 33 EXPERIMENTAL GROUP 2 35	CONTROL GROUP 18 EXPERIMENTAL GROUP 22	CONTROL GROUP 40 EXPERIMENTAL GROUP 1 40 EXPERIMENTAL GROUP 2 40
Target group of the study Age of the participants	most: 35–54	8–10	21–41	18–22
Consistency across settings Types of people and locations included in the study	Most were white and had a college degree. It was done online, but there is no information on where most participants lived.	students from four elementary schools in the United Kingdom	healthy people in the area of Boston, Massachusetts	college students from a university in the Northeast United States
Effect size Size of the difference between the groups	Happiness scores were 4 points higher after giving the letter and 3 points higher after 1 month, compared to the control group.	Cortisol levels stayed about the same for the dog group over 6 weeks, but cortisol levels went up significantly by 0.02 to 0.04 µg/dL in the other two groups.	The optimism-sociability score went down by up to 15% in participants who had 4 hours of sleep but only decreased up to 5% for participants who got 8 hours of sleep.	Bigger and faster decreases in blood pressure and fear, negative feelings, and anger when people watched nature videos compared to people watching traffic or mall videos.

CONTINUED

SECTION 3 Evaluation	RCT A Gratitude Writing	RCT B Pet Therapy	RCT C Sleep Quality	RCT D Green Spaces
What is an alternative explanation for the results? HINT: Is there a possible confound or inadequate sample size?	<i>Maybe writing about early memories reduced positive emotions. But this isn't very likely.</i>	<i>Maybe any break from school lessons reduces stress. But it's more likely the dog actually helped.</i>	<i>Maybe being told not to sleep more than 4 hours made the experimental group mad. But it's more likely it was the amount of sleep they got.</i>	<i>Maybe looking at traffic and the mall continued the stress, and the nature group was neutral. But that's not as likely as the nature group's video being calming.</i>
On a scale of 0–5, how well does the evidence support the study's conclusion(s)?	3.5	3	4	4.5

VISUAL AID 9.1

SCORING GUIDE: ANALYZING AND INTERPRETING DATA (AID)

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.

WHAT TO LOOK FOR:

- Response describes patterns and trends in data.
- Response interprets patterns and trends to describe possible causal relationships.

LEVEL	GENERAL DESCRIPTION
Level 4 Complete and correct	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data and interprets them completely and correctly to identify and describe relationships. When appropriate, the student: • makes distinctions between causation and correlation. • states how biases and errors may affect interpretation of the data. • states how study design impacts data interpretation.
Level 3 Almost there	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data BUT incorrectly and/or incompletely interprets them to identify and describe relationships.

LEVEL	GENERAL DESCRIPTION
Level 2 On the way	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes, BUT does not interpret, patterns and relationships.
Level 1 Getting started	The student attempts to analyze the data BUT does not use appropriate tools, techniques and/or reasoning to identify and describe patterns and relationships.
Level 0 Missing or off task	The student's analysis is missing, illegible, or irrelevant to the goal of the investigation.
X	The student had no opportunity to respond.

ITEM-SPECIFIC SCORING GUIDE

ACTIVITY 9, BUILD UNDERSTANDING ITEM 2

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.

WHAT TO LOOK FOR:

- Response describes patterns and trends in data.
- Response interprets patterns and trends to describe possible causal relationships.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 4 Complete and correct	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data and interprets them completely and correctly to identify and describe relationships. When appropriate, the student: • makes distinctions between causation and correlation. • states how biases and errors may affect interpretation of the data. • states how study design impacts data interpretation.	The student response: • describes the pattern in the data and why the data does not support the claim. • thoroughly describes at least two limitations and provides reasoning for how these limitations affect confidence in the study results. • provides a well-reasoned explanation of why they are or are not recommending the strategy referencing evidence.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 3 Almost there	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data BUT incorrectly and/or incompletely interprets them to identify and describe relationships.	The student response: - describes the pattern in the data and why the data does not support the claim. The student response may have minor errors or limited responses to: - describing at least two limitations and providing reasoning for how these limitations affect confidence in the study results. - providing a reasoned explanation of why they are or are not recommending the strategy referencing evidence.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 2 On the way	The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes, BUT does not interpret, patterns and relationships.	The student response: - describes the pattern in the data but may not explain why the data does not support the claim. The student response may have errors or limited responses/reasoning to: - describing at least one limitation and may not provide reasoning for how the limitation affects confidence in the study results. - stating whether they are or are not recommending the strategy and may not describe evidence.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 1 Getting started	The student attempts to analyze the data BUT does not use appropriate tools, techniques, and/or reasoning to identify and describe patterns and relationships.	The student response: - describes the pattern in the data, may be general, or contain errors. The student response may have significant errors or very limited responses/reasoning to: - describing general limitations. - stating whether they are or are not recommending the strategy.
Level 0 Missing or off task	The student's analysis is missing, illegible, or irrelevant to the goal of the investigation.	
X	The student had no opportunity to respond.	



ACTIVITY 10

Making Decisions with Causal Reasoning

DISCUSSION

ACTIVITY 10

Making Decisions with Causal Reasoning

ACTIVITY SUMMARY

In this culminating activity, students participate in a group decision to choose which well-being strategy to recommend to Salas High School. Students summarize the evidence they've gathered throughout the unit to consider how well each strategy can improve well-being. Each group creates a plan for implementing one of the strategies, including practical considerations and potential challenges. Afterward, the class shares their ideas and comes to a consensus on the best recommendation for the school. Throughout this process, students draw from the unit's key concepts and process skills about causal reasoning to support their decision.

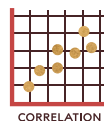
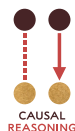
ACTIVITY TYPE
DISCUSSION

NUMBER OF
40-50 MINUTE
CLASS PERIODS
1-2

KEY CONCEPTS & PROCESS SKILLS

- 1 Causal reasoning can be used to identify the cause of an effect and to analyze the effectiveness of potential solutions.
- 2 Confidence in a cause-and-effect relationship should depend on the quality, variety, and consistency of the evidence supporting it.
- 3 Randomized controlled trials (RCTs) are the most reliable method for identifying cause-and-effect relationships because they reduce the likelihood that alternative factors are influencing the effect.

CONCEPTUAL
TOOLS



MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 1.2
“Developing
Communication Skills”
(OPTIONAL)
- VISUAL AID 1.3
“Proposed Well-Being
Strategies for Salas
High School”
(OPTIONAL)

FOR EACH GROUP OF FOUR STUDENTS

- RCT SUMMARY CARDS
FROM ACTIVITY 8
(4 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”
- STUDENT SHEET 10.4
“Writing Frame:
Well-Being
Recommendation Letter”
(OPTIONAL)

Gather the RCT Summary cards that you prepared in Activity 8.

Plan on how you would like the class to decide about their final recommendation for the well-being strategy (see Teaching Step 4). Options include gaining consensus, holding an anonymous vote, or conducting an open vote.

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in lime.

