What Is the Difference between Science and Pseudoscience?

Understanding the difference between science and pseudoscience is critical for students at younger ages as their definitions of these concepts can impact their understanding of the process of science. For example, most major newspapers across the world have sections on astrology on which individuals might base their daily and yearly decisions—such as when to ask for a raise—on these pseudoscientific ideas. Another example is the use of the unscientific technique of dowsing to find groundwater, in which people pay dowsers to find water on their land for a water well. Since dowsing does not work, the landowners actually pay for someone to randomly choose a spot they should dig a well. It is important for students to understand how to evaluate evidence to determine whether or not they are engaging in science or pseudoscience as their decisions may depend on it.

Star chart: www.dreamstime.com

Lesson Overview

This lesson builds an understanding of the nature of science. It can be implemented early in the school year and revisited throughout the year to ensure students develop proficiency in the practices of science. The activities within this lesson may be used individually or taught together to create a lesson.

- *Activity 1 – It's a fact! But is it Science or Pseudoscience? (20 minutes)*
  Students sort cards with science and pseudoscience facts demonstrating their understanding of each.
- *Activity 2 – Dowsing for Water or Dowsing for Nothing? (20 minutes)*
  Students watch a video and participate in a discussion about dowsing.
- *Activity 3 - Astrology - Is it based on science or pseudoscience? (20 minutes)*
  Students will test another subject (astrology) to determine if it is a science or pseudoscience.
- *Activity 4 – Origins of Pseudoscience (10 minutes)*
  Wrap-up the lessons with a discussion about the origin of pseudoscience, and how to recognize it.

Instructional Overview	
Grade Level	Middle School
Instructional Time	70 minutes *(total time needed)*
Standards Alignment	See NSTA: *NGSS Connections to Nature of Science*
Anchoring Phenomenon	Science is a Process
Driving Question	Is it Science or Pseudoscience?
Learning Goals	● List the characteristics of science and pseudoscience ● Determine if a practice is science or pseudoscience and provide evidence for this reasoning
Materials	● 1 set of Science vs Pseudoscience Fact Cards per student or group ● 1 Astrological Descriptions handout per student ● 1 Astrological Sign Answer Strip per student
Material Preparation	❑ Make copies of the cards, handout, and answer strips ❑ Cut the cards and answer strips ❑ Consider laminating for future use
Vocabulary	Dowsing: The practice of using a divining rod to locate underground materials such as water or metals Science: Any system of knowledge that is concerned with the physical world and its phenomena, and that entails unbiased observations and systematic experimentation. (adapted from Britannica: https://www.britannica.com/science/science) Pseudoscience: A collection of beliefs or practices mistakenly regarded as being based on scientific method (adapted from Lexico: https://www.lexico.com/en/definition/pseudoscience)

Activities	Web Links for Lesson Resources Note: all resources are downloaded as pdfs in the *Activity Resources Folder*
Activity 2	Dawkins* Debunks Dowsing: http://www.youtube.com/watch?v=_VAasVXtCOI **Note: Richard Dawkins is often considered controversial because of his anti-religious books, lectures, and videos. Therefore, mentioning that the video is from him could stir negative emotions from students, parents, or administration. However, the video itself is not focused on religion and never mentions Richard Dawkins by name. He is simply narrating and the students and other watchers are not likely to know who he is from the video.The focus of the clip is on his testing of dowsing, which is clearly shown to be a pseudoscience.*

Activity 1
It's a fact! But is it Science or Pseudoscience? (20 minutes)

In this activity students sort the Fact Cards into two piles - science or pseudoscience. It can be done individually or in pairs.

What is the difference between science and pseudoscience?

The term pseudoscience will likely be a new term for students, therefore mention that "psuedo" means "not genuine."

- Tell them you have a stack of facts that pertain to either science or pseudoscience, and they have the challenge of sorting them into two piles - science and pseudoscience.

