What Counts as Science

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A message of alarm arrives from your cousin: what do you know about the science of "fracking"? Fracking is a way to extract oil and gas. It could potentially generate lots of welcome income in their impoverished rural community – while supplying energy domestically. But possibly dangerous chemicals are injected into the earth and collect in waste ponds. Some residents are worrying about contaminated groundwater (Griswold, 2011). It's potentially quite frightening. But also confusing. Your cousin seeks your perspective.

Such a scenario seems to illustrate precisely what science education is ultimately all about: informing policy and decision-making where scientific claims are relevant. Namely, "scientific literacy." How do teachers prepare students for such a role?

Recently I joined a group of teachers in an exploratory exercise, to help understand the educational challenge more deeply. How would a typical student approach this case, given what we taught them? We assumed the role of our students: what could we each learn about fracking in just one hour (our view of sustained student motivation)? Even seasoned teachers found this activity fruitful for reflection – and so I recommend it to you too.

Interpreting our students' point of view and motivation, we all went to the Internet. Wikipedia. Google. Quick, informative, apparently authoritative answers. Many found specialized websites describing how fracking works (energytomorrow.org; fracfocus.org; hydraulicfracturing.com). They were apparently quite frank about safety issues, which seemed fully addressed, including an impressive quote from the head of the Environmental Protection Agency. Yet the teachers all agreed: any genuine information was mixed with a lot of questionable claims and spurious "evidence." A lot was left out. The incompleteness betrayed bias.

Our take-home lesson? What students would likely interpret as sound science, we did not. Here, the foremost knowledge needed for scientific literacy was the ability to distinguish good science from junk and industry propaganda. Second, and perhaps more notably, what the students needed to know was not in the textbook or basic curriculum. The content knowledge that forms the core of most science classes, while often rendered as a foundation, is only of marginal value in such cases. Namely, in the public realm good science and *what counts as good science* differ significantly. We came to doubt a pervasive principle – the sacred bovine on this occasion: that science teachers can just teach the "raw" science itself, while remaining aloof to the cultural politics of science. We cannot responsibly disregard the media contexts through which science is conveyed – and sometimes misconveyed.

○ Demarcating Science

The problem of "junk science" has become more acute in recent years – or perhaps it just seems so. Recently neurobiologist Don Agin (2006) prominently profiled the problem, with cases ranging from fad diets and longevity schemes to images of one-gene, one-behavior. Likewise, physician Ben Goldacre has critiqued "bad science" in a column for London's *Guardian* newspaper since 2003. In a recent book he takes to task commercial claims about cosmetics, nutrition and vitamins, antioxidants, and "detox" treatments (2010). Physicist Robert Park (2000) calls it all "voodoo science," from flawed drug studies to reports that electric power lines can cause cancer. Historians Eric Conway and Naomi Oreskes (2010) have focused on second-hand smoke, acid rain, ozone, global warming, and pesticides, exposing the politics behind generating doubt about their dangers. A false image of scientific uncertainty has prolonged these public debates and delayed prudent action. Former government epidemiologist David Michaels (2008) has noted similar problems in the cases of worker safety regulations on asbestos, dyes, vinyl chloride, benzene, hexavalent chromium, and beryllium. Political reporter Chris Mooney (2005) has profiled systematic selective bias in the use of science even at the level of the Office of the U.S. President. From a legal perspective, Thomas McGarity and Wendy Wagner (2008) have analyzed how industry and special interests "bend" health science: by suppressing publication of negative results, harassing researchers, and spinning research findings. The problem extends into the courtroom, too, through biased "experts" (Huber, 1991). Accordingly, the American Association for the Advancement of Science now has a special office to support the education of judges on scientific evidence and testimony (see http://www.aaas.org/spp/sfrl). Everywhere we turn, it seems, people with particular ideologies or products "conjure" science as a form of authority for their claims (Martin, 1981; Toumey, 1997; Rampton & Stauber, 2001). The impressions of science – what counts as science – can eclipse genuine science.

Of course, none of this is new. Some teachers may recall the crusading work of champion skeptic Martin Gardner, who worked tirelessly to debunk many "fads and fallacies in the name of science" (1957, 1981): dowsing, ancient astronauts, psychokinesis, orgonomy, anthroposophy, Lawsonomy, and more. Delving deeper into history, one encounters the peddlers of "snake oil" remedies or, earlier, of mesmerism (so-called "animal magnetism"). Even in the early 1600s one can find playwright Ben Jonson satirizing a pair of con men who feign competence as *The Alchemists*. Society has long been haunted by those ready to capitalize on the credulity of others.

So how does one prepare students to interpret such cases, as widespread as they seem to be, from fracking to global warming to miracle cures? For many, the challenge may seem familiar. Teachers often try to guide students away from the pretenses of pseudoscience, creationism, and the like. Typically, the strategy has been to neatly distinguish science from non-science (or pseudoscience, or junk/voodoo/bad/bent/bogus science). In this view, all one needs to do is clearly define what makes science *science*. Sorting is easy with the right criterion.

Philosophers have certainly tried to characterize the boundary of legitimate science: what they call the *demarcation problem*. But defining the edge of science clearly and definitively proves notoriously frustrating.

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One wants to exhort students to simply be "objective" or "rational," to maintain a skeptical attitude, and to heed the evidence (for example, Park, 2000; Shermer, 2002; Agin, 2006; Pigliucci, 2010). But this counsel, while easily dispensed, is not so easily articulated in practice. Philosophers have tried to identify particular signature roles for logic, for verifiability, for falsifiability, for progress, and so on – each abandoned in turn. After their many trials and successive failures, philosophers have largely abandoned this project as unrealizable. There is no simple, single criterion that distinguishes science from non-science.

