

AEROSPACE MICRO-LESSON

Easily digestible Aerospace Principles revealed for K-12 Students and Educators. These lessons will be sent on a bi-weekly basis and allow grade-level focused learning. - AIAA STEM K-12 Committee.

ERRORS, HOAXES, AND JUST PLAIN BAD SCIENCE

The development of science is one of the most important accomplishments of humankind: it has allowed us to cure diseases, travel the world (and beyond) and improve the welfare and health of society. While we like to think of the advance of science as a smooth progression forward, the reality is much messier. For every scientific theory that reflects reality and helps in our understanding of the universe, there are many others that are simply wrong. Worse, many people promote theories or make scientific claims that simply do not fit the facts as they are known. Understanding what separates “good” science from “bad” science is important not just for scientists but for all 21st-century citizens.

Next Generation Science Standards (NGSS):

- * Discipline: Earth’s Place in the Universe.
- * Crosscutting Concept: Scale, proportion, and quantity.
- * Science & Engineering Practice: Engaging in argument from evidence.

GRADES K-2

NGSS: Science & Engineering Practice: [Engaging in argument from evidence.](#)

NGSS: Earth’s Place in the Universe: [Use observations of the sun, moon, and stars to describe patterns that can be predicted.](#)

How do scientists figure out how the universe works? The answer is beautiful in its simplicity – they make educated guesses, and see which guesses are the most accurate. Scientists call their “guesses” *hypotheses*; if a scientist wants to understand something, he or she will suggest a hypothesis and then find a way to test it. A hypothesis that has been tested and found accurate is called a *theory*. Scientists will then test the theory further. If the theory matches what scientists see in their tests (or *experiments*), then the theory is a good one. If many scientists do experiments which all support one theory, then that theory becomes accepted as scientific fact. This process, the *Scientific Method*, was formally established by a scientist named Francis Bacon in the 1700s, but scholars and thinkers since ancient times have used similar methods to understand the world.

As you might guess, establishing scientific fact (or *consensus*) can take a long time. Along the way, many theories and ideas turn out to be incorrect. For example, people in very ancient times thought that the Earth was flat because it looked flat to them (except for mountains and valleys). People later realized that the Earth is round but that it is so large

GRADES K-2 (CONTINUED)

that any local area looks flat (there is a common misconception that people in the Middle Ages thought that the Earth was flat, but it is unlikely that any educated person in the Middle Ages believed that).

Later, people thought that the Earth sat still at the center of the universe and that the Sun, Moon, planets, and stars revolved around it – after all, we see the sun and moon rise in the East and set in the West, exactly as they would if they were travelling in circles around the Earth. The Earth must be stationary, people thought; otherwise people would feel a wind all the time as the Earth’s surface moved underneath the atmosphere. Later, scientists realized that there was no wind because the Earth’s atmosphere rotates along with the planet. It took centuries of further observations of the sky for astronomers to figure out that the Moon moves around the Earth while the Earth and the planets revolve in orbits around the Sun.

The development of all of these theories follows the same pattern: scientists take a first look at a phenomenon and make a theory to explain what they observe. Then, they observe the phenomenon further and in more detail; new details force the scientists to revise their theory. Sometimes they need to discard the theory and come up with a new one altogether, like the change from the earth-centered to the sun-centered model. Other times, they can make minor changes to make the theory more accurate. Either way, this process can take a long time—hundreds of years, in the example of planetary motion.

GRADES 3-5

NGSS: Science & Engineering Practice: [Engaging in argument from evidence.](#)

NGSS: Matter and Its Interactions: [Develop a model to describe that matter is made of particles too small to be seen.](#)

When considering scientific theories that turned out to be wrong, we need to resist the temptation to label those who believed those things as stupid. For the most part, those people were just trying to come up with reasonable theories to explain the data that they had at the time. When people in ancient times thought that a moving body is propelled by an “[impetus](#)” which pushed it on until it was overcome by a “resistance,” they were making a guess based on the best observations that they had made. Indeed, [an “impetus” view of motion is the one that comes naturally to people.](#) The “resistance” that the ancients theorized about is now

GRADES 3-5 (CONTINUED)

called “friction.” It was a great insight on the part of scientists like Galileo and Newton that without friction, a body would keep moving forever and ever at a constant velocity. Today, scientists take advantage of this principle to help spacecraft navigate in outer space, where there is no significant friction.

Similarly, the theory that matter is made up of atoms was controversial into the twentieth century. While chemists used atomic theory as a convenient model to explain chemical laws such as the Law of Constant Proportions, there was no direct evidence for the existence of atoms until Einstein used the atomic theory in 1905 to explain Brownian motion. Until then, respectable scientists could differ over whether matter was composed of atoms or whether it was made up of continuous “stuff.” The matter was disputed widely enough that the 1926 Nobel Prize in Physics was awarded to [Jean Baptiste Perrin](#) in part “for his work on the discontinuous structure of matter.”

Many intelligent, successful scientists have believed theories which turned out to be wrong, but there is a difference between supporting a theory which has not yet been proven or disproven, and believing a theory that has already been disproven. People who believed theories which now are outdated or incorrect were doing the best they could with the information which they had; today, people who hold onto older, outdated theories must ignore a lot of newer scientific data which helped inform the scientific consensus on a topic.

