

## Default Assumptions About Causal Patterns That Impede Science Learning

Students tend to assume that causality is:	Example	Instead of:	Example
Linear	When I suck on the straw, I make the juice come up.	Nonlinear	I create less air pressure inside the straw than outside, so the imbalance results in the juice getting pushed up the straw.
Direct without intervening steps	Green plants matter to animals that eat them but not to animals that eat the ones that eat green plants.	Indirect	If the green plants disappeared, it would eventually impact other organisms in the food web.
Unidirectional	Bees take nectar from flowers for their food.	Bi-directional or mutual	Bees take nectar from flowers for their food and they cross-pollinate the flowers resulting in the production of fruit.
Sequential with step-by-step processes	The electrons crowd onto the circuit going to each bulb. The first one gets power first.	Simultaneous	The electrons move like a bicycle chain turning in a circle all at once making the bulb light when it moves.
The result of obvious, perceptible characteristics	The object sinks because of its weight.	The result of non-obvious, imperceptible variables	Density, an intensive quantity, impacts sinking and floating.
Due to active or intentional agents	The electrons move to make static electricity.	Due to passive or unintentional causes.	Protons and electrons are attracted to each other. Seat belts passively cause us to stop when the car stops.
Event-based	If something happens I pay attention to it.	Due to steady states	Bridges stand because of balanced forces.
Deterministic; Effects always follow "causes"	I did it before and didn't get sick, so it won't make me sick.	Probabilistic	Getting sick depends upon many things. Even if I didn't get sick before, I can still get sick now.



Spatially close to its effects	Satellites have a driving force in them.	Distant	The forward motion of the satellite and Earth's gravitational attraction result in a satellite's path.
Temporally close to its effects	I can't see any bad effects of getting a suntan right now.	Having a delay between cause(s) and effect(s)	The hurtful effects of getting a suntan accumulate and appear after a delay between cause and effect.
Due to the first cause that they identify	The boiling of the water is the result of the flame under the container. The writing on cemetery stones is hard to read because of the age of the stone.	Potentially the outcome of a different single cause (If there are multiple sufficient causes) or the outcome of multiple causes in combination	The boiling of the water is due to increasing the pressure in the container by reducing the volume. The writing on cemetery stones may have eroded due to combinations of acid rain, physical abrasion, the softness of the stone, etc.
Centralized with few agents	The queen bee directs the activity in a beehive.	Decentralized with distributed agency and emergent effects	The behaviors and interactions of many bees result in an organized system.