GETTING STARTED (10 MIN)

1 Present the final fictional scenario of the unit.

- Have students read the Introduction. Then, begin the activity by reviewing the scenario. The scenario presented in Procedure Step 1 can be shared with the class in multiple ways. Read the scenario aloud to the class or have individual students read it aloud while others follow along with the text (either as a whole class or in small groups).
- Let students know that in this activity, they will play the role of the Salas High School Well-Being Task Force and have an opportunity to apply what they've learned in the unit into a final recommendation.
- Before beginning the rest of the procedure, consider displaying optional Visual Aid 1.3, "Proposed Well-Being Strategies for Salas High School," as a review for all four well-being strategies and to prepare them to think of proposed plans later in the activity.
- Help students gather their completed student sheets from Activities 5 and 9 as they will need them for this activity. Each group member will complete one copy of a student sheet for one well-being strategy being considered. Depending on your students, you may want to assign each group one well-being strategy to analyze instead of having each group analyze all four of the strategies. This way, students only need to complete one student sheet and then share their results.
- Another possible accommodation for the procedure, if appropriate, is to prepare the student sheets in advance, either by using some of your own students' work or the sample student responses from the previous activities.

PROCEDURE SUPPORT (20 MIN)

2 Support students as they analyze the evidence in the unit.

- In Procedure Step 2, provide each group with all 4 RCT Summary cards from Activity 8. Groups are already familiar with one of the cards, and now they will analyze the other three cards.
- In Procedure Step 3, hand out 4 copies of Student Sheet 10.1, “Weighing Evidence for the Well-Being Strategies,” to each group. Support groups as they complete Procedure Step 3. Encourage group members to work through the evidence, activity by activity, as each group member completes the table on their student sheet. A sample student response for each of the four well-being strategies is found at the end of this activity.
- In Procedure Step 4, have group members compare their research findings and discuss how strong the evidence is for each strategy.

Sample Student Response, Procedure Step 4

The studies for gratitude writing had strong evidence, with one study showing it boosted happiness for up to one month. The sleep studies also had very strong research since it was tracked over time and showed a big effect on reducing stress and improving mood. The pet therapy studies seemed less certain because they tested fewer people. The green space studies were strong, especially since even watching nature videos helped. While all the well-being strategies had good support, we think quality sleep had the strongest impact on overall well-being.

- In Procedure Step 5, hand out 4 copies of Student Sheet 10.3, “Comparing Well-Being Strategies and Proposed Plans,” to each group. Lead a discussion for students to compare the strength of the scientific evidence for each well-being strategy. Ask, **Which strategy has the strongest evidence for improving well-being and why?** Guide the conversation by asking students to share specific studies or findings from Student Sheet 10.1 that support their choices. Encourage students to use concepts from the unit, such as indicators of causation and study design elements to compare the strength of the evidence for each well-being strategy. **If each group analyzed only one well-being strategy in Procedure Step 3, have groups share their summaries of the evidence with the other groups. This way, all students will be familiar with the strength of the evidence for all four strategies.**
- Encourage students to reflect on the class discussion and rate the strength of the evidence for each well-being strategy on a scale from 0 (no relevant evidence) to 5 (very strong evidence) and record their ratings in the first row of the table on Student Sheet 10.3. Student ratings will vary, but one sample student response for Student Sheet 10.3 can be found at the end of this activity.

3 Students design well-being plans and, as a class, choose the best ones.

- For Procedure Steps 6–7, hand out 1 copy of Student Sheet 10.2, “Proposing a Plan,” to each group. Assign each group one of the four well-being strategies for them to use as they design a specific plan for Salas High School. Guide students in designing plans that are realistic for a school set-

ting and that consider potential challenges. While students don't have details about Salas High School's exact location, demographics, or budget, they can assume it has similar resources to their own school. Groups' plans should be detailed and yet adaptable to work in most school settings.

- In Procedure Step 8, students share their plans and practical considerations with the class. If you would like students to formally present their plans, consider providing expectations for each group's presentation. Possible choices include completing a written proposal, designing a poster for a poster session and/or a gallery walk, or creating a slideshow to present to the class.
- After all groups have presented, hold a class discussion. Ask, **What are the strengths and weaknesses of each plan?** Consider listing student responses to help compare the plans. Student responses will vary. Examples of strengths and weaknesses for two proposed plans include:
 - Gratitude writing in notebooks:
 - STRENGTHS**
easy to supply paper and pens
 - WEAKNESSES**
a lot of people may not want to do it because it seems cheesy
 - Later school start time:
 - STRENGTHS**
it positively impacts all students equally
 - WEAKNESSES**
it may conflict with after-school activities, especially in the winter when it gets dark earlier

Help the class select one plan for each strategy, focusing on how clear and practical the plans are. Have students record the names of each proposed plan on Student Sheet 10.2 and then rate and record each plan's practicality on a scale from 0 (extremely impractical) to 5 (very practical).

4 Part C: Help students compare the four strongest plans by conducting a Walking Debate.

- In Procedure Step 10, use the literacy strategy of a Walking Debate to encourage students to discuss which of the four plans should be chosen. Students should use their ratings and their understanding of the evidence from Student Sheets 10.1 and 10.2 to discuss their positions on the recommendation. See [Appendix 1: Literacy Strategies](#) at the end of the Teacher's Edition for more guidance and information on using the Walking Debate strategy with your students.
- To support students' discussion, you may wish to use optional Visual Aid 1.2, "Developing Communication Skills," to help guide student interactions. Visual Aid 1.2 is a tool to help students effectively participate in class discussions by providing sentence starters that students can use to initiate a conversation and express their ideas. For more information about Developing Communication Skills, see [Appendix 1: Literacy Strategies](#).
- In Procedure Step 11, help the class decide on a final recommendation for a well-being strategy. This recommendation can be decided by consensus, an anonymous vote, an open vote, or any other method that works for your students. While the class selects one strategy, keep in mind that

in Build Understanding item 1, students will have the opportunity to reflect on how the class's decision compares to their own choices. Their individual recommendations may be the same or different from the class's decision.

SYNTHESIS OF IDEAS (20 MIN)

5 Students complete a written recommendation for the well-being strategy.

- In Build Understanding item 1, students write a letter to the leadership of Salas High School with their recommendation. This task should include the culmination of key concepts in the unit. Encourage students to be specific about the evidence they cite, its relative strength, and its importance to their reasoning.
- Optional Student Sheet 10.3, "Writing Frame: Well-Being Recommendation Letter," provides additional support for students responding to Build Understanding item 1. A Writing Frame can support learners, particularly emerging multilingual learners, in decoding scientific ideas, constructing meaning, sensemaking, and language acquisition. This strategy, which has been deemed effective for emerging multilingual learners, was built on and adapted from strategies for English-proficient learners. You may wish to provide students with the Writing Frame to compose their responses or simply as a reference or checklist to help them organize how they will respond. Consider posting an enlarged version of the writing frame on a classroom wall for students to refer to. For more information on a Writing Frame, see [Appendix 1: Literacy Strategies](#).

6 Connect the key ideas of the unit to students' everyday lives.

- Review student responses to Connections to Everyday Life item 2. Use this prompt for a final discussion on how the Salas High School scenario applies to students' own school and lives. Most students are likely to choose the same recommendation for their own school, but some may consider unique aspects of their school's environment or community that could influence their choice. For example, if their school already has a garden, they might suggest incorporating that into their proposed plan, as long as the well-being strategy's evidence supports it.
- Finish the activity by revisiting the Guiding Question, *How can scientific evidence for causation be used to inform decisions?* Use responses to this question to formatively assess students' understanding of the key concepts and process skills related to using evidence in causal reasoning.

