Cause and Effect: Mechanism and Explanation

If something happens there is a cause. Investigating and explaining cause and effect relationships and their mechanisms help students build an understanding of the rules that govern the natural and engineered worlds. What, why, and how questions can be used to determine the effect (what), the cause (why), and the mechanism (how). Mechanisms can be tested across given contexts and used to predict and explain new contexts.

K-2	3-5	MS	HS
• Events have causes that generate observable patterns. • Simple tests can be designed to gather evidence to support or refute student ideas about causes.	• Cause and effect relationships are routinely identified, tested, and used to explain change. • Events that occur together with regularity might or might not be a cause and effect relationship.	• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. • Cause and effect relationships may be used to predict phenomena in natural or designed systems. • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.	• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. • Systems can be designed to cause a desired effect. • Changes in systems may have various causes that may not have equal effects.

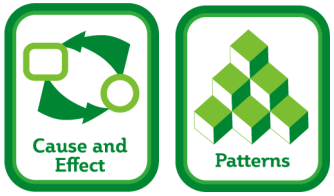
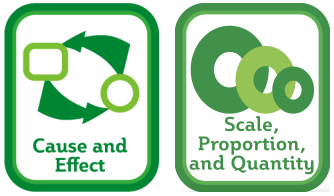
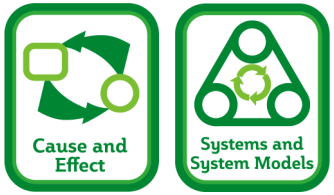
Sample Prompts and Questions

- What happened? Why did it happen? How did it happen?
- What caused the patterns you observed?
- What caused the pattern to change?
- How do the patterns in the data allow you to decide whether _____ caused _____?
- How do you know that ____ caused ____? What evidence can you provide?
- Does the fact that the data showed that ____ happened [after/ whenever] ____ mean that ____ causes ____? Why or why not?
- What [properties, entities, or rules] that aren't described explain what you see happening?
- Draw a diagram that shows how changes to [one component of the system] affects components that are not directly connected to that component.
- How does ____ affect ___?
- How does changing ___ affect ____?
- How do ____ and ____ affect ____? What evidence can you provide?
- How do ____ and ____ affect each other over time?
- How can a small change to ____ have a big effect on ____?
- Why does a [small/big] change to ____ have a [big, small] effect on ____?
- What evidence presented supports the claim that ____ causes ____?
- Is the evidence presented sufficient to conclude that ____ caused ____? If not, what additional evidence is needed?
- Why does ____ cause the observed changes in the system?
- What causes ____ to move into and/or out of the system?
- Would you say that the relation between _____ and _____ is causal or correlational? What evidence can you provide?

Sample Prompts and Questions for Cause and Effect (continued)

- What are some other possible causes for ____?
- How can you represent this cause and effect relationship with an expression or equation? Describe the process that connects the cause and effect.
- What [properties, entities, rules] explain what you see happening [in the scenario]?
- How can you design a test to [gather evidence/refute ideas] about a possible cause?
- What cause and effect relationship(s) can you identify?
- If your [observations/data] show that two things happen together regularly, does this mean that one caused the other? How do you explain this?
- What feedback loops are causing this system to be in [balance/equilibrium]?
- What other causes may help you explain this phenomenon?
- What is the probability that _____ caused _____? How do you know?

Cause and Effect Coupled with Other Crosscutting Concepts

	K-2	3-5	MS	HS
		• Patterns of change can be used to make predictions.	• Patterns can be used to identify cause and effect relationships.	• Empirical evidence is needed to identify patterns. • Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.
			• Scientific relationships can be represented through the use of algebraic expressions and equations.	• Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).
			• Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.	• Systems can be designed to do specific tasks.

Sample Prompts and Responses (Cause and Effect)

Example 1: This example provides sample prompts and possible student responses based on the identified phenomenon when using **cause and effect** coupled with **patterns** and **stability and change**.

