SCIENCESPLOSION™

Curriculum Based Study Guide and Lesson Plan

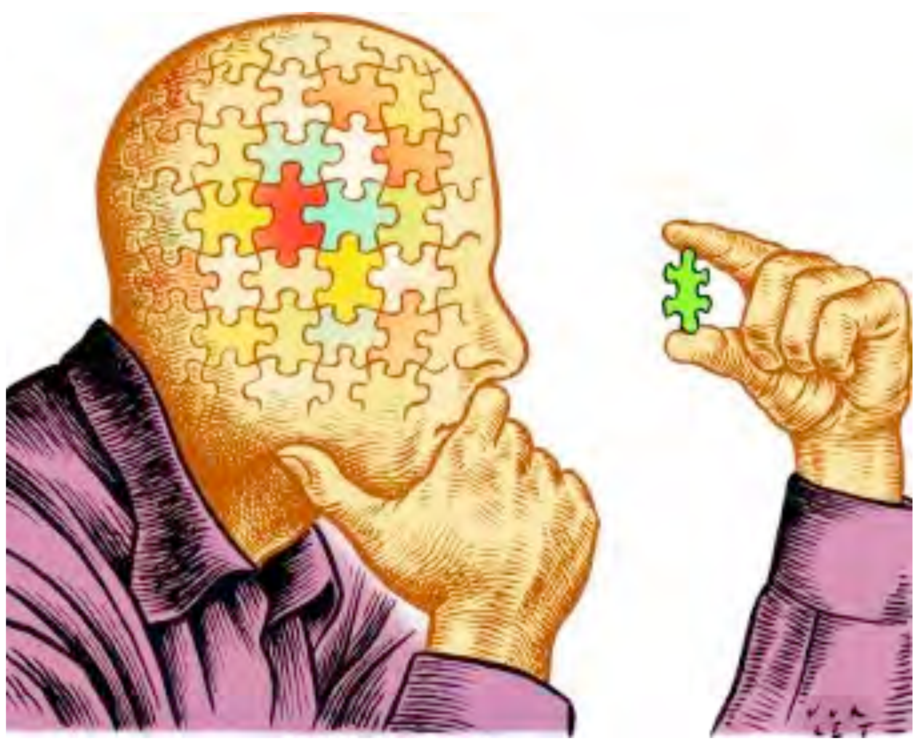
http://nizer.com

Sciencesplosion™ is a educational outreach science program that merges Mark Nizer's stage performance with scientific principles and school curriculum. This guide will give you the background and material that Mark will cover in his Sciencesplosion™ show.

We will cover:

Critical Thinking

- **Critical thinking: Ask open-ended questions.** Asking questions that don't have one right answer encourages students to respond creatively without being afraid of giving the wrong answer.
- **Critical thinking: Categorize and classify.** Classification plays an important role in critical thinking because it requires identification and sorting according to a rule, or set of rules, that students must discover, understand, and apply. If you play classification games at home, be sure to follow up the activity with questions about the similarities and differences between the groups. You can sort everything from dirty laundry to Legos to produce to doll clothes to promote critical thinking.
- **Critical thinking: Work in groups.** In a group setting, students are exposed to the thought processes of their peers. Thus, they can begin to understand how others think and that there are multiple ways of approaching problems — not just one correct way.
- **Critical thinking: Make decisions.** Help your students consider pros and cons, but don't be afraid to let them make a wrong choice. Then evaluate the decision later. Ask your students, "How do they feel about their decision? What would they do differently next time?"
- **Critical thinking: Find patterns.** Whatever you're doing, whether it's going to the park or watching television, encourage your students to look for patterns or make connections for critical thinking practice.