7 Revisit the Unit Driving Question, *How can scientific investigations provide evidence for cause-and-effect relationships, such as how different factors affect health and well-being?*

- Wrap up the unit by asking students to reflect on what was most valuable about their growth in causal reasoning. Ask, *How might the causal reasoning tools you learned about in this unit affect how you make decisions in your own life?* Accept all responses and connect students' ideas to

their everyday decisions, especially important ones. Remind students that although the scenario in this unit was related to well-being—which they also learned about—the point of the unit was to gain the thinking tools related to evaluating evidence for causation.

EXTENSION (60 MIN)

8 Use the Extension as an opportunity for advanced learning.

- If students are enthusiastic about improving well-being at their school, help them create a letter or presentation that proposes a well-being strategy for their school community. Students can use their responses to Build Understanding item 1 as a starting point. Assist them in selecting key evidence for their proposal, helping them think about potential challenges, and proposing solutions that are relevant to their school.

SAMPLE STUDENT RESPONSES

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.

New Message

To: Salas High Principal <principal@salashigh.edu>

From: Salas High School Task Force <taskforce@salashigh.edu>

Dear School Leaders,

Thank you for the opportunity to consider different well-being strategies at Salas High. We, the task force, recommend...

Send

Dear School Leaders,

I'm recommending the idea of creating a school garden to improve well-being at Salas High School. The plan would be for students to have regularly scheduled science and environmental lessons there, which would give students a hands-on way to learn. It would also provide a place for students, teachers, and staff to relax and be active while also helping everyone feel better, mentally and physically.

Research shows that spending time in green spaces, such as gardens, can help reduce stress and improve mood. One study found that even watching videos of nature can lower stress levels. Scientists think this happens because natural scenes help calm the nervous system. Another study showed that walking in nature can help people feel happier and better able to reflect. Also, better social connections can also improve well-being, so a school garden where students and staff spend time together would help even more.

While the evidence for the benefits of a school garden is strong, we would need to consider a few practical things. The garden would need regular care, so students could take turns planting, watering, and harvesting. We'd also need to find a good location on school grounds that gets enough sunlight and has enough space for a variety of plants. A teacher or staff member could be in charge of making sure the garden stays healthy and that everyone benefits from it. Plus, teachers would need to organize how and when the garden could be used for teaching students.

Another thing to think about is how the garden could bring the community together. Parents, local businesses, and/or community organizations might be willing to donate resources or volunteer their time. This would create a connection between the school and the community, making the garden a source of pride for everyone involved.

Thank you for considering my idea! I believe the school garden would be a great way to improve the well-being of students and staff at Salas High School.

*Sincerely,
Stu Dent*

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.

I don't think creating a school garden would work at my school. While the idea sounds great, we don't really have a big enough space for it on the school grounds. Finding a good spot for a garden with enough sunlight would be really difficult. Plus, the teachers are already stretched with their lessons and wouldn't have time to manage a garden. Although it would be a good way to relax and spend time outside, I think it would be difficult to make it happen with the current setup at my school.

Instead, I think a better plan would be to have students write gratitude letters to someone at their school. This would be something students could easily do during a class period or as part of a special event, and it wouldn't require a lot of space. Writing a letter to someone they're grateful for would not only boost students' own well-being, but it would also help build stronger connections with others in the school. Plus, it would be a simple way to practice gratitude without needing extra resources or time.

- 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.

I would choose improving my sleep quality as the well-being strategy because getting enough sleep is super important for my mood and focus. Poor sleep can affect your mood and health, and I know that I don't always get enough sleep during the school week. I can get cranky and can't concentrate during class if I'm sleepy. If I made changes, like going to bed at the same time every night and turning off my devices before bed, I think I'd feel more energized and be able to do better in school. I know it might be hard at first, but I've noticed that when I get more sleep, I'm much happier and more focused.

Well-Being Strategy: _____

EVIDENCE LOCATION	SUMMARY OF EVIDENCE	STRENGTH OF EVIDENCE 0 (LOW) – 5 (HIGH)
Activity 5		
Activity 8		
Activity 9		
Other		

Well-Being Strategy: Gratitude Writing

EVIDENCE LOCATION	SUMMARY OF EVIDENCE	STRENGTH OF EVIDENCE 0 (LOW) – 5 (HIGH)
Activity 5	- A correlation of 0.51 for gratitude vs. positive emotions in 201 college students. Moderate correlation. 77 couples wrote letters, and it increased social connection. Could be a mechanism. 132 college students were tested. Those that wrote about grateful things had higher life satisfaction after. Shows timing.	4
Activity 8	- RCT of 129 college students; 10 weeks of writing things they were grateful for vs. things they were annoyed with. Experimental group had higher gratitude, life satisfaction, and more positive emotions. - It's better evidence because it's an RCT. However, we're not sure how big the effect was. Also, the control group wrote things that annoyed them so this could be a confound.	3
Activity 9	- RCT of 150 adults to write about memories or write and give a letter to someone they are grateful for; happiness scores were 4 points higher than the control for immediately after giving the letter and 3 points higher after 1 month. - Good evidence because it's an RCT and the effect lasts a long time, although it does not seem like a huge effect.	4
Other	The Harvard Study and other research shows that social connection also increases well-being. Maybe the effect is stronger because giving letters to people increases social connection.	3

Well-Being Strategy: Pet Therapy

EVIDENCE LOCATION	SUMMARY OF EVIDENCE	STRENGTH OF EVIDENCE 0 (LOW) – 5 (HIGH)
Activity 5	- No information about the strength of an association for being around a dog vs. more positive emotions in 99 children. - Time with dogs increased hormone oxytocin levels in 20 dog owners. Could be a mechanism. 27 different studies all showed only one-third of people with disabilities had higher well-being after time with dogs.	3
Activity 8	- RCT of 163 college students; 20 minutes with a dog or studying. Experimental group had less stress and more of a sense of belonging. - Good evidence because it's an RCT; not sure how big the effect was. However, there was a good sample size.	3
Activity 9	- RCT of 87 elementary students: 20 minutes with a dog time prevented cortisol levels from going up compared to relaxation or nothing. - Good evidence because it's an RCT and because measuring cortisol seems like a good measure of stress levels; However, there was a small sample size for each group.	3
Other	People already in a good mood might be more likely to spend time with dogs, which could explain their improved well-being.	3

Well-Being Strategy: Quality Sleep

EVIDENCE LOCATION	SUMMARY OF EVIDENCE	STRENGTH OF EVIDENCE 0 (LOW) – 5 (HIGH)
Activity 5	• A correlation of 0.45 for sleep quality vs. overall well-being emotions in 488 adults. Moderate correlation. • Many studies show poor sleep can cause the immune system to not work as well. This could be a mechanism. • 34 teenagers tested for less sleep. 5 hours per night led to low well-being.	3
Activity 8	• RCT of 452 adults in India with poor sleep; experimental group with naps during the day increased well-being. • It's an RCT, which makes it better evidence; not sure how much it improved well-being (the effect size). Good sample size.	4
Activity 9	• RCT of 42 adults for 12 days. Group that got 4 hours of sleep per night had 3 times lower scores for well-being than the group with 8 hours of sleep per night. • Good evidence because it's an RCT; also there's a large effect size and it has a high sample size.	4
Other	• Poor sleep might lower well-being, but lower well-being might also lead to poor sleep. Unless you measure how a person is feeling before and after, it can be hard to know which is causing which.	2