GRADES 6-8

NGSS: Science & Engineering Practice: [Engaging in argument from evidence.](#)

NGSS: Earth’s Place in the Universe: [Analyze and interpret data to determine scale properties of objects in the solar system.](#)

Just as some people choose to ignore scientific consensus to believe unproven or disproven theories, some people subscribe to unprovable theories about history or current events – so-called “conspiracy theories.” For example, some believe that people never landed on the Moon. They claim that the Apollo program was a fraud and that everybody involved was induced (bribed, threatened, or otherwise) to keep quiet about it. While it is never possible to disprove a “conspiracy theory” completely—any evidence one presents is called fake and any witnesses are claimed to be part of the conspiracy—one can show that it is unlikely in the extreme. To fake the Apollo lunar landings, conspirators would have to

GRADES 6-8 (CONTINUED)

include not just the astronauts, but also the ground crews, those who supposedly “created” the allegedly false evidence such as the moon rocks, and anybody who could have independently checked whether the moon landings were actually taking place. This last group consists of many people, many more than one would think of at first sight. For example, it includes the government of the Soviet Union, which at the time was racing with the United States to land a person on the Moon and would have been delighted to expose the Apollo lunar missions as a fraud, as well as governments of other countries which also would have been happy to embarrass the United States. It also includes amateur radio operators from around the world who were monitoring the radio broadcasts back and forth from the Apollo spacecraft.

Some conspiracy theorists argue that they are simply using the scientific method to question conventional wisdom, much like scientists throughout history did in the development of our modern understanding of the universe. However, there is a big difference between questioning a scientific theory that doesn’t line up well with existing evidence (such as the earth-centered universe or flat-earth theories) and denying a well-supported scientific or historical idea based on a few pieces of scattered “evidence.”

Several moon-landing conspiracy theorists will point out aspects of the video footage and still photographs taken by astronauts on the moon which they believe to indicate a fraud – such as American flags waving in a vacuum where they should not, shadows pointing the wrong way, and strange lighting. However, these conspiracy theorists ignore scientists who explain that the flag is not waving but swaying slightly from being hammered into the ground; that the shadows point in different directions because the ground is uneven; and that the lunar surface reflects light differently than soils and rocks here on Earth.

Conspiracy theories are inherently unscientific because they rely upon people to ignore scientific consensus. Consensus-independent verification and agreement among educated scholars—is the most important part of the scientific method, so any “theory” which relies upon shrugging off or gainsaying educated scientists without a counterargument is not scientific.

GRADES 9-12

NGSS: Science & Engineering Practice: [Engaging in argument from evidence.](#)

NGSS: Waves and their Applications in Technologies for Information Transfer: [Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.](#)

Ignoring established science is one “red flag” that is likely to indicate a conspiracy theory, hoax, or example of bad science. Here are a few others:

1. **Ignoring established science** – In the 1950s, a psychologist named Immanuel Velikovsky published [several books](#) in which he theorized that the planets Venus and Mars had nearly collided with the Earth in early historical times, causing the plagues of Egypt recorded in the Book of Exodus, before settling down in their present orbits. No matter how many historical sources Mr. Velikovsky cited and how much geological evidence he presented, his theory directly contradicted Newton’s laws of motion, which dictate that planets do not behave like this on a time scale of a few thousand years. The scientific community overwhelmingly accepts that Newton’s laws of motion accurately describe planetary motion, so there must be an issue with Velikovsky’s theory. If there is any single objection to a scientific theory that the theory cannot explain, that theory cannot be correct. To be correct, a theory must be correct in all of its facets; to be wrong, it needs to be wrong only once.
2. **Jumping to conclusions** – A logical leap from a phenomenon to an explanation without considering other possibilities is a hallmark of bad science. [An “ancient aliens” author in the 1970s](#) cited the description of the Hebrew Ark of the Covenant found in Exodus 37:1-9 and concluded with the declaration—with no support—that to him, it sounded just like a description of a radio transmitter. In fact, a much simpler explanation is that the Ark of the Covenant was simply a religious article as described in the book of Exodus.
3. **Ulterior Motives and Vested Interests** – Often, lobbyists and other commercial entities will try to use bad science to advance their own interests. If somebody is trying to [sell a product](#), any new scientific claim that he makes should be considered suspect. Many crackpots and pseudo-scientists promote bad science to sell books, or, more insidiously, medical products. For example, some companies market “water alkalizers” to decrease the acidity of drinking water. This doesn’t make

GRADES 9-12 (CONTINUED)

scientific sense (drinking water is acidically neutral and the acidity of the digestive system is much more complicated than this idea suggests) and [several doctors and scientists have debunked the claims](#). However, marketers produce bogus scientific studies to convince people to buy alkaline water or water alkalizers.

Some people who claim to be a part of the scientific community are really just trying to sell books or promote themselves. The number of pseudo-scientists who promote bad science in order to sell books is legion. As an extreme example, a conspiracy theorist named Bart Sibrel is now known solely because [Buzz Aldrin once knocked him down for harassing him](#); for some people a punch in the jaw is a small price to pay for fame.

4. **Assuming an air of authority** – Often, a person will try to sway an argument by citing his or her impressive academic credentials. In truth, the strength of an argument has nothing to do with the person who is making it. A proposition needs to stand or fall on its own merits, not on the merits or demerits of its proponents. It is worth noting that the consensus among established scientists is *usually* right; the difference is that the consensus supports a theory because it is right rather than the theory being right just because the consensus supports it. However, one person with apparent credentials promoting an outlandish claim is not likely to overturn the entire scientific community.

This is not an exhaustive list, but it covers the general idea behind bogus science. Unfortunately, inaccurate, misleading, and even malicious “science” is fairly common on the internet, in social media, and even occasionally in the news. Understanding how to recognize bad science is a critical skill for 21st-century citizens; try finding some examples of questionable science on your own, and see if you can prove them wrong!

Sixty Years Ago in the Space Race:

June 22, 1957: [The Soviets tested the R-12 “Dvina” three-stage liquid-fueled rocket for the first time; it went on to become the SS-4 “Sandal” nuclear missile.](#)