THE SCIENTIFIC METHOD

Introduction to the Scientific Method

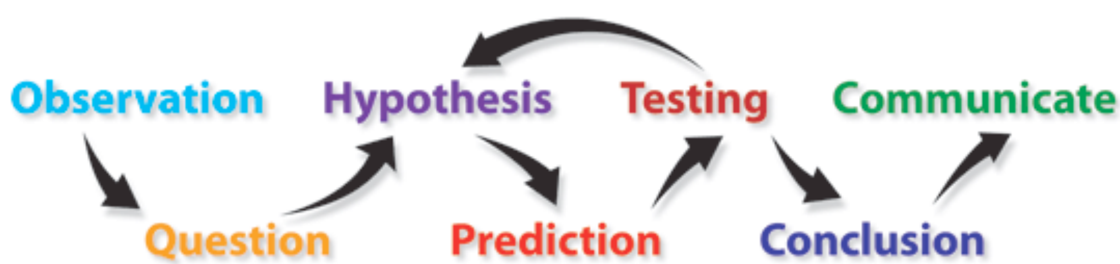
The scientific method is the process by which scientists, collectively and over time, endeavor to construct an accurate (that is, reliable, consistent and non-arbitrary) representation of the world.

Recognizing that personal and cultural beliefs influence both our perceptions and our interpretations of natural phenomena, we aim through the use of standard procedures and criteria to minimize those influences when developing a theory. As a famous scientist once said, "Smart people (like smart lawyers) can come up with very good explanations for mistaken points of view." In summary, the scientific method attempts to minimize the influence of bias or prejudice in the experimenter when testing an hypothesis or a theory.

The scientific method has four steps

- Observation and description of a phenomenon or group of phenomena.
- Formulation of an hypothesis to explain the phenomena. In physics, the hypothesis often takes the form of a causal mechanism or a mathematical relation.
- Use of the hypothesis to predict the existence of other phenomena, or to predict quantitatively the results of new observations.
- Performance of experimental tests of the predictions by several independent experimenters and properly performed experiments.

If the experiments bear out the hypothesis it may come to be regarded as a theory or law of nature (more on the concepts of hypothesis, model, theory and law below). If the experiments do not bear out the hypothesis, it must be rejected or modified. What is key in the description of the scientific method just given is the predictive power (the ability to get more out of the theory than you put in; see Barrow, 1991) of the hypothesis or theory, as tested by experiment. It is often said in science that theories can never be proved, only disproved. There is always the possibility that a new observation or a new experiment will conflict with a long-standing theory.



Testing hypotheses

As just stated, experimental tests may lead either to the confirmation of the hypothesis, or to the ruling out of the hypothesis. The scientific method requires that an hypothesis be ruled out or modified if its predictions are clearly and repeatedly incompatible with experimental tests. Further, no matter how elegant a theory is, its predictions must agree with experimental results if we are to believe that it is a valid description of nature. In physics, as in every experimental science, "experiment is supreme" and experimental verification of hypothetical predictions is absolutely necessary. Experiments may test the theory directly (for example, the observation of a new particle) or may test for consequences derived from the theory using mathematics and logic (the rate of a radioactive decay process requiring the existence of the new particle). Note that the necessity of experiment also implies that a theory must be testable. Theories which cannot be tested, because, for instance, they have no observable ramifications (such as, a particle whose characteristics make it unobservable), do not qualify as scientific theories.

If the predictions of a long-standing theory are found to be in disagreement with new experimental results, the theory may be discarded as a description of reality, but it may continue to be applicable within a limited range of measurable parameters.

We are all familiar with theories which had to be discarded in the face of experimental evidence. In the field of astronomy, the earth-centered description of the planetary orbits was overthrown by the Copernican system, in which the sun was placed at the center of a series of concentric, circular planetary orbits. Later, this theory was modified, as measurements of the planets motions were found to be compatible with elliptical, not circular, orbits, and still later planetary motion was found to be derivable from Newton's laws.

Common Mistakes in Applying the Scientific Method

As stated earlier, the scientific method attempts to minimize the influence of the scientist's bias on the outcome of an experiment. That is, when testing an hypothesis or a theory, the scientist may have a preference for one outcome or another, and it is important that this preference not bias the results or their interpretation. The most fundamental error is to mistake the hypothesis for an explanation of a phenomenon, without performing experimental tests. Sometimes "common sense" and "logic" tempt us into believing that no test is needed. There are numerous examples of this, dating from the Greek philosophers to the present day.