Well-Being Strategy: Green Spaces

EVIDENCE LOCATION	SUMMARY OF EVIDENCE	STRENGTH OF EVIDENCE 0 (LOW) – 5 (HIGH)
Activity 5	- A correlation of 0.30 for time in nature vs. positive emotions for 51 students who were measured 1,120 times. Weak correlation but it has a large sample size. 46 college students had activation of the nervous system after nature images to calm them down. Could be a mechanism. - Green walls in elementary classrooms. No information if well-being changed or not.	3
Activity 8	- RCT of 76 college students; 10-minute walk in nature or in the city and then reflecting on things. Experimental group had more positive emotions, better ability to reflect. - The study only found slightly more positive emotions. It is an RCT though, which makes it better evidence.	2
Activity 9	- RCT of 120 young adults to watch nature or urban videos to de-stress. Nature group had faster decreases in blood pressure and negative feelings. - This is good evidence because it shows the effect size was strong; Also, they saw the same effect in both physical and mental measures of stress.	4
Other	Maybe people who spend time in green spaces are not necessarily feeling better because of nature but because they are more likely to get exercise or spend time with people there.	3

Proposed Plan Name: _____

Specific Plan Description

(when and where it would take place, how often it would happen, who would be involved)

Practical Considerations

SUPPLIES NEEDED equipment, space, cost, anything else	IMPLEMENTATION CHALLENGES AND SOLUTIONS

Proposed Plan Name: Take a Grateful Break

Specific Plan Description

(when and where it would take place, how often it would happen, who would be involved)

In this plan, we would recommend that during the midday break, students hear an announcement from a fellow student to write what they are grateful for in a small notebook. The announcement would happen three days per week, and we would provide a small notebook and a pen in school colors to each student.

Practical Considerations

SUPPLIES NEEDED equipment, space, cost, anything else	IMPLEMENTATION CHALLENGES AND SOLUTIONS
<i>We would need the notebooks and pens to be donated</i> <i>We would need an organized group of students to make the announcements</i>	<i>Students might not stop and do the task, but we could make a school club to run the announcements and encourage people to do it. It would have higher success if the announcement came from students.</i> <i>Some students don't like to use pen and paper. Maybe we offer an electronic alternative.</i>

Proposed Plan Name: Dog Love!

Specific Plan Description

(when and where it would take place, how often it would happen, who would be involved)

In this plan, we would provide a therapy dog from the local shelter once a week that students would have the opportunity to pet and interact with during passing periods, lunch, and study halls. The dog would have to stay outside of the building, and students would sign up to walk and play with the dog.

Practical Considerations

SUPPLIES NEEDED equipment, space, cost, anything else	IMPLEMENTATION CHALLENGES AND SOLUTIONS
• We would need to have some pet supplies donated: feed bowls, waste bags, chew toys. • We would need to work with the local shelter to get the dog on a weekly basis. • There needs to be an organizing committee that gets students to sign up to take care of the dog.	• The dog would have to be well-behaved so we would have to work with the shelter to get a good one. • Students might need some training on how to handle a dog, but we could make sure there was an experienced student dog owner at every session to help other students. • We would have to advertise the program in the newsletter and morning announcements to make sure enough students show up. • Students would have to pick up after the dog! If they don't, they won't be allowed back.

Proposed Plan Name: Sleep On, Students!

Specific Plan Description

(when and where it would take place, how often it would happen, who would be involved)

In this plan, we would recommend that the school move the start of school 30 minutes later every day so students could get more sleep. Class periods would stay the same length, so school would end 30 minutes later.

Practical Considerations

SUPPLIES NEEDED equipment, space, cost, anything else	IMPLEMENTATION CHALLENGES AND SOLUTIONS
<i>No extra equipment needed.</i>	• <i>Need to know the public bus routes in the morning to make sure the timing works. Could adjust time a little to accommodate bus schedules.</i> • <i>Sport teams would start later in the afternoon. That could be a problem in the winter when the days are shorter, and it gets dark sooner, but most of the winter sports offered are inside.</i>

Proposed Plan Name: Green Thumb Garden

Specific Plan Description

(when and where it would take place, how often it would happen, who would be involved)

In this plan, we would start a school garden in a location on school property where people could easily pass by it and sit on a bench near it. The garden would be open whenever school is open so people could visit it before, during, and after school.

Practical Considerations

SUPPLIES NEEDED equipment, space, cost, anything else	IMPLEMENTATION CHALLENGES AND SOLUTIONS
<i>We would need soil, seeds, watering can—maybe donated from a local nursery or from parents.</i> <i>There would have to be some research and guidance from a gardener on what to plant and how to take care of it.</i> <i>There would need to be students to get the garden ready and to maintain it.</i>	<i>There isn't a lot of time in the school day to sit by the garden, but if we could locate it near the cafeteria, there might be more time at lunch.</i> <i>It may be difficult to maintain the garden for a long time. A garden club could be created to maintain the garden.</i> <i>The garden may not be appealing in the winter.</i>

	WELL-BEING STRATEGIES			
	GRATITUDE WRITING	PET THERAPY	QUALITY SLEEP	GREEN SPACES
Evidence for the Well-Being Strategy RATING 0 TO 5				
Proposed Plan Name				
Practical Considerations for the Proposed Plan RATING 0 TO 5				

Notes on Other Groups' Proposed Plans

	WELL-BEING STRATEGIES			
	GRATITUDE WRITING	PET THERAPY	QUALITY SLEEP	GREEN SPACES
Evidence for the Well-Being Strategy: RATING 0 TO 5	4	3	4	3
Proposed Plan Name	Take a Grateful Break	Dog Love!	Sleep-On Students!	Green Thumb Garden
Practical Considerations for the Proposed Plan: RATING 0 TO 5	5	1	3	3

Notes on Other Groups' Proposed Plans

- **Green Thumb Garden:** A school garden with a bench to visit anytime. Students take care of it. Not much time during school, but if it's by the cafeteria, could be visited during lunch. Maybe a garden club to tend it.
- **Dog Love!:** A therapy dog from a local shelter, once a week; during passing periods and lunch. Students sign up for walks. The dog stays outside. Students have to pick up after the dog. ☹️
- **School Pet Day:** Bring in dogs after school for one day a month. Need space for dogs (maybe the courtyard?), need treats and dog toys. The dogs might not be friendly.
- **Gratitude Box:** Box for thank-you letters that are delivered every week. Only need a cardboard box, construction paper, pens, and pencils. Maybe some kids won't get notes? Volunteers to write extra ones.
- **Sleep on, Students!:** Start of school is 30 minutes later; students can sleep in. School schedule stays the same, though. No extra equipment needed. Bus routes won't work for it though.
- **Classroom Gardens:** A window box for plants in classes. Buy soil and seeds. But there would be dirt in classrooms and not sure which students would take care of it.
- **Nap Room:** Small room with cots and blankets; naps during lunch or free periods. Need a quiet room, cots, blankets, pillows. It should be supervised by a teacher.

Dear School Leaders,

I recommend the _____ well-being plan for Salas High School.