- Distribute the cards to individuals or pairs of students and allow them 10 minutes to sort the cards into piles. Walk around while students are doing this, and observe their progress. Make note of the conversations students are having if they are working pairs. If they are working individually, allow students about 5 minutes to share their results with another student. Be sure to capture the arguments students are having about the sort, noting where they are in error and where they are in agreement.

- Review the card sort by asking students to share the contents of their piles. Let students lead the discussion while noting the strengths and weaknesses in their arguments. Ask students to use the facts on the card to determine which of these are examples of science and which are examples of pseudoscience: Archeology, Astronomy, Astrology, Biology, Chemistry, Geology, Glaciology, Paleontology, Physics, Psychic Abilities. Ask them to justify their responses using the facts from the cards.

- Wrap up this activity by asking students to provide examples of a scientific claim and a pseudoscience claim asking them why they are examples. Mention that in the next activity they will be introduced to the practice of dowsing to find groundwater.

- Set the cards aside to use at the end of the lesson if students are still unsure about the differences between science and pseudoscience.

Card Sort Answer Key:

These are some facts about science:

- It is testable and falsifiable.
- It incorporates multiple pieces of evidence (ex: chemistry, physics).
- Experiments and results should be repeatable.
- Hypotheses and theories are often modified or discarded whenever new or better observations or experiments no longer support them.
- There is no such thing as absolute truth in science, but enough evidence can be collected and analyzed to obtain an objective truth that is considered beyond all reasonable doubt.
- Evidence is really all that matters and is more important than opinion, even by scientists.
- Science only investigates the natural universe and does not operate in the realm of the supernatural.
- Science cannot answer questions about right, wrong, or meaning/purpose, but scientific conduct must be ethical.

On the other hand, these are facts about pseudoscience:

- Pseudo means false, therefore pseudoscience means false science or really is not a scientific endeavor.
- Does not comply with the usual scientific evidence and tests.
- May claim to be at a higher level than science, or in an area that science can not understand like the supernatural realm. Therefore, it is irrefutable even when contradicted by science.
- Often inconsistent with existing, well-established scientific knowledge.
- It is stated as being true based on a belief that is often not testable or falsifiable, or if it is, has been falsified.
- Often uses scientific sounding language.
- Claims are often so vague as to be essentially meaningless or are bound to be true sometimes.
- Truth is based on arguments of authority of a famous person rather than evidence.

Activity 2
Dowsing for Water or Dowsing for Nothing? (20 minutes)

An excellent example of pseudoscience is the practice of dowsing where a dowser attempts to locate groundwater or other buried materials using a divining rod. This practice is not supported by science. In this activity, students watch a video and participate in a discussion about it.

- Ask students if they ever heard of the practice of dowsing. If not, spend a few minutes letting students seek and share information about the practice. Ask them if the practice fits into science or pseudoscience, and how they know. Tell them that as they watch this video (approximately 5 minutes) to note the process the experimenters use to verify that dowsing is or is not supported by science.

  Video clip: Dawkins* Debunks Dowsing:
  http://www.youtube.com/watch?v=_VAasVXtCOI

  **Note: Richard Dawkins is often considered controversial because of his anti-religious books, lectures, and videos. Therefore, mentioning that the video is from him could stir negative emotions from students/parents/administration. However, the video itself is not focused on religion and never mentions Richard Dawkins by name. He is simply narrating and the students and other watchers are not likely to know who he is from the video. It just might be best to not mention him and focus on his testing of dowsing, which is clearly shown to be a pseudoscience.*

- After the video elicit student comments about dowsing and the experimental design used by the scientists in the video.

  Which of the Fact Card sort were evident in the video? Which pile pseudoscience—are science or pseudoscience—are they from?

- Tell students that in the next activity they will take a closer look at the practice of astrology to determine if it is science or pseudoscience.