Another common mistake is to ignore or rule out data which do not support the hypothesis. Ideally, the experimenter is open to the possibility that the hypothesis is correct or incorrect. Sometimes, however, a scientist may have a strong belief that the hypothesis is true (or false), or feels internal or external pressure to get a specific result. In that case, there may be a psychological tendency to find "something wrong", such as systematic effects, with data which do not support the scientist's expectations, while data which do agree with those expectations may not be checked as carefully. The lesson is that all data must be handled in the same way.

Another common mistake arises from the failure to estimate quantitatively systematic errors (and all errors). There are many examples of discoveries which were missed by experimenters whose data contained a new phenomenon, but who explained it away as a systematic background. Conversely, there are many examples of alleged "new discoveries" which later proved to be due to systematic errors not accounted for by the "discoverers."

Conclusion

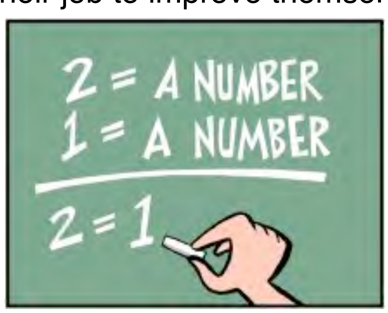
The scientific method is intricately associated with science, the process of human inquiry that pervades the modern era on many levels. While the method appears simple and logical in description, there is perhaps no more complex question than that of knowing how we come to know things. In this introduction, we have emphasized that the scientific method distinguishes science from other forms of explanation because of its requirement of systematic experimentation. We have also tried to point out some of the criteria and practices developed by scientists to reduce the influence of individual or social bias on scientific findings. Further investigations of the scientific method and other aspects of scientific practice may be found in the references listed below.

LOGICAL FALLACIES

A logical fallacy is a flaw in reasoning. Logical fallacies are like tricks or illusions of thought, and they're often very sneakily used by politicians and the media to fool people. Don't be fooled!

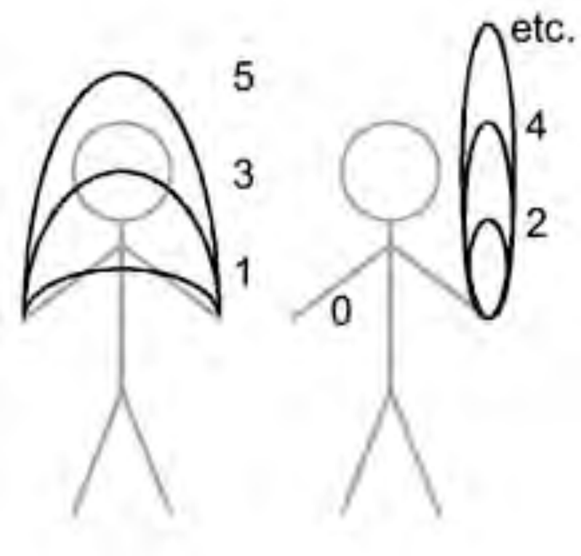
TOP LOGICAL FALLACIES

- **Ad Hominem:** This occurs when an author attacks his opponent instead of his opponent's argument. Example: Trina thinks guns should be outlawed but Trina doesn't go to church, so we shouldn't listen to her.
- **Ad Populum:** Ad Populum attempts to prove an argument as correct simply because many people believe it to be so. Example: 80% of people are for the death penalty, therefore, the death penalty is moral.
- **Appeal to Authority:** In this fallacious argument, the author claims his argument is right because someone famous or powerful supports it. Example: We should change the drinking age because Einstein believed that 18 was the proper drinking age.
- **Begging the Question:** This happens when the author's premise and conclusion say the same thing. Example: Fashion magazines don't hurt women's self esteem because women's confidence is intact after reading the magazine.
- **False Dichotomy:** This fallacy rests on the assumption that there are only two possible solutions, so disproving one solution means that other solution should be utilized. It ignores other alternative solutions.Example: The teacher gives too many A's and therefore must be fired because grade inflation is unfair to other students.
- **Hasty Generalization:** Hasty Generalization occurs when the proponent uses too small of a sample size to support a sweeping generalization. Example: Sally couldn't find any cute clothes at the boutique and neither could Maura, so the boutique doesn't have any cute clothes.
- **Post Hoc/ False Cause:** This fallacy assumes that correlation equals causation or, in other words, if one event predicts another event it must have also caused the event. Example: The football team gets better grades than the baseball team, therefore playing football makes you smarter than playing baseball.
- **Missing the Point:** In Missing the Point, the premise of the argument supports a specific conclusion but not the one the author draws. Example: Antidepressants are overly prescribed which is dangerous, so they should clearly be made illegal.
- **Spotlight Fallacy:** This occurs when the author assumes that the cases that receive the most publicity are the most common cases. Example: 90% of news reports talk about negative events. Therefore, it follows that 90% of events that occur in the real world are negative.
- **Straw Man:** In this fallacy, the author puts forth one of his opponent's weaker, less central arguments forward and destroys it, while acting like this argument is the crux of the issue. Example: My opponent wants to increase teachers' pay but studies have shown that professors with tenure don't work as hard at their job to improve themselves.



