TIPS, TRICKS & TECHNIQUES

Preparing Students For Science in the Face of Social Controversy

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Abstract

Science educators often teach topics that are largely resolved in the scientific community yet remain controversial in broader society. In such cases, students may perceive the teacher as biased. We present two exercises that foster more objective learning about the scientific underpinnings of socially controversial topics. The first exercise clarifies why the scientific resolution of an issue does not necessarily align with social perception. The second applies this concept by having students discriminate science-based claims from other claims.

Key Words: *Nature of science; pseudoscience; rationalism; skepticism; empiricism.*

○ Introduction

One of the many challenges for science educators is teaching about topics that are largely resolved in the scientific community yet remain controversial in broader society. Such topics often make students uncomfortable and, worse, meet with resistance to learning (Johnson & Peeples, 1987; Byford et al., 2009). For example, the science of geology continues to refine estimates of the age of the Earth, but the social controversy over how to resolve science–faith conflict regarding the age of the Earth is far from over. The same is true when biologists teach evolution and when environmental scientists teach about global warming. This should be no surprise, given that students come from American society, not from a pool of American scientists. When instructors present such topics as no longer under question, students are likely to perceive the teacher as strongly biased to one side of a controversy that they see as ongoing.

One of the many challenges for science educators is teaching about topics that are largely resolved in the scientific community yet remain controversial in broader society.

We believe that this conflict of perception arises partly from a lack of a meaningful understanding of how scientific thinking differs from the broader practices of everyday thinking (hereafter "social thinking"). In our courses, we have found that explicit instruction on the difference between scientific and social thinking enables students to think more objectively when learning the scientific underpinnings of controversial subjects. In turn, instructors are better able to break through socially derived barriers to learning (Clough, 1994; Sinclair et al., 1997; Shipman et al., 2002).

Here, we present two classroom exercises that support this goal. The first engages student understanding of the distinction between scientific and social thinking and clarifies why the scientific resolution of a controversial issue does not necessarily align with social perception. The second exercise puts this concept into action by having students discriminate claims that are science-based from those that are not. Because many pseudoscientific practitioners are adept at making their claims sound like legitimate science – by using scientific-sounding jargon, relying heavily on confirmation rather than refutation, or exaggerating evidence – this exercise helps students learn to separate the factual from the fraudulent.

○ Methods

Exercise 1: Distinguishing Scientific Thinking from Social Thinking

a. *Materials needed.* List of knowledge statements, preferably taken from cited sources.
b. *Teacher implementation.* The exercise takes 30–40 minutes. The instructor introduces the exercise as a metacognitive study that attempts to answer the question "How do you know?" Metacognition is the effort to understand one's own thought processes, in addition to understanding the thought processes used by others. Students are split into small groups of three or four individuals seated to foster within-group discussion while

The American Biology Teacher, Vol. 77, No. 4, pages 284–288. ISSN 0002-7685, electronic ISSN 1938-4211.
DOI: 10.1525/abt.2015.77.4.8

Table 1. Statements used to discriminate different ways of knowing that are employed in social thinking.

"Truth" Statement	Typical "Way of Knowing" Categories Identified by Students
Eggs are fragile.	• Personal experience
The nucleus, which occupies the interior of a cell, is smaller than the cell itself.	• Logic
Water freezes at 32°F.	• Authority • Personal experience (often listed, then retracted after students realize they have never personally measured the temperature of freezing water)
Everyone has a moral sense.	• Desire for the statement to be true • Authority • Intuition
I don't trust him/her. (Having just met the person.)	• Intuition
A higher power is punishing America for its acceptance of sinful lifestyles.	• Authority • Desire for the statement to be true • Direct revelation
If a = b and b + 1 = 5, a = 4.	• Logic
There are 10 fundamental rules that a higher power instructs us to live by.	• Direct revelation (if Moses) • Authority (everyone else)
President Obama does not have a valid American birth certificate.	• Authority • Rumor mill (no identifiable authority, but so often repeated that the statement becomes accepted as truth)
Crystal therapy can restore harmony and peace of mind by clearing negative energy blocks that we have deep within us.	• Authority • Personal experience • Desire for the statement to be true

minimizing between-group discussion. They are presented with four or five of the statements listed in Table 1. The statements are distributed so that each is reviewed by two groups.