This plan involves

There is strong evidence supporting the effectiveness of this strategy, such as

This evidence supports the idea that the plan would improve well-being by

Some potential challenges to the plan include

One other thing to consider about the plan is

Thank you for considering my recommendation.

Sincerely,

Dear School Leaders,

I recommend the Gratitude Writing well-being plan for Salas High School.

This plan involves

students writing gratitude letters to people who have made a positive impact on their lives.

There is strong evidence supporting the effectiveness of this strategy, such as

studies showing that writing about gratitude can improve mood and reduce stress. Research also suggests that focusing on positive things helps increase happiness and well-being.

This evidence supports the idea that the plan would improve well-being by

encouraging students to focus on the good things in their lives, which can help them feel happier and less stressed.

Some potential challenges to the plan include

that some students may feel uncomfortable writing gratitude letters, and it could be difficult to find time in the school schedule to do it regularly.

One other thing to consider about the plan is

that it could help create a positive atmosphere at school by promoting kindness and appreciation among students and staff.

Thank you for considering my recommendation.

Sincerely,

Stu Dent

APPENDIX 1

LITERACY STRATEGIES

Teaching ***Scientific Thinking for All: A Toolkit*** provides constant opportunities for students to improve their English language skills. For example, students are expected to read informational text and procedures, write clearly to respond to assessment items, and use oral language skills during discussions. Research-based support strategies are embedded throughout the activities to help students process new content, develop analytical skills, connect concepts, become more proficient readers, and express their knowledge.

The literacy strategies offered in the curriculum depend on the instructional needs of the activity in which they are embedded. Because a full explanation of each research-based strategy is not practical to provide in the Teaching Notes of the Teacher Edition, a more detailed description for each goal is described below.

Eliciting Prior Knowledge

Anticipation Guide

Concept Map

Processing Information

Fayer Model

Venn Diagram

Word Sort

Reading Comprehension

Directed Activity Related to Text (DART)

Read, Think, and Take Note

Word Wall

Oral Discussion and Debate

Developing Communication Skills

Walking Debate

Writing Support

Science Notebook

Writing Frame

ANTICIPATION GUIDE

What It Is

An Anticipation Guide is a pre-reading exercise to help students activate their background knowledge about a topic and generate curiosity about the material they will learn. Students answer a set of prompts before reading; after reading, students discuss how their predictions compare with the information in the reading.

Why Use It?

The value of an Anticipation Guide is in the discussion that occurs before and after the reading. Before reading, students discuss their predictions and the reasons for them. During this discussion, the teacher gleans information about the depth of students' existing knowledge and their misconceptions about a topic. The post-reading discussion on how students' answers have changed allows teachers to formatively assess what students gained from the reading.

How To Use It

Students begin by individually responding to a series of statements related to the text they will read. They state whether they agree or disagree with a statement by marking it with a + (agree) or a – (disagree). The statements give students a sense of the key ideas in the reading and elicit their current ideas about and knowledge of the material. Students then discuss their predictions as a class. After completing the reading and participating in another discussion, students revisit the statements and record whether they now agree or disagree with each one. Their final task is to cite information from the reading to explain how the text either supported or changed their initial ideas.

Where It Is

The Anticipation Guide Student Sheet can be found in the Teacher Edition for the activities in which it is used. Sample student responses are also located in the Teacher Edition.

CONCEPT MAP

What It Is

A concept map is a visual representation of the relationship between ideas and concepts. Concept maps ask students to make and describe relationships between main ideas and subtopics and among the subtopics themselves.

Why Use It?

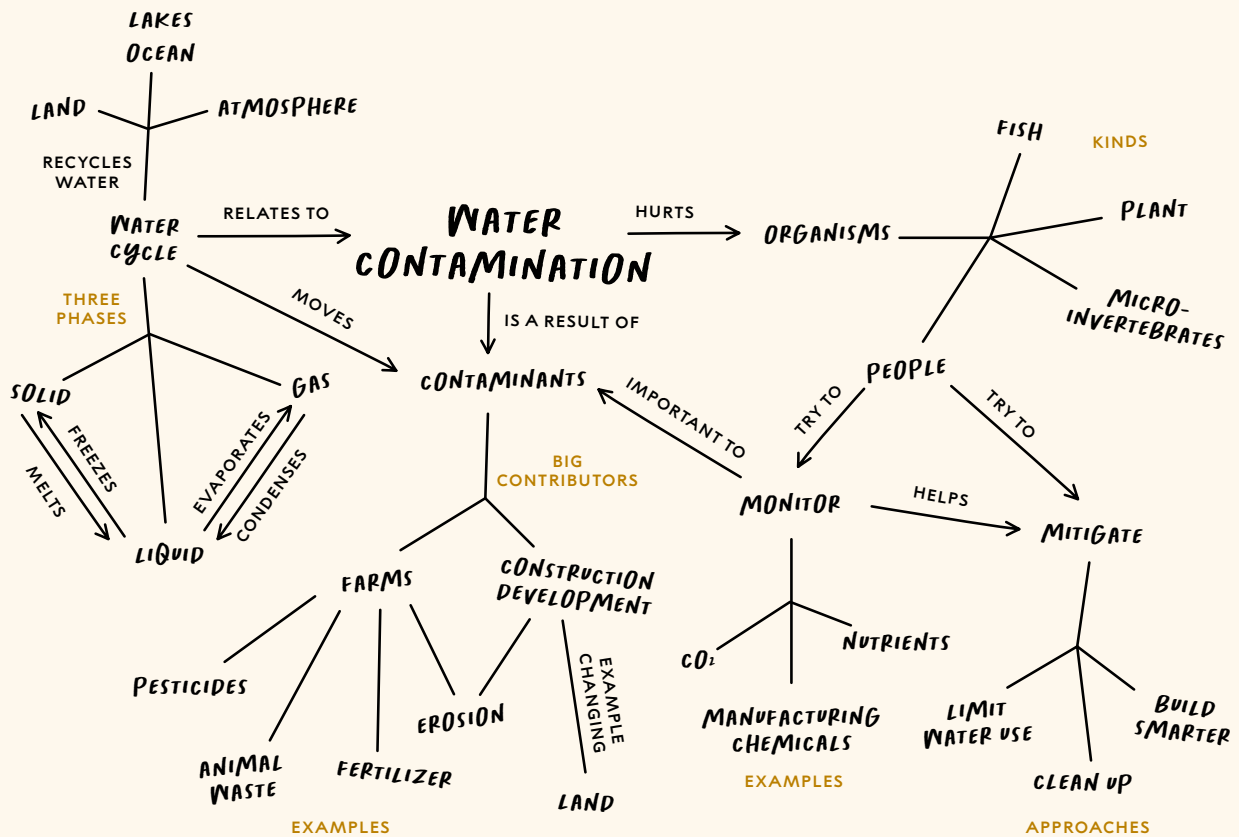
Concept maps demonstrate students' understanding of the connections between topics in a spatial manner. They also allow students to expand their knowledge related to a topic.

How To Use It

The main concept is written in the center of a page (or on the board), and students place subtopics around it, connecting lines between each subtopic and the main concept. On or near each line they've drawn, students add a brief description of the relationship between the two words.

The following example is from a prompt in a unit in which students are asked to draw a concept map about water contamination.

