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# K-12 Partnership Lesson Plan

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# *Expecting the Unexpected*

# *Adventures in Critical Thinking*

## Overview

## How do we know we can trust a source or a claim made by someone? What constitutes “good science”? Knowing the answers to these questions is an important critical thinking skill for all students and is even more important in this digital age where students are exposed to information from many different sources with varying degrees of accuracy and qualifications. Everyone, including your students, is constantly facing confusing news stories and conflicting data and evaluating these claims requires the ability to think critically about all the information being thrown at them.

This lesson contains activities that you can do with your middle and high school students to teach them critical thinking skills such as the importance of attempting to disprove a hypothesis, using hypotheses to make testable predictions, and examining a recent case of “bad science” that has resulted in harmful consequences. In addition, we include modifications for doing similar activities with elementary school classes. We’ll also give you tools to deal with news that your students bring in with them, and how to help them go from just repeating data, to thinking about it.

<http://scienceornot.net/> is a teacher resource with worked examples of how to reason through scientific claims made in the media, and general critical thinking. This is an excellent primer if you’re not already comfortable with the material in this lesson plan.

**Objectives**

At the conclusion of the lesson, students will be able to:

* Look for data that would disconfirm their ideas
* Understand different types of evidence, and how useful they are
* Make predictions based on incomplete evidence

**Length of Lesson**

About an hour

**Grade Levels**

Designed for middle and high school, but activities have elementary school level alternatives

**Standards covered (NGSS)**

Disciplinary Core Ideas:

* **MS-LS4-1**: Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.
* **MS-LS4-2**: Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

Cross Cutting Concepts:

* Patterns

Science and Engineering Practices

* Asking questions and defining problems
* Analyzing and interpreting data
* Constructing explanations and designing solutions
* Engaging in argument from evidence
* Obtaining, evaluating, and communicating information

**Materials**

* Powerpoint (elementary level alternatives are the “skipped slides” in the presentation)
* Scientific Method game handout and teacher guide (or suitable alternative such as wooden blocks of varying sizes and colors)
* “A Rough Guide to …” handouts
* Paper and colored pencils

**Background**

Humans are very good at finding patterns, even when they aren’t there. Commonly when we think we see a pattern, we look for evidence that supports it rather than attempt to disprove it. This can result in invalid results and lead us to miss alternative explanations. Rather than look for confirming evidence, scientists must design their experiments to attempt to disprove their hypotheses, as well as seek out and disprove alternative hypotheses. A scientific idea becomes a theory or fact, not when evidence is found that supports it, but only when every alternative explanation has been ruled out.

The game in this lesson introduces students to this very concept. If they are told to guess the number rule based on a set of numbers such as 5,7,9, they may immediately assume the “rule” is that numbers must be odd; or increase by twos. Rather than trying to disprove this hypothesis, students continue to test similar patterns- “11, 13, 15”; “2, 4, 6”. If the rule is simply “ascending numbers” they may think they are confirming their hypothesis if they continue to get a “yes” response. Only those that attempt to disprove their hypothesis (ex. “1,2,3”; “3,10,14”; “5,4,3”) will be able to determine the number rule accurately.

The second component to this lesson introduces students to a situation where scientists may test a hypothesis by using it to make a prediction. In the search for a “missing link” between fish and tetrapods, scientists predicted there should be an intermediate organism that had some fish-like qualities but with the first adaptations to living on land. However, a fossil of such a creature had not been found yet. To find it, scientists looked for exposed rock strata from the Devonian period (the period which they predicted they would find this fossil if it existed) and ended up searching in the Arctic Circle. After a lot of searching, they found Tiktaalik- the fossilized remains of an organism that was intermediate between fish and tetrapods! This creature had scales and fins like a fish, but had developed a neck and strong front and hind limbs that could support its weight. Presumably, this creature was adapted to life in shallow water where it needed to stand and raise its head to look over the water. The existence of Tiktaalik supported the hypothesis that tetrapods evolved from fish. The great thing about fossil evidence is that it has the potential to disprove hypotheses about evolution based on what species are found in which rock layers.

