

1.6: Limitations of the Scientific Method

Learning Objectives

- To understand the limitations in the scientific method, one must become familiar with the scientific method and its components.

Pseudo-science, basically "fake"-science," consists of scientific claims which are made to appear factual when they are actually false. Many people question whether Pseudo-science should even contain the word "science" as Pseudo-science isn't really even an imitation of science; it pretty much disregards the scientific method all together. Also known as alternative or fringe-science, Pseudo-science relies on invalid arguments called sophisms, a word Webster dictionary defines as "an argument apparently correct in form but actually invalid; especially : such an argument used to deceive". Pseudo-science usually lacks supporting evidence and does not abide by the scientific method. That is, pseudo-theories fail to use carefully cultivated and controlled experiments to test a hypothesis. A scientific hypothesis must include observable, empirical and testable data, and must allow other experts to test the hypothesis. Pseudo-science does not accomplish these goals. Several examples of Pseudo-Science include phrenology, astrology, homeopathy, reflexology and iridology.

Distinguishing Pseudo-Science

In order to distinguish a pseudoscience, one must look at the definition of science, and the aspects that make science what it is. Science is a process based on observations, conjectures, and assessments to provide better understanding of the natural phenomena of the world. Science generally always follows a formal system of inquiry which consists of observations, explanations, experiments, and lastly, hypothesis and predictions. Scientific theories are always challenged by experts and revised to fit new theories. Pseudo-science, however, is mostly based on beliefs and it greatly opposes contradictions. Their hypothesis are never revised to fit new data or information. Scientist continually disprove ideas to achieve a better understanding of the physical world, whereas pseudo-scientists focus on proving theories to make their claims seem plausible. For example, science text books come out with new editions every couple of years to correct typos, update information, add new illustrations, etc. However, it has been observed that pseudo-science textbooks only come out with one edition, and is never updated or revised even if their theory has been proven to be false.

Pseudo-science beliefs often tend to be greatly exaggerated and very vague. Complicated technical language is often used to sound impressive but it is usually meaningless. For example, a phrase like "energy vibrations" is used to sound remarkable but a phrase like this is insignificant and doesn't really explain anything. Furthermore, Pseudo-science often consists of outrageous, yet unprovable claims. Thus, pseudo-scientists tend to focus on confirming their ideas, rather than finding evidence that refutes them. The following dialogue contains the thought-processes behind Pseudo-Science.

1. My friend and I think unicorns exist
2. Science has no evidence about unicorns.
3. Science therefore cannot prove if unicorns do or do not exist.
4. One day my friend, a very trustworthy person, said she saw a unicorn in the field by her house. There is no other evidence, other than the fact that my friend saw it.
5. Unicorns exist and any scientist who tries to deny the existence of unicorns is a fun-sucking, hostile human being.

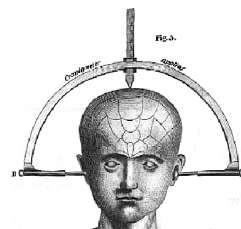
The dialogue above features many key characteristics of Pseudo-Science. The speaker makes his or her point valid though the two facts alone that her friend had a personal experience and that science has no proof to prove the theory wrong. Finally, the speaker insults anyone who would challenge the theory. In science, challenges to a theory are accepted as everyone has the same common goal of improving the understanding of the natural world. Below is a table that lays out the key characteristics of Science and Pseudo-Science

SCIENCE	PSEUDO-SCIENCE
Science never proves anything.	Pseudoscience aims to prove an idea.
Self-correcting methodology which involves critical thinking.	Starts with a conclusion and gives easy answers to complex problems.