Initially, students may find it helpful to have a list of words that must be included in the map or an incomplete concept map to fill in. Later, students might brainstorm words that should be included and make a list before beginning their concept maps. It may also be helpful to write each subtopic on an index card or sticky note so students can physically manipulate them and lay out the map.



If your students are unfamiliar with concept maps, model the process by using a familiar central idea, such as school. Write “school” on the board and with the class, brainstorm subtopics to place around it (i.e., What are words and ideas associated with school?). Off to the side, organize these subtopics in a hierarchy, listing the more general ideas first and the more specific ones toward the bottom. Arrange the ideas spatially on the map, with the more general ideas closer to the central topic and the more specific ideas radiating out from the general ideas. Link the general ideas to the central concept with specific ideas, words, or short sentences defining the connection between the concepts. Then add links explaining the connection between the general and more specific ideas.

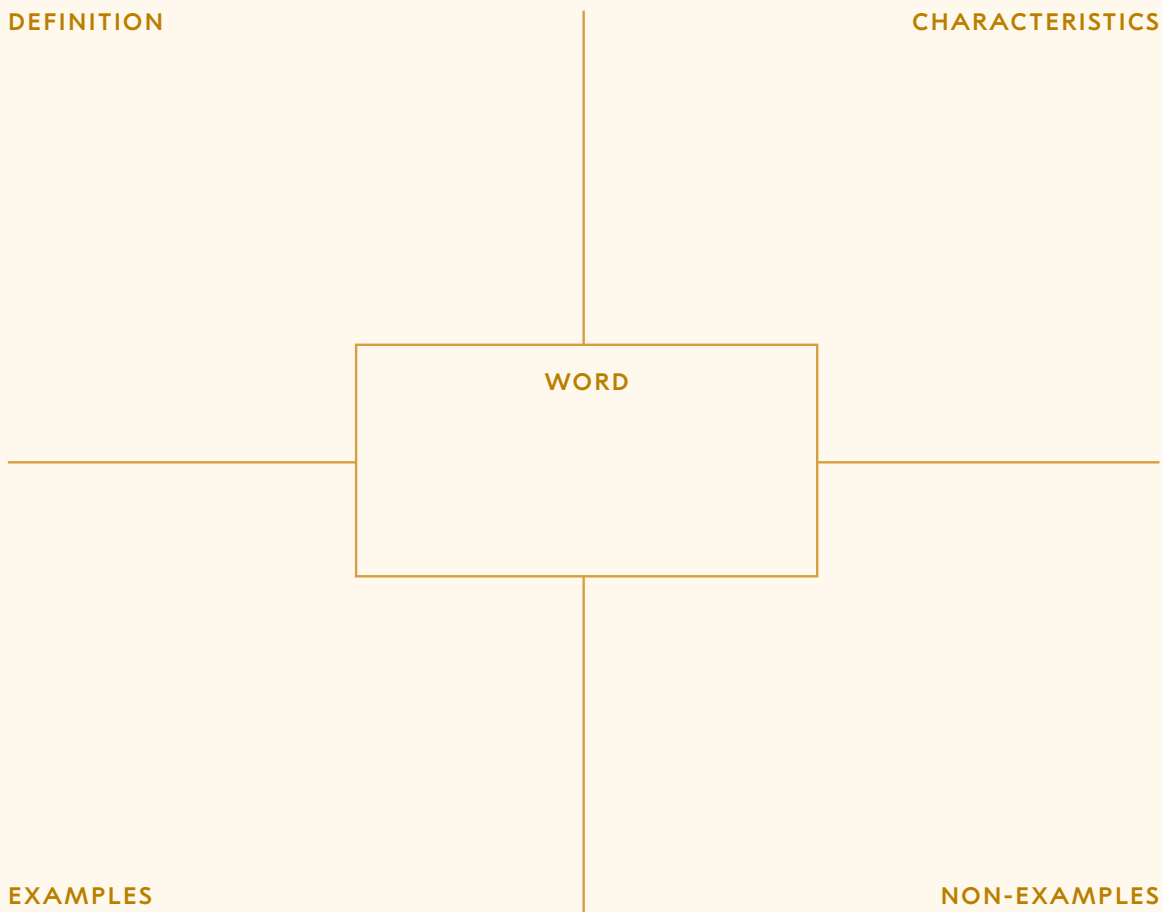
Where It Is

Concept maps are most often part of the Teaching Notes in the Teacher Edition; they may also be Build Understanding items in the Student Book. Instructions for constructing a concept map can be found in the Teacher Edition.

FRAYER MODEL

What It Is

The Frayer Model is a graphic organizer used in direct instruction of discipline-specific vocabulary. In a Frayer Model, students define a word and examine its characteristics and then offer examples and non-examples to build a deep conceptual understanding of the word.



Why Use It?

The Frayer Model offers support as students examine the conceptual meaning of discipline-specific vocabulary. The Frayer Model supports the conceptual development of terms and concepts as they are introduced. Students can return to the Frayer Model as they continue to use the word throughout a course of learning to revise the model, based on their deepening understanding of the word.

Where It Is

Frayer Models can be found in the Teaching Steps in the Teacher Edition and as Build Understanding items in the Student Book.

VENN DIAGRAM

What It Is

A Venn diagram is a strategy for comparing the relationship between two ideas or concepts in a simple visual format. Students visually map the characteristics that are unique to a set of ideas or concepts and the characteristics that are shared.

Why Use It?

By placing words on a page in relation to each other and then explaining their placement, students show that they understand the meaning of each word and the relationship between them. A Venn diagram can be used as a focus for a discussion or for a writing assignment that asks students to compare and contrast ideas. It can also be used as a formative assessment that probes students' understanding of a set of concepts. The simplicity and flexibility of setting up a Venn diagram makes it easily adaptable to many classroom situations.

How To Use It

A Venn diagram involves drawing two to four overlapping circles, each labeled according to the subject being compared. In the outer part of each circle, students write the information that is unique to the subject of the circle. In the overlapping spaces, they write the elements common to all subjects. Students may complete Venn diagrams as a class, in groups, or individually.

Where It Is

Venn diagrams can be found in the Teaching Steps in the Teacher Edition and as Build Understanding items in the Student Book.

WORD SORT

What It Is

A word sort is a categorization activity that helps students synthesize science concepts and vocabulary. Students classify words and phrases into categories based on the relationship between them.

Why Use It?

Word sorts encourage students to accurately draw on what they've learned and to use logic to determine how different words and phrases are related. Teachers can use students' explanations as a formative assessment of how well they understand the overall concepts.

How To Use It

Students are first asked to look for a relationship among a list of four or five words or phrases related to a topic and to cross out the one word or phrase that does not belong. Next, they are asked to circle or highlight any word or phrase that includes all the other words. (There may be more than one correct answer to a single word sort.) Finally, students must explain how the circled word or phrase is related to all the other words or phrases in the list.

Where It Is

Word sorts can appear in the Teaching Steps in the Teacher Edition or as Build Understanding items in the Student Book.

DIRECTED ACTIVITY RELATED TO TEXT (DART)

What It Is

A Directed Activity Related to Text (DART) supports reading comprehension and critical thinking by having students interact with and manipulate the information they are reading. Examples of DARTs are matching and labeling exercises, sequencing, grouping, predicting, and completing a diagram or table. DARTs that require higher-order processing include extracting information and placing it in tables and flowcharts.