Phenomenon: A drinking straw appears to be bent and larger when it is placed in a bottle of water.

Possible Prompts	Possible Student Responses
• What *causes* the straw to look different above and below the liquid?	• The *causes* of the straw looking different above and below the water are due to how light is refracted differently in air and water.
• Why does *changing* the density of the fluid *affect* how light moves through the liquid?	• When light interacts with matter it is *changed* causing it to *change* speed. The density increases the amount of matter the light interacts with and so how the matter *affects* the path of light depends on the density of the liquid it is traveling through.
• How are properties of light *affected* by its interaction with matter?	• The interaction of light with matter *causes* the velocity and wavelength of the light to *change*, but not its frequency. The *changes* in the light wave *cause* objects to bend.
• What *patterns* do you see that can be used as evidence that light *behaves differently* as it travels from one medium to another?	• The *change* in the appearance of the object is *caused* by differences in the densities of the liquids the light passes through; the *pattern* we see from the investigation is that the denser the liquid, the more the object appears to be bent.

Example 2: This example provides sample prompts and possible student responses based on the identified phenomenon when using **cause and effect** coupled with **systems and system models**; **energy and matter**; **system and system models**; **stability and change**; and **scale, proportion, and quantity**.

Phenomenon: When oysters are added to a tank that has cloudy sediment-filled water, the water in the tank becomes clearer than a tank without oysters.

Possible Prompts	Possible Student Responses
• How do differences in the components of each tank *cause* *changes* in the two *systems*?	• The only difference between the two *systems* is the oysters are in one tank, but not the other. • The *system* with oysters *changes* by becoming clearer, but the tank without oysters does not appear to *change*.
• How does the *matter* move between the components of each *system*?	• Water and sediment are *matter* and the sediment stays in the oysters and the water moves through the oysters. The oysters are part of the *system* but are a *system* themselves. • Sediment stays in the oyster's' body *system*, but water moves out of the

	oyster's' body *system*. • In the tank without the oysters, the *proportion* of water and sediment does not *change*.
• What *changes* in the *system* would you predict to be observable after *one minute, one hour, two days*?	• The proportion of gunk causing cloudiness in the system will decrease over time because the oysters are causing a change in the system. • The system will change more after one day than after one minute. • The quantity of sediment removed after one day is greater than after one hour.
• How does the number (*quantity*) of oysters in the tank *affect* the rate of *change* in the *system*?	• Putting more oysters in the *system* will *cause* a faster *change* in the tank. • The *system* will not *change* without oysters in the tank; perhaps the tank will not clear up at all.
• How does your model show *changes* in the *system* that are difficult to see directly?	• We can't see inside of the oysters, but our model shows the oyster as a living *system* and the sediment stays inside of the oyster *system*. • Our model shows *changes* that are too slow or too small to see directly.
• How does your model demonstrate how oysters *change* the number of particles of matter in the water?	• Our model shows *changes* in the *quantity* of particles in the water. • Our model shows that oysters decrease the *quantity* of particles in the water.
• How long will it take for the oysters to *cause* a *change* in the water quality (clarity?) of the Chesapeake Bay ecosystem?	• The *changes* to the *system* will take a long time because the *scale* of the Chesapeake Bay is much larger than the aquarium. You know more water and more sediment, but hopefully there will be more oysters too. • Perhaps it is the *proportion* of oysters to water and sediment in the two *systems* that is different, so it will take a long time for *change* to occur. But the oysters will help *cause* the *change* in the *system*.

This resource was developed by the San Diego County Office of Education (2023) and is adapted from: *Using CCCs to Prompt Student Responses, by CCSSO, 2018; STEM Teaching Tool #41: Prompts for Integrating the CCCs into Assessment and Instruction, by William Penuel and Katie Van Horne, 2018;* and *NGSS Appendix G - Crosscutting Concepts, 2013*.