SCIENCE	PSEUDO-SCIENCE
An on-going process to develop a better understanding of the physical world by testing all possible hypotheses.	Often driven by social, political or commercial goals.
Involves a continual expansion of knowledge due to intense research.	A field has not evolved a lot since the beginning. If any research is done, it is done to justify the claims, rather than expand them.
Scientists constantly attempt to refute other scientists' works.	An attempt to disprove the beliefs is considered hostile and unacceptable.
When results or observations are not consistent with a scientific understanding, intense research follows.	Results or observations that are not consistent with current beliefs are ignored.
Remains questionable at any time. There are two types of theories: those that have been proven wrong by experimentation and data, and every other theory. Thus, no theory can be proven correct; every theory is also subject to being refuted.	Beliefs of the field can not usually be tested empirically so will likely not ever be proven wrong; Thus, Pseudo-scientists believe that they are right just because no one can prove them wrong.
Concepts are based on previous understandings or knowledge.	Pseudo-Scientists are often not in touch with main-stream science and are often driven by the egos of the "scientists". Furthermore, famous names and testimonials are often used for support rather than scientific evidence.
Findings must be stated in unambiguous, clear language.	Pseudoscience often uses very vague, yet seemingly technical terms.

Phrenology

Phrenology, also known as craniology, was a "science" popular during the early 1800s that was centered around the idea that the brain was an organ of the mind. During this time, most people believed that the brain was divided into distinct sections that all controlled different parts of a person's personality or intelligence. The basis of phrenology revolves around the concept that the brain mirrors a muscle and those parts of the brain which are "exercised" the most, will be proportionally larger than those parts of the brain that aren't often used. Thus, the scientists pictured the brain as a bumpy surface, with the make-up of the surface differing for every person depending on their personality and intelligence. By the mid 19th century, automated phrenology machines existed, which was basically a set of spring loaded probes that were placed on the head to measure the topography of one's skull. The machine then gave an automated reading about a person's characteristics based on this.



Let's consider some of the key characteristics of pseudo-science from our chart, and see how they apply to phrenology.

- Pseudo-Scientists are often not in touch with main-stream science: Scientific research has since the 1800s shown how though the brain is indeed divided into sections, each section does not determine a characteristic or personality trait, but instead controls a specific function such as memory or motor skills. Likewise, it has been concluded that the brain conforms to the shape of the skull, rather than the skull conforming to the shape of the brain (meaning the bumps of a person's skull have nothing to do with the shape of the brain). Back in the 1800s, little knowledge existed about the realities of brain structure and function, so the concept wasn't as reflexive of pseudo-science as it is today. However, some doctors and scientist still believe in the basic tenets of phrenology. Phrenology today exists as a classic form of pseudo-science as it goes against the common understanding about how the brain functions.
- Often driven by social, political or commercial goals- Indeed, the main goal of phrenology was a political and social one: to prove the dominance of the white race over other races. "Scientists" measured the brains of both races and concluded that the brains of white people were larger than that of people of African descent. Therefore, they concluded, they were smarter and superior. It was later revealed that the scientists were biased while conducting the experiment and that they were previously aware of what race each brain belonged to. The experiment was repeated and this time the scientists were not aware of the race and they concluded that the brains were of equal size. The second experiment better conforms to the scientific method, as in this case the scientists objectively measured the brains, while in the first case the bias of the scientists led to their conclusions. Thus, this situation demonstrates a two-fold level of defective science because not

only was the idea of measuring the brains to determine personality and intelligence not correct all together, but the methods in which the scientists were doing this was also flawed. Phrenology was also commercially driven, since phrenology parlors were very wide spread and many devices were on the market to be used to measure.

- Pseudo-Scientists are often driven by the egos of the "scientists"- In the book *Phrenology and the origins of Victorian Scientific Naturalism* by John Van Whye, Van Whye quotes about the main discoverer of Phrenology Franz Joseph Gall, that "the peculiar incentive behind Gall's fascination with explaining individuals' differences may have lain in his hubris" (Van Whye 18). Of the 12 children in his family, Gall was the sharpest and brightest and naturally interested in distinguishing factors between children. Even as a young school boy, Gall noticed that the other children who were just as good at memorization as he was all had protruding eyes, which lead him to the idea of the basis of phrenology, that the characteristics of one's head indicates his or her intelligence.

Reflexology

Reflexology is a way of treatment that involves physically applying pressure to the feet or hands with the belief that each are divided up into different zones that are "connected" to other parts of the body. Thus, reflexologists assert that they can make physical changes throughout the body simply by rubbing ones hands or feet. Like we did with phrenology, lets go through some of the main characteristics of Pseudo-Science and see how they apply to reflexology.

