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.

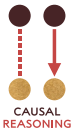
ACTIVITY TYPE
INVESTIGATION

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).**

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.

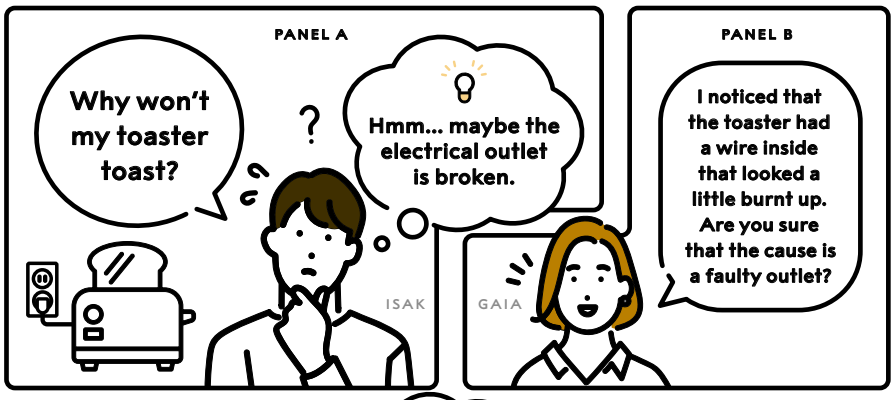
I tried listening to calming music before bed to help me sleep better. It was effective because I felt more relaxed and fell asleep faster than usual.

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.