c. *Student instructions.* Students are asked to proceed through each statement, imagining themselves as a person who takes the statement to be true. What would they give as their basis for accepting its truth? From this, the instructor compiles on the board a list of "ways of knowing" (i.e., various ways that people claim to know truth). Typical student responses are shown in Table 1. It is not important that students use the terminology presented in Table 1 or that they produce a list with seven categories of knowledge. The point of the exercise is to have students recognize that social thinking incorporates a wide variety of thought processes.

d. *Metacognition.* After listing the "ways of knowing," students are asked to sketch their own methods of cognition. They are given a cartoon of a brain and instructed to draw arrows from each "way of knowing" toward the brain, with the width of the arrows being proportional to the amount of knowledge they accept to be true that comes from each. Then they compare diagrams and discuss the difference among their group members.

e. *Science as a delimited way of knowing.* In the last part of the exercise, students are asked to strike lines through ways of knowing that are not used in science. Some ways of knowing are eliminated easily (revelation, desire for a thing to be true, rumor mill), whereas others require deeper analysis. For example, intuition is used in science for formulating ideas, but not as a basis for concluding that ideas have scientific validity. Typically, three ways of knowing are left by the end: authority, logic, and personal experience. The instructor elaborates that, in scientific thinking, these are also delimited. For example, the ultimate authority in science is empirical evidence; any expert, group of experts, or published source can be found to be wrong at any time. Personal experience is also delimited – it must be in the form of data that can be independently verified by other investigators. No observation that is restricted to one individual (e.g., "I can see auras") is accepted as reliable. Finally, the application of logic incorporates all scientific knowledge, precluding sustained conflict among the fundamental concepts held by different branches of science. No principle of chemistry can be in conflict with the principles of physics, and no biological theory can require an exception to the laws of thermodynamics.

f. *Summation.* By comparing the ways of knowing used in social thinking to those used in science, one can see why social controversies often persist when a scientific consensus has been reached. Social thinking incorporates a wider variety of ways of knowing and is not necessarily grounded in the three tenets of science (Schafersman, 1997): (a) empiricism, a demand for data that can be independently verified; (b) skepticism, a willingness to abandon established conclusions in light of new information; and (c) rationalism, the principle of noncontradiction. From this point, it is up to the student to evaluate the relative merits of social and scientific thinking.

Table 2. Ten important criteria for determining what is science.

Criterion	Questions to Ask When Analyzing a Claim or Belief
1. Science is logical and rational.	1. Does the claim make logical sense or is it very unrealistic? Does the claim deal with the natural world or the supernatural world? Does it seem possible? Does it fit into the laws of nature as we understand them? Is there a logical, rational line of thought that leads to the conclusion?
2. Science makes well-defined claims.	2. Does the claim state specifically what happens? Does it explain in detail why it happens? Does it answer the questions what, where, when, how, and whom – or is it vague? Are you able to predict things with the belief? Are all parts of the belief well defined?
3. Scientific hypotheses are falsifiable.	3. Is there a possible way to disprove the claim or is it impossible to disprove? What possible results would disprove it? Do the believers rely on scientists to disprove the claims?
4. Scientific experiments are repeatable.	4. Has the experiment or event been repeated with the same results? Are results consistent? If it is an event that hasn't been witnessed, are there any more reasonable, natural explanations that could give the same results? If it is a one-time phenomenon, could models be made to replicate results?
5. Science requires that claims be examined by peers.	5. Has the phenomenon or experiment been verified by other scientists? Can anyone get the same results or is it limited to those who have special "gifts" or "spiritual" connection? Do the believers seem to have something to hide from the scientific community?
6. Science views unexplained gaps in theories with suspicion.	6. Is there a cause-and-effect relationship working here? Are there unexplained portions to the belief that are just accepted without investigation? Are the claims based on incomplete results? Do believers jump to a large conclusion based on a small amount of evidence?
7. Science requires caution in examining evidence.	7. Do the extraordinary claims have extraordinary evidence? Good scientists are careful about rushing to judgment on promising leads. Is this the case? Has there been a lot of research and verification about the claim? Are miraculous claims based on early or incomplete evidence? Are claims exaggerated?
8. Science requires objectivity.	8. In science, opinion and "facts" must be corrected when faced with solid evidence to the contrary. Is this the case with the belief? Do believers have a bias or personal stake in their claim? Can the claim be studied without bias or subjectivity? Is there external evidence or only eyewitness accounts? Is mysticism at work here?
9. Science does not accept coincidence as proof.	9. Is it only a coincidence that this claim occurs or is there a verified cause-and-effect relationship? Does the belief take the laws of probability into account?
10. Science does not accept anecdotal evidence as proof.	10. Is the evidence based on stories or testimonials? Do the believers rely on "historical" practices or beliefs as proof? Is the belief primarily dogma? Where is the evidence that gave the believers the anecdotes in the first place?