How To Use It

A DART must be prepared before students begin so that it can be tailored to a particular text. Students usually complete the DART after they finish the reading. To help students further engage with the content, they may discuss the DART in groups before completing it or complete it as a group.

Where It Is

DARTs are usually found as Build Understanding items or as Student Sheets in the Teacher Edition for the activity in which they are used.

READ, THINK, AND TAKE NOTE

What It Is

Read, Think, and Take Note is a strategy that helps students externalize their thinking by recording their thoughts, reactions, or questions on sticky notes as they read. The notes serve to make concrete the thoughts arising in students' minds and then serve as prompts to generate conversation or write explanations.

Why Use It?

Asking students to record thoughts on sticky notes as they read helps with literacy development by providing a structure for students to record the thinking process. Students may later return to that record to clarify misconceptions or to add depth to their thoughts. The notes also provide a way for the teacher to see how students think as they read, enabling the teacher to select appropriate supports. For example, a student who is unsure of the meaning of a word benefits from the teacher's suggestion to look up the definition. Or, if a student has noted how a reading reminds them of an event from their own life, the teacher can note how making those connections helps with comprehension.

How To Use It

Teachers can explain to students that as they follow this strategy, they are learning some ways that proficient readers think while reading. After reviewing the Read, Think, and Take Note Guidelines in the Student Book, teachers can then model the strategy, using a section of text from the Student Book. There are many ways to respond to text, and each student will create a unique set of comments. Teachers should emphasize that everyone is learning and has questions and that they should all be respectful of one another's ideas. One option is to conduct small-group discussions or a class discussion during which students can clarify any points of confusion, and the teacher can see how students are interpreting the reading.

Where It Is

The Read, Think, and Take Note Guidelines can be found in the Student Book and the Teacher Edition.

WORD WALL

What It Is

A word wall is a collection of words displayed in a classroom for students to use during reading and other classroom activities.

Why Use It?

Word walls are interactive tools that can help students build vocabulary, support reading, and make connections between ideas. The prominently displayed words provide a visual point of reference when students are reading, writing, and discussing their ideas.

How To Use It

Consider the instructional goals of the activity or unit and select vocabulary terms that are important for the topic. Display the words prominently on a wall, bulletin board, or other surface. The words should be visible at all times during class and can be organized alphabetically or grouped, based on the topic.

Where It Is

Suggestions for when to use or add terms to a word wall can be found in the Teacher Edition for the activities in which it is used.

DEVELOPING COMMUNICATION SKILLS

What It Is

The Developing Communication Skills Visual Aid is a tool to help students effectively participate in class discussions. It promotes positive classroom discourse by suggesting how students might appropriately express disagreement, seek clarification, or build on one another's ideas.

How To Use It

Suggestions are presented in the form of sentence starters that students can use to initiate a conversation and express their ideas. Teachers can gradually incorporate this strategy into group work by introducing one sentence starter at a time to elicit students' ideas.

Where It Is

The Developing Communication Skills Visual Aid can be found in the Teacher Edition for the activities in which it is used.

DEVELOPING COMMUNICATION SKILLS

COMMUNICATION	SENTENCE STARTERS
to better understand	One point that was not clear to me was . . . Are you saying that . . . ? Can you please clarify . . . ?
to share an idea	Another idea is to . . . What if we tried . . . ? I have an idea—we could try . . .
to disagree	I see your point, but what about . . . ? Another way of looking at it is . . . I'm still not convinced that . . .
to challenge	How did you reach the conclusion that . . . ? Why do you think that . . . ? How does it explain . . . ?
to look for feedback	What would help me improve is . . . Does it make sense, what I said about . . . ?
to provide positive feedback	One strength of your idea is . . . Your idea is good because . . .
to provide constructive feedback	The argument would be stronger if . . . Another way to do it would be . . . What if you said it like this . . . ?
to discuss information presented in text and graphics	I'm not sure I completely understand this, but I think it may mean . . . I know something about this from . . . A question I have about this is . . . If we look at the graphic, it shows . . .

WALKING DEBATE

What It Is

A Walking Debate allows students to practice oral argumentation. The teacher designates specific locations around the classroom that represent differing perspectives on an issue. Students stand in the location that best represents their opinion regarding the issue. In turns, students argue for the merits of their perspectives and support their arguments with evidence. As they hear others' arguments and evidence, students can opt to change their opinions and physically move to the area of the room that best represents what they now believe.

Why Use It?

Walking Debates require students to physically engage in oral discourse in the classroom. By committing to a position, both literally and figuratively, Walking Debates support oral discourse that uses claims, evidence, and reasoning. Students' engagement in scientific argumentation is motivated by seeing the distribution of perspectives among their classmates. Research also suggests that the inclusion of movement in the activity provides sensory input to the brain that enhances learning.

How To Use It

Begin by identifying the question or issue to be debated and designate different parts of the classroom as representing certain points of view. For example, for the question *Which vehicle do you think is safer, Vehicle 1 or Vehicle 2?*, one corner of the room could be designated as Vehicle 1 and a different corner designated as Vehicle 2.

Students walk to the corner that best represents their point of view and then talk within that group to come up with a convincing argument to bring people from the other area(s) to their own area. It is helpful to have students keep a record of the evidence they will consider for the Walking Debate, especially when they are new to the strategy. Teachers might also have students work in pairs to generate the evidence.

Each group makes its presentation, and students from the other group(s) may ask questions. When all groups have presented, students who change their minds move to the area that represents their final position.

Where It Is

Walking Debates are usually identified in the Procedure steps in the Student Book. The corresponding Teacher Edition provides instructions on how to run the specific debate.

SCIENCE NOTEBOOK

What It Is

The science notebook is an informal place for students to record their ideas and develop new constructs that aid in their sensemaking. In their notebooks, students bring together their ideas as they make sense of the unit issue and key concepts.

Why Use It?

A science notebook allows students to authentically engage in the practices of science. It supports students' efforts to process ideas, ask questions, keep track of data during investigations, and build their scientific-observation skills and writing skills. Students can also use the science notebook to keep complete records of their data and investigations.

How To Use It

When introducing science notebooks, introduce guidelines for how to keep good records and model how students should record information. Include the purpose, background, hypothesis, experimental design, data, and conclusion for an investigation.

Where It Is

The Student Book regularly prompts students to use their science notebooks, particularly during Procedures.

WRITING FRAME

What It Is

A Writing Frame creates an outline to guide student composition. It can be geared to a particular type of explanatory writing, such as arguments that depend on evidence. Through prompts that students briefly respond to in writing, the Writing Frame leads students to develop headings, sentences, and main content points.

Why Use It?

Writing Frames are an excellent strategy to help students develop and organize their ideas prior to writing extended analysis-item responses or completing a writing assignment. Writing Frames also support assessment of student work.

How To Use It

Teachers first provide direct instruction on the appropriate type of Writing Frame and the components it includes. When introducing the Writing Frame, teachers instruct students on the components essential to the structure of the essay, including an opening sentence that states the decision or conclusion each student has come to, evidence that supports the decision or conclusion, and a discussion of the trade-offs associated with their conclusion.