THE MATH OF JUGGLING

Juggling contains a hidden math called Siteswaps. Siteswap is a juggling notation used to describe or represent juggling patterns. It encodes the number of beats of each throw, which is related to their height, and the hand to which the throw is to be made: "The idea behind siteswap is to keep track of the order that balls are thrown and caught, and _only_ that." It is an invaluable tool in determining which combinations of throws yield valid juggling patterns for a given number of objects, and has led to previously unknown patterns (such as 441). However, it does not describe body movements such as behind-the-back and under-the-leg. Siteswap assumes that, "throws happen on beats that are equally spaced in time."



Siteswap beats shown as relative height

The numbers are as follows:

- 0 = "missing"/rest [empty hand]
- 1 = pass [between hands]
- 2 = hold [one hand/no toss]
- 3 = (3-ball) cascade toss [between hands]
- 4 = (4-ball) fountain toss [up and into same hand]
- 5 = high toss [between hands]

For example, a three-ball cascade may be notated "3", while a shower may be notated "5 1".The name siteswap comes from the ability to generate patterns from "swapping" numbers in preexisting patterns, such as 55500 and 50505 (or Flash and Snake).

How to check if a siteswap is valid:

For each throw, add up the time of the throw plus the height. Then divide by the period (i.e., the length of the string) and take the remainder.

If all those remainders are different, then you have no collisions, it's a valid siteswap.

Example: If my phone number is 5159. Those are the heights. The times are 1234. So we add heights plus times:

5+1 = 6.
1+2 = 3.
5+3 = 8.
9+4 = 13.

Now the period is 4, so we divide by 4 and take the remainders:

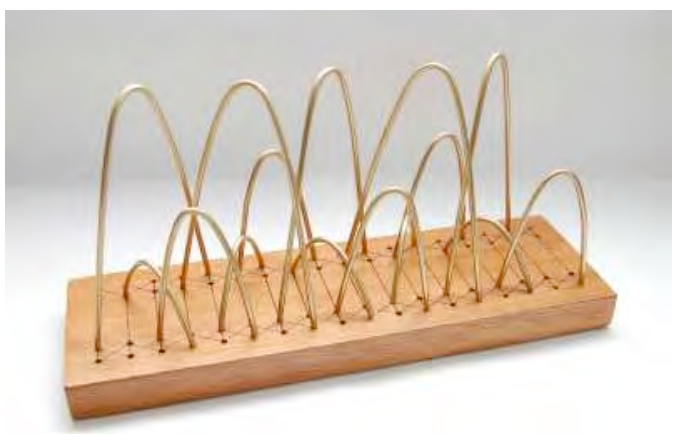
6/4 has a remainder of 2.
3/4 has a remainder of 3.
8/4 has a remainder of 0.
13/4 has a remainder of 1.

2,3,0,1 are all different, so 5159 is a valid siteswap. That means I'm incredibly cool.

If my phone number is 5158:

5+1 = 6.
1+2 = 3.
5+3 = 8.
8+4 = 12.

6/4 has a remainder of 2.
3/4 has a remainder of 3.
8/4 has a remainder of 0.
12/4 has a remainder of 0.