This exercise has been used with approximately 100 college students, including senior-level biology majors taking a capstone seminar course and junior-level non–biology majors enrolled in a Scholars Program (top 5% of the student population). Feedback has been overwhelmingly positive. Biology majors often suggest moving the exercise to the Introductory Biology course for majors. Students in the Scholars Program have cited it as an exercise that clarified their thinking about social controversies in many courses.

Exercise 2: Discriminating Scientific Ideas from Nonscientific Ideas

a. *Materials needed.* Tables 2 and 3.

b. *Teacher implementation.* This exercise takes 25–35 minutes. The instructor explains that popular culture is flooded with extraordinary claims, but "an extraordinary claim requires extraordinary proof" (Truzzi, 1978). Aaseng (1994) provides a simple list of "Ten Important Criteria for Determining What Is Science," which is helpful in discriminating between scientific and unscientific claims. The instructor goes through each criterion and the accompanying questions that should be asked of a claim to determine whether it violates the statement. It is important for the instructor to point out the difference between nonscientific and pseudoscientific claims when engaging students in such activities. Non-sciences, such as religion, do not typically claim that beliefs are scientific in nature. They tend to rely on articles of faith rather than empirical evidence. Pseudosciences, on the other hand, will often try to disguise themselves as science to gain respectability and acceptance with the general public. The instructor should avoid having students pit purely religious claims against scientific criteria, which could unnecessarily bring about conflict.

c. *Student instructions.* Students are asked to proceed through each extraordinary claim in Table 3. They then determine which

Table 3. Extraordinary claims and scientific criteria violations.

Extraordinary Claim	Scientific Criterion That the Statement Violates
1. A psychic claims that next year will bring "many drastic global changes."	2. Science makes well-defined claims. What specifically are drastic global changes?
2. There is an old story that claims a Ouija board "screamed" when a person lit it on fire.	10. Science does not accept anecdotal evidence as proof. An old story frequently retold does not give the statement scientific credence.
3. When the moon is full, there is more crime. Therefore, the moon causes people to act strangely and dangerously.	6. Science views unexplained gaps in theories with suspicion. What is the cause–effect mechanism at work?
4. Some scientists have claimed to have discovered "cold fusion." Other scientists have not been able to get the same results with the same experiment.	4. Scientific experiments are repeatable. Why can't other scientists verify the results under the same conditions?
5. A person claims to have special powers and can read auras (mystical energy fields coming off of the body). She claims only people with this special ability can see auras.	5. Science requires that claims be examined by peers. Why can't others, or instruments, detect these?
6. Airplanes can fly only because they have invisible angels carrying them in the sky.	1. Science is logical and rational. Is this a natural or logical explanation?
7. Aliens are visiting the Earth undetected.	3. Scientific hypotheses are falsifiable. Is there any way to disprove this claim?
8. A rock was found with both fossilized dinosaur footprints and what appear to be human footprints. This definitely proves that both must have existed at the same time.	7. Science requires caution in examining evidence. How good is the evidence? Does any other evidence support this claim?
9. The president of the Flat Earth Society uses his religious documents as evidence that the Earth is shaped like a pizza, not a ball.	8. Science requires objectivity. Is the Flat Earth president biased in his conclusions?
10. My horoscope claimed that I would have good luck, and today I found $5. It was correct!	9. Science does not accept coincidence as proof. Is it just a coincidence that I happened to find money today?