Lastly, students will be introduced to a current example of the drastic consequences of misinterpreting science: the (false) link between vaccines and autism. This link was originally proposed by a scientist in a now infamous paper, which purported to find a causal association between vaccines and autism. This has recently spurred a large anti-vaccine movement, resulting in the re-emergence of formerly eradicated diseases such as measles, mumps, and whooping cough. By examining the science behind this claim, students will be introduced to a number of fallacies and “warning signs” of misleading graphs.

### Activities of the session

1. Scientific Method game – This game is very similar to the old story about many blind people describing an elephant and getting wildly varying results.
   1. You will provide students with a set of three numbers and have them guess what your “number rule” is. To test their guesses, students will write their own sets of three numbers and you will tell them “yes” or “no” based on whether their set fits the number rule you have in mind. They can do this as many times as they want.
   2. The essential part of making this exercise work is to have a pattern that can have many answers that look right, depending on how you think about it, but that has only one truly right answer. Preferably, the simplest solution is correct. Students must look for disconfirming evidence of their hypothesis in order to find the right answer, just like the scientific method
   3. You can use any number rule to play the game. However, it works best if you use very simple rules for the correct answers, but presented in such a way that there are many plausible looking answers. Examples of good rules are: Numbers must be ascending (2, 4, 6) or numbers must be descending (6, 4, 2)
2. Tiktaalik Prediction – This exercise is designed to demonstrate how science works in situations where one can’t easily do experiments to disprove an idea. Instead, you can use existing data to make specific hypothesis about what you expect to find, AND what sort of evidence would disprove it.
   1. First, introduce students to the “missing link” that was predicted to exist between fish and tetrapods and show them the closest relatives that we know of (provided in powerpoint).
   2. Ask them to draw what they think an intermediate creature might look like. Ask them to predict whether it has qualities such as fins, lungs, gills, scales, etc. Also ask them to think about what habitat this species might have been adapted to.
   3. You can then show them the Tiktaalik fossil and discuss how similar their predictions were
3. Misleading graphs
   1. Introduce the graph that appears to show a relationship between vaccines and autism. What is wrong with this graph (answers in powerpoint)?
   2. Discuss the study that claimed to demonstrate a link between vaccines and autism. What is wrong with this study?
   3. If there is time, show students more graphs from the “spurious correlation” website (below).

**Resources**

* Teacher resource with worked examples of how to reason through scientific claims made in the media, and general critical thinking. This is an excellent primer if you’re not comfortable with the material in this lesson plan <http://scienceornot.net/>
* Spurious Correlation Graphs: <http://www.tylervigen.com/>

**Extensions and Modifications**

More logic problems are provided in the Scientific American article “Rational and Irrational thought: the thinking that IQ tests miss”.

Students can read ‘A Case Study in Graphical Misrepresentation’ for more details about the retracted autism study and how to spot data misrepresentation.

Elementary School Modifications

Scientific Method Elementary modification:Use tangible objects, and have your students determine how you made your “set”. For instance your set rule could be “shapes with corners”, choose three blocks of varying colors and shapes, and tell your students to figure out what those three have in common, by making their own sets. Some students will likely keep your color pattern, while others will keep your shape pattern.

Missing Link Elementary modification: Instead of using fossils and rock strata to predict the location and characteristics of ‘missing links’ use familiar things that occur in series. For instance, use Google to search the web for “mickey mouse evolution” images. You’ll find hundreds of time series drawings of Mickey from his debut in 1928 to the present. Choose a series you like, and cover up a Mickey in the middle. Have your students predict what characteristics the missing Mickey must have, and why (i.e. he has gloves before and after the missing image, so he should have gloves). Have them draw the Mickey missing link. Tell the students that you have found several Mickey images that **could** be the missing link, and have them make a list of characteristics that would **disqualify** images and why. (i.e. Any potential Mickeys who aren’t wearing gloves are disqualified). This is essentially how paleontologists look for missing links in the fossil record. They predict in what rock layer the animal should be to fall between the known fossils, and what characteristics it should and should not have. Fossils found in the wrong place or time would lead to reinterpretations of the evolutionary history of that organism.

**Assessment**

Have students look for a current news story about a scientific topic that includes data (and/or graphs). Ask them to critically evaluate the claims made in the news story.