- Pseudo-Scientists are often not in touch with main-stream science: No Scientific research has proven the validity of reflexology and how in fact it would actually work. In 2009, the Australian Medical Journal conducted an extensive study on reflexology and concluded "The best evidence available to date does not demonstrate convincingly that reflexology is an effective treatment for any medical condition". However, despite this lack of evidence, Reflexology continues.
- Pseudoscience often uses very vague, yet seemingly technical terms A main focus of reflexology is that the pressure on the foot removes any blockage of Qi, the "life energy force" and restores balance to lead to better health. Terms like "vital energy" or "energy blockage" which are used to talk about reflexology are classic pseudo-science terms; they sound impressive yet have no meaning to us
- Furthermore, famous names and testimonials are often used for support rather than scientific evidence. Because pseudo-science beliefs do not use scientific data for support, they must rely on individual circumstances when their product, idea, etc. appeared to have worked. For example, on the home page of well-known reflexologist Laura Norman's home page, she has a quote of Regis Philbin (past host of *Who Wants to be a Millionaire?*) saying "Laura Norman's Reflexology spared me from a kidney stone operation and saved my life.", opposed to a quote from say, a medical journal, that would cite how many studies say reflexology is an extremely effective form of treatment.

Distinguishing Pseudo-Science from other types of invalid science

An important distinction should be made between Pseudo-science and other types of defective science. Take for example, the "discovery" of N-rays. While attempting to polarize X-rays, physicist René Prosper Blondlot claimed to have discovered a new type of radiation he called N-rays. After Blondlot shared with others his exciting discovery, many other scientists confirmed his beliefs by saying they too had saw the N-rays. Though he claimed N-rays contained impossible properties, Blondlot asserted when he put a hot wire in an iron tube, he was able to detect the N-rays when he used a thread of calcium sulfite that glowed slightly when the rays were sent through a prism of aluminum. Blondlot claimed that all substances except some treated metals and green wood emit N-rays. However, Nature magazine was skeptical of Blondlot and sent physicist Robert Wood to investigate. Before Blondlot was about to show Wood the rays, Wood removed the aluminum prism from the machine without telling Blondlot. Without the prism, the rays would be impossible to detect. However, Blondlot claimed to still see the N-rays, demonstrating how the N-rays did not exist; Blondlot just wanted them to exist. This is an example of Pathological science, a phenomenon which occurs when scientists practice wishful data interpretation and come up with results they want to see. This case of Pathological science and Pseudo-science differ. For one, Blondlot asked for a confirmation by other experts, something Pseudo-science usually lacks. More importantly, in pathological science, a scientist starts by following the scientific method; Blondlot was indeed doing an experiment when he made his discovery and proceeded to experiment when he found the substances that did not emit the rays. However, Pseudo-science usually includes a complete disregard of the scientific method, while Pathological scientists includes following the scientific method but seeing the results you wish to see.

Another type of invalid science, called hoax science occurred in 1999 when a team at the Lawrence Berkeley National Laboratory claimed to have discovered elements 116 and 118 when they bombarded Lead with Krypton particles. However, by 2002 it had been discovered that physicist Victor Ninov had intentionally fudged the data to get the ideal results. Thus, the concept of hoax

science, which occurs when the data is intentionally falsified, differs both from pathological and pseudo science. In pathological science, scientists wishfully interpret the data and legitimately think they see what they want to see. However, in Hoax science, scientists know they don't see what they want to see, but just say they did. Finally, in Pseudo-Science, scientists don't consider the scientific method at all as they don't use valid experiments to back up their data in the first place.