Two 0's means we have a collision, so 5158 is not valid. That means I am not cool.

Evolution

Using juggling as a metaphor students will learn that there are four essential components of natural selection — an important mechanism of evolution:

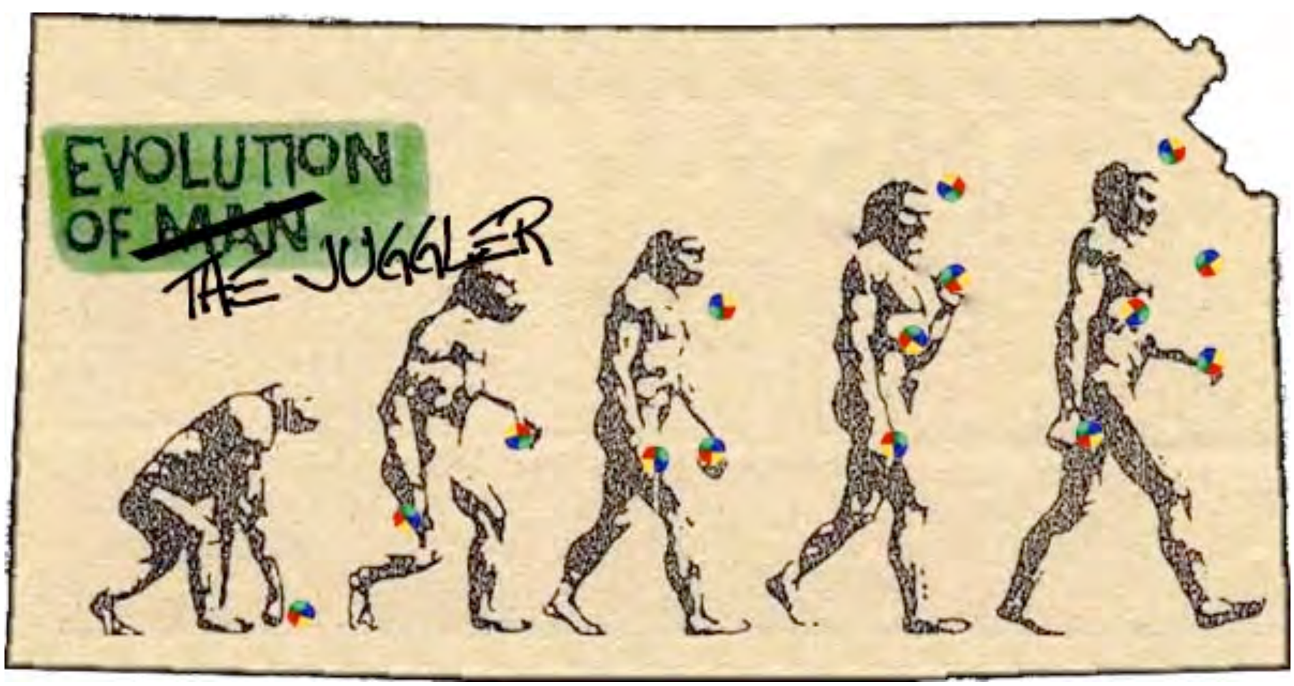
Variation: All life forms vary genetically within a population.

Inheritance: Genetic traits are inherited from parents and are passed on to offspring.

Selection: Organisms with traits that are favorable to their survival and reproduction are more likely to pass on their genes to the next generation.

Time: Evolutionary change can happen in a few generations, but major change, such as speciation, often takes many thousands of generations.

Students should understand several of these components. They should understand that all individual living things have features that they inherit from their parents. However, offspring vary—they do not look exactly like their parents or exactly like one another. Usually, closely related individuals (e.g. brothers and sisters) resemble one another more than do distant relatives (e.g. cousins). This initial awareness of variation and inheritance will lay the foundation for understanding the process of natural selection later on.



ABOUT

Mark Nizer has been performing and teaching juggling for over 40 years. His passion of both juggling and science has led to a life of learning and invention.

Mark can adapt the amount and focus of each of these components to better suit the ages and students present.

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