of the "Ten Criteria for Determining What Is Science" is violated and provide reasons to justify their answer. It should be noted that one claim may violate several scientific criteria. For example, statement number 10 may also violate the second criterion, which states that "Science makes well-defined claims." What defines good luck – finding some money or something much more extraordinary? Nevertheless, Table 3 has been set up so that each criterion is used at least once.

d. *Application and assessment.* This project could be assigned over a few days to allow adequate time for research. For a deeper understanding of how to distinguish science from unscientific ideas, students are asked to choose a pseudoscientific belief (rather than just one claim), research it, and describe this belief in detail. An extensive list can be found on Wikipedia under "List of topics characterized as pseudoscience." They report on the history of the pseudoscience and list any "evidence" that the belief relies upon. Once students become familiar with the belief and its claims, they scrutinize the belief by applying the "Ten Important Criteria for Determining What Is Science" to their topic and explain how it fits or does not fit each criterion. Students then make a conclusion about the belief. They determine whether the belief is really scientific; what the faults in the belief are; which criteria it stands up to and which it fails; and whether it qualifies as a pseudoscience or a protoscience (a new science trying to establish its legitimacy). A true science will stand up to all applicable criteria. A pseudoscience may stand up to some of the criteria but ultimately will violate at least one of them. A protoscience is typically distinguishable from a pseudoscience by welcoming criticism, testing, and a willingness to be disproved.

e. *Summation.* After students familiarize themselves with how to use the criteria for determining what science is, they should be able to discriminate between scientific and nonscientific statements. However, it is important for instructors to understand that students may not readily dismiss a pseudoscientific belief merely because it fails certain scientific criteria – nor will they always accept a scientific theory (specifically evolution or climate change) even though it stands up to the defining criteria of good science. Students enter the classroom with a worldview created from the contributions of a variety of sources – their parents and relatives, teachers and spiritual leaders, peers, and popular culture. Misconceptions about how things work or prior beliefs about certain phenomena can be extraordinarily obstinate, and conceptual change does not come easily. Nevertheless, when students understand scientific thinking and how claims are evaluated, perhaps they can articulate that their objections to some scientific theories are for social rather than scientific reasons.

These exercises and assessment projects have been done with hundreds of high school students over the course of many years. Students report that the topic is of high interest, and they enjoy researching a pseudoscientific belief of their choosing. Students also report that they enjoy listening to their classmates' findings – and many admit that they had accepted some of the pseudoscientific beliefs (the existence of Bigfoot, psychic readings, and astrology for example) as fact without ever scrutinizing the evidence. Since these activities are done during a "Nature of Science" unit at the beginning of the year, students often bring in examples of pseudosciences that they find in the media over the course of the term.

Acknowledgments

We are indebted to many colleagues who provided commentary and critical feedback during the development of these exercises. David W. Hale provided a thorough review of the manuscript.

References

Aaseng, N. (1994). *Science versus Pseudoscience*. New York, NY: Franklin Watts.

Byford, J., Lennon, S. & Russell, W.B., III (2009). Teaching controversial issues in the social studies: a research study of high school teachers. *Clearing House, 82,* 165–170.

Clough, M.P. (1994). Diminish students' resistance to biological evolution. *American Biology Teacher, 56,* 409–415.

Johnson, R.L. & Peeples, E.E. (1987). The role of scientific understanding in college. *American Biology Teacher, 49,* 93–98.

Schafersman, S.D. (1997). An introduction to science: scientific thinking and the scientific method. Available online at http://www.geo.sunysb.edu/esp/files/scientific-method.html.

Shipman, H.L., Brickhouse, N.W., Dagher, Z. & Letts, W.J., IV (2002). Changes in student views of religion and science in a college astronomy course. *Science Education, 86,* 526–547.

Sinclair, A., Pendarvis, M.P. & Baldwin, B. (1997). The relationship between college zoology students' beliefs about evolutionary theory and religion. *Journal of Research and Development in Education, 39,* 118–125.

Truzzi, M. (1978). On the extraordinary: an attempt at clarification. *Zetetic Scholar, 1,* 11.

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