Activity 3
Astrology—Is it based on science or pseudoscience? (20 minutes)

In this activity students use the Astrological Descriptions handout (one double-sided page for each student in the class) and the Astrological Sign Answer Strips (cut the strips found on the page; one page is enough for 14 students). The answer key can be found below and should not be available to students.

- Discuss daily horoscopes and whether or not they think horoscopes are accurate.

  How would you design a test to determine the accuracy of the horoscopes?

- Tell them to consider the important aspects of the experimental design they say in the video of the previous activity in this lesson. Allow approximately 10 minutes for students to collaborate, and then seek a class consensus on an experiment. Possible experiments may include the model described below which, similar to the dowsing experiment, uses probability to determine the veracity of the practice.

- Tell students that they will participate in a class experiment to determine the accuracy of horoscopes which vary depending on their astrological sign. Ask them if they know their astrological sign and the personality characteristics generally associated with their sign. Most students will probably know their astrological sign, but not know the personality characteristics associated with it. Share the dates and signs so that all students know their sign:

  Aquarius (Jan. 21st–Feb. 19th), Pisces (Feb. 20th–Mar. 20th), Aries (Mar. 21st–Apr. 20th), Taurus (Apr. 21st–May 21st), Gemini (May 22th–June 21st), Cancer (June 22nd–July 22nd), Leo (July 23rd–Aug. 21st), Virgo (Aug. 22nd–Sep. 23rd), Libra (Sep. 24th–Oct. 23rd), Scorpio (Oct. 24th–Nov. 22nd), Sagittarius (Nov. 23rd–Dec. 22nd), Capricorn (Dec. 23rd–Jan. 20th).

- Distribute the Astrological Sign Answer Strips and ask students to write their name and astrological sign on their strip.

- Distribute the Astrological Descriptions handout to each student. Ask them to read the descriptions and write the number which best fits their personality on their answer strip.

Ask students not to write on the descriptions page so that it can be used again in the future.

- Collect the strips from each student as they finish and count how many strips correctly matched the sign and the description. If astrology is a science then their personalities should match their sign. If it is a pseudoscience, we would expect 1 out of 12 students to match the sign up by random chance. Share these numbers with the students and lead a discussion about the results which includes the facts found in the card sort.

  Which of the Fact Cards connect with astrology? Which pile—science or pseudoscience—are they from?

Answer Key to Personality Descriptions:
Aries = 1; Gemini = 2; Virgo = 3; Leo = 4; Cancer = 5; Libra = 6; Pisces = 7; Aquarius = 8; Taurus = 9; Sagittarius = 10; Capricorn = 11; Scorpio = 12

Activity 4
Origins of Pseudoscience (10 minutes)

To wrap this lesson up, consider having a discussion about the origins of pseudoscientific thought.

- The discussion may start out by making a claim such as: “I saw Bigfoot on my way to school!” Can students “disprove” your claim? The students won’t believe you, but they also won’t be able to “disprove” your claim because you can always make up excuses or scenarios. Because it is something you believe you actually saw, there is nothing they can do.

- Ask them to develop a plan to determine if you did see Bigfoot (e.g., setting up cameras, interviewing those in the area where Bigfoot was sighted).

- Then point out how claims like these are pseudoscience because:
    - Pseudoscientific claims are often based on personal, anecdotal evidence.
    - Essentially they convey second-hand stories: “I saw Bigfoot.” or “I was abducted by aliens.”

- Share with students that in addition, there are alternative explanations for pseudoscience:
    - Human error (e.g., mistaken observations and/or inferences).
    - Fraud/trickery (e.g., fake Bigfoot photos, stage magic masquerading as ESP).
    - Chance (e.g., coincidental events, a long run of heads in coin flipping).
    - Non-occurrence of the event: It did not happen.
    - Scientific evidence may refute it.

  Ask students to brainstorm examples of each of the above, if they can while referring to the facts found in the card sort. End the lesson with a report out of their examples.