From Pseudo-Science to Science

There have been incidents where what was once considered pseudo-science became a respectable theory. In 1911, German astronomer and meteorologist Alfred Wegener first began developing the idea of Continental Drift. The observation that the coastlines of African and South American seemed to fit together was not a new observation: scientists just couldn't believe that the continents could have drifted so far to cross the 5,000 mile Atlantic Ocean. At the time, it was a common theory that a land bridge had existed between Africa and Brazil. However, one day in the library Wegener read a study about a certain species that could not have crossed the ocean, yet had fossils appeared on both sides of the supposed land bridge. This piece of evidence lead Wegener to believe that our world had once been one piece, and had since drifted apart. However, Wegener's theory encountered much hostility and disbelief. In this time, it was the norm for scientists to stay within the scopes of their fields, meaning biologists did not study physics, chemists did not study oceanology and of course, meteorologists/astronomers like Wegener did not study geology. Thus, Wegener's theory faced much criticism just due to the fact that he was not a geologist. Also, Wegener could not explain why the continents moved, just that they did. This lack of reasoning lead to more skepticism about the theory and all these factors combined lead to the viewing of continental drift as Pseudo-Science. However, today much evidence exists that shows that Continental Drift is a perfectly acceptable scientific theory. Today, the modern ideas of plate tectonics can help explain Continental Drift, as the Plate Tectonic Theory presents the idea that the earth's surface is made up of several large plates that often move up to a few inches every year. Also, the development of paleomagnetism, which allows us to determine the earth's magnetic poles at the time a rock formed, suggests that the earth's magnetic poles have changed many times in the last 175 million years and that at one time South America and Africa were connected.

Limitations of the Scientific Method

Due to the need to have completely controlled experiments to test a hypothesis, science can not prove everything. For example, ideas about God and other supernatural beings can never be confirmed or denied, as no experiment exists that could test their presence. Supporters of Intelligent Design attempt to convey their beliefs as scientific, but nonetheless the scientific method can never prove this. Science is meant to give us a better understanding of the mysteries of the the natural world, by refuting previous hypotheses, and the existence of supernatural beings lies outside of science all together. Another limitation of the scientific method is when it comes making judgements about whether certain scientific phenomena are "good" or "bad". For example, the scientific method cannot alone say that global warming is bad or harmful to the world, as it can only study the objective causes and consequences. Furthermore, science cannot answer questions about morality, as scientific results lay out of the scope of cultural, religious and social influences.

Concept Assessment

Determine if each statement is true or false (see answers at bottom of the page)

1. What is considered Pseudo-Science today will always be considered Pseudo-Science
2. A person has a cold and decides to seek reflexology treatment. The next day, the person gets better. This means reflexology is a valid scientific theory
3. Just because "science" is immoral or defective does not necessarily mean it is Pseudo-Science
4. Famous people are used in advertisements for products such as gatorade. This means these products are Pseudo-Science
5. Medically based Pseudo-Science such as homeopathy, reflexology or acupuncture have absolutely no benefits to people

References

1. Ernst, Ezard. "Is Reflexology an Effective Intervention? A Systematic Review of Randomised Controlled Trials." *The Medical Journal of Australia* 191.5 (2009): 263-66. Print.
2. Van, Wyhe John. *Phrenology and the Origins of Victorian Scientific Naturalism*. Aldershot, Hanst, England: Ashgate, 2004. Print.
3. Yount, Lisa. *Alfred Wegener: Creator of the Continental Drift Theory*. New York: Chelsea House, 2009. Print.

Answers to concept assessment

1. False- just because something is considered pseudo-science today, does not mean it will always be. Take for example, our discussion about Continental Drift. Continental Drift used to be considered Pseudo-Science, but now since there is scientific evidence to prove it, the theory is considered a product of science.
2. False- Just because a person got better after having reflexology treatment does not mean the treatment, which has no scientific evidence behind it, is the sole reason for a person's recovery. Many other factors could have lead to a person's healing, such as medication or time to let the body fight by itself so it would be impossible to determine that reflexology caused a person to get over a cold
3. True- Pseudo-Science is a specific type of defective. See the discussion about pathological and hoax science to learn how to distinguish Pseudo-Science from other types of invalid Science.
4. False- The common characteristic of relying on testimonials or celebrity support of Pseudo-Science is just one of the many characteristics on Pseudo-Science. Before declaring something as Pseudo-Science or science, it is important to consider various characteristics of both and focus on whether or not the ideas have experimentally determined data to support them. There has indeed been Scientific Data to support the use of Gatorade.
5. False- though there is little scientific evidence to support these types of medical treatment, it does not mean that they have no value. The Placebo effect may be relevant here, as people may believe that the methods are working, which may trigger the body to actually feel better.

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