REFERENCES

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



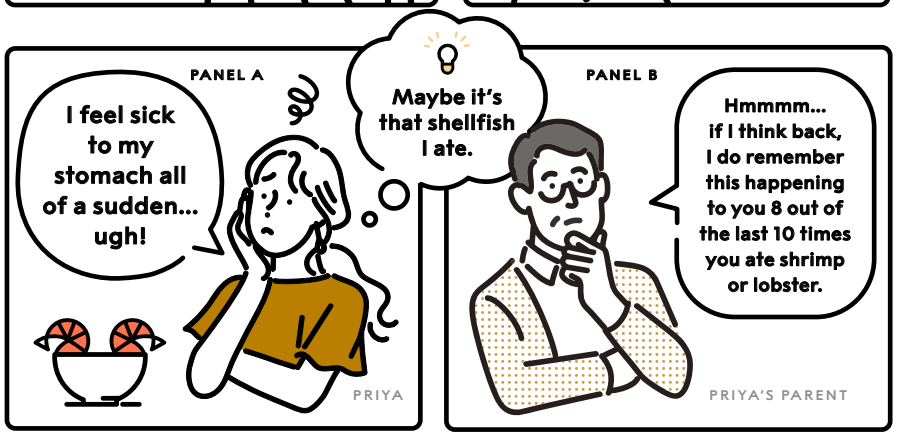
Cartoon 1

KIND OF QUESTION ABOUT CAUSATION

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



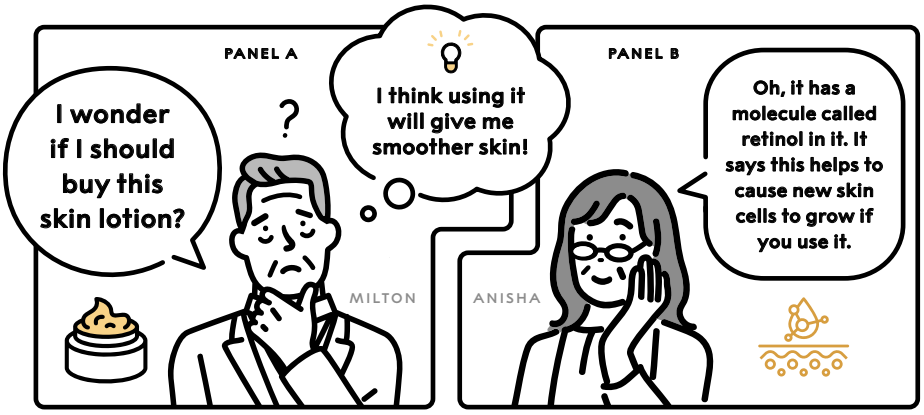
Cartoon 2

KIND OF QUESTION ABOUT CAUSATION

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



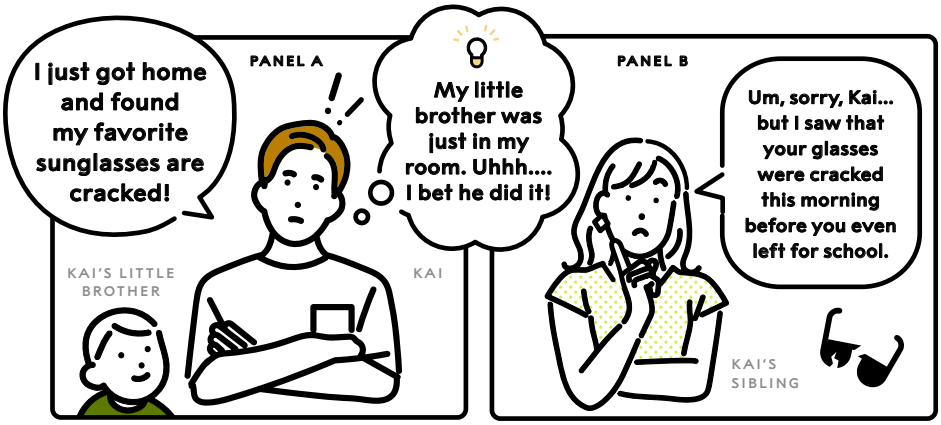
Cartoon 3

KIND OF QUESTION ABOUT CAUSATION

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



Cartoon 4

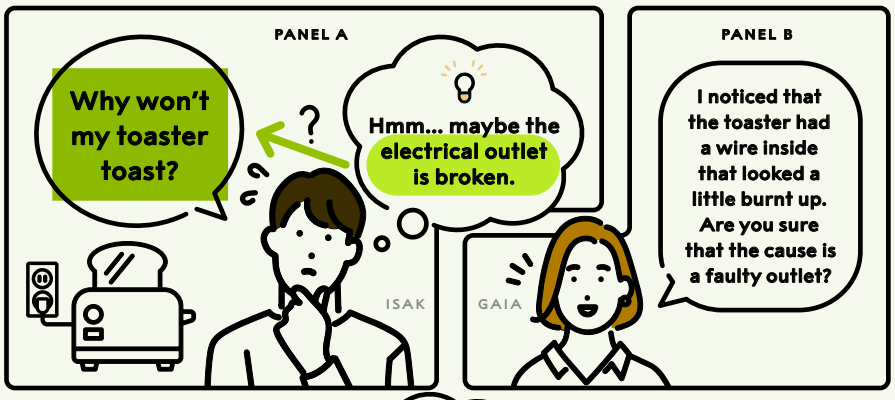
KIND OF QUESTION ABOUT CAUSATION

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM

SAMPLE STUDENT RESPONSE



Cartoon 1

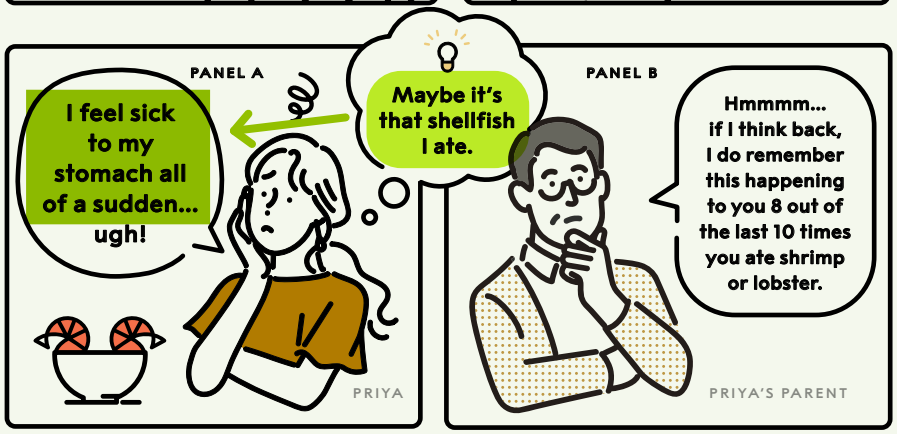
KIND OF QUESTION ABOUT CAUSATION

Alternative Explanation

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



Cartoon 2

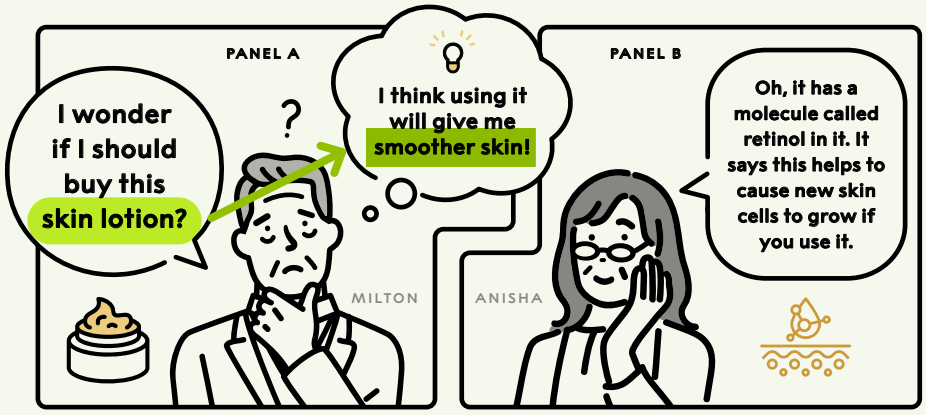
KIND OF QUESTION ABOUT CAUSATION

Association

CIRCLE ONE:

STRENGTHENS CLAIM

WEAKENS CLAIM



Cartoon 3

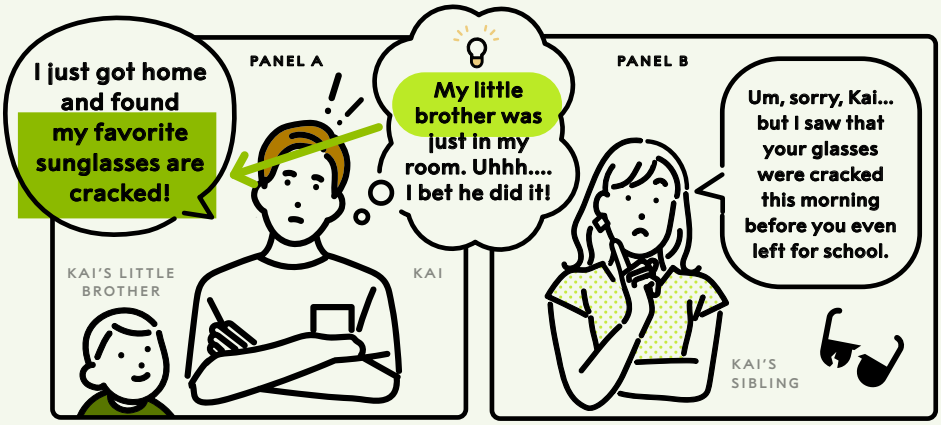
KIND OF QUESTION ABOUT CAUSATION

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?**

VISUAL AID 3.1b | THE CASE OF THE SPILLED PAINT: QUESTIONS ABOUT CAUSATION

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