

Designing Experiments – Cause and Effect Relationships

- » In Canada many people wash their cars or fill bird baths with cold water during winter months. Why? Because they believe it will delay freezing of the water (the cold water will freeze more slowly than the hot).
- » In Tanzania a high school student was participating in a high school science fair project making ice cream. The experimental design was to heat milk, mix in sugar (why then?), let the mixture cool to room temperature (???), and put into a walk-in electric freezer to freeze. By accident, due to being late for class, he didn't bother to cool the mixture and a fellow classmate didn't even bother to heat his mixture before both were placed in the freezer. They were shocked to find that the hot mixture froze minutes before the originally cooler mixture froze.
- » Can you identify variables in the experimental design? What variables would be held constant and why? How could he change the experimental design to reduce the number of variables?
- » What are three possible scientific reasons why hot water might freeze faster than cold water?
 - a) In the container with the hotter sample of water the hot water in the central region moves rapidly to the walls of the container and to the top surface of the liquid where heat is lost quickly. This process is known as _____.
 - b) Heating the water causes dissolved gases to be released (come out of solution). Water with dissolved gases cools more slowly than water that has lost dissolved gases. Think about three examples: wrapping water pipes under your house during the winter, preferences by fish for either warm pond water or cold mountain streams, and soft drinks losing their carbonation.
 - c) The warmer water will lose mass due to evaporation at a much faster rate than the cooler water. Less mass from which heat must be removed allows a much faster change in temperature.
- » To isolate just one variable for study at a time:
 - a) boil water to remove any dissolved gas – allow all to remove to room temperature before starting the experiment.
 - b) remove any impurities from water used
 - c) cover beakers to prevent evaporation (how)
 - d) do not use dehumidifier blowers in freezer
 - e) use identical beakers with cork mats underneath each one
 - f) keep door closed
 - g) use thermistors with computer interfaces to monitor temperatures
 - h) develop technique for moving water from heat to freezer area consistently

Experimental Objective: Measure time needed for water to reach 0° C (will have a thin layer of ice on surface)

Results:

- a) 50 mL of water in beaker at 99° C reached freezing point 7 minutes faster than water that began at 60° C.
- b) 100 mL of water at 95° C reached freezing point 3 minutes before water starting at 80° C.

Conclusions:

- a) evaporation losses are very important
- b) from surface, heat loss is primarily by evaporation; from sides, heat loss is by convection and radiation

Experimental Options:

- a) in walk-in freezer use beakers on lab scales to identify loss of mass
- b) try fresh water versus boiled water, tap water versus distilled
- c) add salt – lowers the freezing point
- d) try alcohol instead of water (it evaporates quickly)
- e) try different methods to reduce evaporation (oil on surface)

Data Collection Definitions

- a) hypothesis – explanation made to answer or solve the problem
- b) theory – usually explains many observations
- c) controls – things kept the same during each experimental run
- d) variables – things that change to allow for experimentation
- e) model – idea or set of equations that ties together bits and pieces of information on a single concept
- f) conclusion – a judgment based on analysis of data from experiments
- g) law – only describes what happens (not why it happens)
- h) Scientific Method – build models to explain the Universe – these models, theories, laws change as we seek the best possible explanation
 - 1) observe phenomena – see something that we can repeat under controlled conditions
 - 2) educated guess – make hypothesis (a reasonable explanation)
 - 3) test hypothesis – do this experimentally or mathematically – control all variables except the one you are interested in
- i) There is no absolute proof – if hypothesis works out you can call it a theory – if theory holds on long enough you can call it a law (as long as no one can find a single exception).

Ice Age Problem of 30 million years ago:

» Earth's climate patterns would have predicted a normal warm period 30 million years ago. How would a prediction such as this be made? Look for causal factors occurring in the world at that time (what would cause an ice age to occur?) What big thing happened that might have some effect on global climate?

- a) Himalayan mountains were formed when the Indian tectonic plate was pushed upward into Asia forming the Tibetan Plateau
- b) 1st supposition = did this huge elevation change of the plateau have the needed effect to cause an ice age? A large land mass elevated to 15 000 feet would cause air masses coming from the West to go upward resulting in cooling which would cause large amounts of rainfall. Would this lower global temperatures enough to start glaciation processes? NO
- c) What other global changes occurred that might in fact change the temperature enough for this glaciation? 2nd supposition = if large amounts of CO₂ were taken out of the atmosphere the heat retention of the atmosphere would decrease thus lowering the global temperature. But what could cause this?

d) When the Himalayan mountains were pushed up this exposed a vast amount of rock – when the tremendous rain that was created by the elevation of the air masses passing over the plateau started falling the water combined with CO₂ in the atmosphere to form a weak carbonic acid which dissolved much of the rock. Was there enough depletion of the CO₂ in the atmosphere for this to happen and how could it be proven?

e) 3rd supposition = when rock is decomposed (by chemical weathering) by carbonic acid a product of this decomposition is the isotope of strontium – 87. To determine if the chemical weathering took place scientists had to look at the amount of strontium – 87 in core samples from off-shore ocean sediments. In layers that represent dates of 30 million years ago the amount of strontium – 87 increases dramatically.

f) Final summation: Plate tectonics start pushing up Himalayas exposing large amount of rock, with a secondary effect of huge amounts of rainfall as the lifted air loses its moisture. This rainfall becomes weak carbonic acid which helps to dissolve the rock. The depletion of CO₂ in the atmosphere decreases the Greenhouse Effect thus lowering the global temperatures enough to start glaciation. (hint: why does increased CO₂ in the atmosphere generate the Greenhouse Effect and raise the global temperature????)

Other Ice Age Ideas:

It is an established idea that melting of glacial ice in North America occurred about 11 000 years ago. This produced Lake Agassiz in central Canada with an average depth of 125 ft and an area of 175 000 mile². There was some drainage into the Mississippi but most of the drainage ran into the St. Lawrence River which drains into the North Atlantic. This changed the salinity of these waters which changed the density.

In the northern hemisphere the ocean currents transport heat from the southern to northern latitudes in what is called the “Atlantic Conveyor”. Warm ocean water goes north at moderate depths till it hits much colder, more dense water near Iceland. It rises to the surface, releases enormous quantities of heat and contributes to the relatively mild climate of Northern Europe. The water, now cooled, is dense enough to plunge downward, and close the loop by flowing southward along the deep ocean floor.

The theory is that the drainage of Lake Agassiz diluted the Atlantic Conveyor water and disrupted the flow. The less dense fresh water diluted the surface water so that the flow to the depths is stopped. In a very short time geologically Northern Europe was deprived of its major source and heat and froze over. The time required for this change can be as little as hundreds of years.

Global warming may cause the gradual melting of polar ice caps which could dilute the Atlantic Conveyor. Over a short period of time the latitudes close to the equator would lose a major heat sink (a mechanism to get rid of heat) and Northern Europe would undergo another ice age.

We will use the Loop Airplane Experiment (found elsewhere on the website) to develop a better awareness of experimental design.