Where It Is

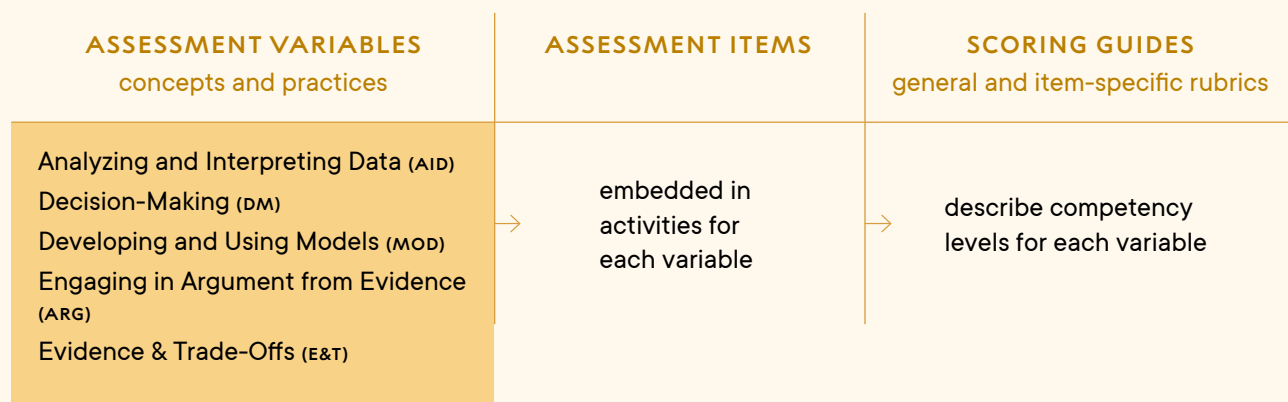
The Writing Frame Student Sheet can be found in the Teacher Edition for the activities in which it is used. Sample student responses are also located in the Teacher Edition.

APPENDIX 2

ASSESSMENT RESOURCE

The assessments provided in *Scientific Thinking for All: A Toolkit* are designed to be used as formative and summative assessment of students' progress. Assessments support classroom instruction while ensuring that students are provided with adequate opportunities to demonstrate their developing understanding of the content and receive feedback to further this learning process. Teachers can use this research-based approach for interpreting students' work to monitor and facilitate their progress. The assessment approach for the course shifts the assessment of knowledge from **what students know to how they are able to apply what they know**. As such, students engage in the key concepts and process skills of the course as they analyze evidence and make decisions related to everyday issues.

Assessment tasks are embedded in the curriculum and are an integral part of the learning activities. Teachers can use these assessments to inform future instruction, with the aim of helping to enhance students' learning. This is done through the use of purposefully designed assessment variables, assessment items, and Scoring Guides, as shown in the following diagram and description of each component.



ASSESSMENT VARIABLES

The assessment variables listed in the second column of the following table are the key areas across which students are expected to progress throughout a unit or sequence of units. Each unit focuses on one of these variables as shown here.

UNIT	ASSESSMENT VARIABLE	DESCRIPTION
1 Evidence & Iteration in Science	Evidence and Trade-Offs (E&T)	This Scoring Guide is used when students are making a choice or developing an argument about a socioscientific issue where arguments may include judgments based on nonscientific factors.
2 Scientific Modeling	Developing and Using Models (MOD)	This Scoring Guide is used when students develop their own models or use established models to describe relationships and/or make predictions about scientific phenomena.
3 Scientific Uncertainty and Probabilistic Reasonings	Analyzing and Interpreting Data (AID)	This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.
4 Investigating Evidence for Causation	Analyzing and Interpreting Data (AID)	This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.
5 Human Bias in Science	Engaging in Argument from Evidence (ARG)	This Scoring Guide is used when students are developing arguments about alternative explanations of scientific phenomena.
6 Group Decision-Making	Decision-Making (DM)	This Scoring Guide is used when students are making a decision by integrating evidence, facts, and values.

Within each unit, the focus should be on progress, and each student's goal should be to improve with each subsequent assessment in a unit. Across the units, the variables build on one another as the curriculum progresses. Over time, the progression of variables supports students' increasing sophistication in using the conceptual thinking tools of the curriculum for decision-making in their everyday lives. For example, in Unit 1, students are assessed on their ability to use evidence to make a decision and identify simple trade-offs based on that decision. By Unit 5, students' understanding of how evidence is used in claims has increased, and they are expected to articulate their decision using more complex claims, evidence, and reasoning.

ASSESSMENT ITEMS

Assessment items are questions, tasks, or prompts related to the assessment variables that are designed to gather evidence about students' progress. Assessment items may take the form of a procedural step, a Build Understanding or Connections to Everyday Life prompt that asks students to communicate about a new idea, analyze data from an experiment, model concepts and relationships, transfer their understanding to a novel context, or make predictions. For example, in Unit 6, students make a recommendation for a fictional community's energy generation system. After their group collectively comes up with a recommendation, each student is assessed on their individual response to a Build Understanding item that prompts students to describe in detail how they used facts and values to make a decision.

SCORING GUIDES

Scientific Thinking for All: A Toolkit Scoring Guides directly correspond with each assessment variable and are used to interpret students' responses. Scoring Guides allow teachers and students to monitor students' growth and encourage their progression from novice to expert on each variable. The general Scoring Guides are formatted as holistic scoring guides. Additionally, all items designated as assessments within the curriculum also have detailed Item-Specific Scoring Guides with criteria specific to each assessment item. These Item-Specific Scoring Guides can be found in the Teacher Edition for the activity in which a summative assessment appears.

Students' responses are categorized into the following scoring levels:

Level 4	Complete and correct
Level 3	Almost there
Level 2	On the way
Level 1	Getting started
Level 0	Missing or off task

To achieve a particular scoring level, a student's response must fulfill all the requirements of that level. A Level 4 response indicates that the student has mastered the practice or concept. The Teacher Edition includes Level 1–4 student exemplar responses in the Teaching Steps or sample responses for each designated assessment item.

Note that while the Scoring Guides involve assigning numerical values to student work from 0 to 4, these scores are not equivalent to a grading system. Rather, scores on assessment items are indicative of the level of performance demonstrated by the student on a specific task, evaluated through a clearly defined lens. They are meant to reflect levels of performance on individual tasks, whereas a grading system inevitably reflects the goals and desired outcomes of a district, school, and/or teacher.

USING A SCORING GUIDE

Initially, it is not reasonable to expect students to perform at Levels 3 and 4. The targets for a scoring level may vary over the course of a unit and a school year. Likewise, it is not always useful to use students' work to set the standards for each scoring level. For example, the best student response should not automatically be given a score of 4. The important thing is that both teacher and student understand what each various scoring level represents and that it can identify growth over multiple uses of the Scoring Guide. For most students, achieving consistent improvement of one level or more in an assessment variable over the course of a unit is an indicator of academic progress.

Before using a Scoring Guide, teachers must make sure that the criteria for each scoring level are clear to themselves and their students and that everyone understands the distinctions between levels. While the Item-Specific Scoring Guide is provided only for teacher use, as it can reveal an appropriate response, students should be provided the general Scoring Guide in advance of an assessment item. They should be encouraged to refer to the Scoring Guide as they develop their responses. This helps them develop the ability to evaluate their own work and take on more ownership of their learning.

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