○ The Psychology of Belief

But all is not lost. As the case of fracking indicates, what matters ultimately is a practical understanding of how to distinguish reliable claims from unreliable ones. One can bypass the contentious labeling of "science." A common strategy here is to equip students with some critical acumen. Teach them to judge claims fully on their own. For example, the American Dietetic Association presents "Ten Red Flags of Junk Science" for diagnosing diet claims (Duyff, 2002). For example, avoid recommendations that promise a quick fix. Claims that sound too good to be true are usually just that: untrue. Or: dismiss simplistic studies – those that ignore individual or group differences, or that are based on a single investigation. Robert Park (2003) provides his own list of "The Seven Warning Signs of Bogus Science." For example, beware anecdotal evidence. Don't trust those working in isolation, or claiming that the "establishment" is suppressing their results. The website Understanding Science (2012) provides a "Science Toolkit" of six questions for evaluating scientific messages. For example, are the views of the scientific community, and their confidence in the ideas, accurately portrayed? Is a controversy misrepresented or blown out of proportion?

Of course, one might equally heed the observation that we tend to be beguiled by handy short lists. They certainly help sell magazines. People seem drawn to a small set of enumerated tips, rules, "secrets," or principles. The magic numbers are between 6 and 13 (Freedman, 2010, p. 75). Even such lists, then, may be viewed critically.

Indeed, we should give due attention to our inherent cognitive tendencies. Even when good information is available, we do not always "recognize" it. For example, emotions or first impressions can easily trump due reflection (Lehrer, 2009; Kahneman, 2011). Prior beliefs can shape what we "hear" or how we interpret it (Gilovich, 1991; Sunderland, 1992; Hallinan, 2009). We can endorse testimony we "want" to hear (or that just "seems right"). We can discount evidence that doesn't match our previous way of thinking. Even otherwise intelligent people can believe weird things (Shermer, 2002, pp. 279–313). This is how our minds work. Sometimes they can lead us astray. What counts as science can be victim to how our brains typically function.

That is, we will be favorably disposed to some claims, *regardless* of the evidence, whether it is fair *or* distorted. Science journalist David Freedman describes how we respond to *resonant* advice (2010, pp. 76–80, 184, 217–224). For example, we prefer information that is presented as clear-cut and definitive: why fuss with uncertainties? We prefer a rule that can be applied universally: why learn more than one? We like things simple: why bother with time-consuming complexities? We follow others: why work harder than you need to? These all reflect a tendency of "cognitive economizing." Mental short-cuts are the norm. We also respond more favorably to positive or upbeat pronouncements.

We prefer concrete, actionable advice, not information or perspective merely. Drama stirs the emotions. As does novelty. Stories make the facts more vivid. The *appeal* of a claim can be quite strong, apart from the quality of the evidence and, mostly, apart from conscious deliberation. A good deal of what counts as science reflects the psychology of belief and persuasion, more than anything about our understanding of science or evidence.

The profound lesson is that we may not truly engage evidence, even when it is presented to us. Therefore, we need to see our minds as cognitive machines that are not perfect. Our cognitive dispositions can lead us astray. Understanding the psychology of belief matters. Learning how our minds work – and how they can fail us – is a first step toward securing reliable knowledge (Gilovich, 1991; Suinderland, 1992; Hallinan, 2009; Lehrer, 2009; Kahneman, 2011; *Sacred Bovines*, August, 2010). Namely, without proper habits of reflection and self-analysis, scientific evidence will have little import. That means some basic lessons in psychology and cognitive science, now generally outside the standard K–12 curriculum.

○ Credibility

Another educational approach for improving the status of what counts as science publicly is to foster independent scientific reasoning. The goal is to enable students to interpret the evidence on their own. So, many teachers aim to inculcate skills in the critical analysis of evidence: from recognizing the need for controls or randomized clinical trials to distinguishing cause from correlation or interpreting the degrees of uncertainty conveyed by statistics. Such skills can prove useful, of course (if one is first aware of the common cognitive pitfalls noted above).

Yet the fracking case was again very informative. Students might evaluate the evidence if it was available. But a chief problem is that much relevant information seems missing. For example, the list of the chemicals injected into the ground is not fully disclosed, under appeals to proprietary information. There are few details about the storage, transport, or treatment of the chemical waste. Also, the geological knowledge required to interpret, say, claims about increased risks of earthquakes is well beyond the average citizen. The very list of relevant environmental or health concerns itself requires sophisticated knowledge of the process. In all these ways and more, interpreting this case requires specialized content expertise, not just generic scientific judgment. Indeed, this seems true for most contemporary socioscientific issues, whether it is assessing the risks in prostate cancer screening or estimating the cod populations off the New England shore (Brownlee & Lenzer, 2011; Goodnough, 2011; Harris, 2011; Rosenberg, 2011). The vision of transforming every student into an independent scientific agent for all occasions is utopian. In our current culture, we all rely on experts for their specialized knowledge (Hardwig, 1991).

Indeed, the impression that one's own judgment can substitute for scientific expertise opens the way to significant mischief. This is the tactic of many anti-climate-change websites (for example, globalwarminghoax.com, globalclimatescam.com, globalwarminghysteria.com, climatechangedispatch.com, globalwarming.org, and co2science.org). They depend on an individual's sense of autonomy. They encourage independence and the freedom to disagree with the expert scientific consensus. Using fragments of contrary evidence, and an intuitive appeal to the concept of falsification, they leverage doubt and disbelief. Of course, their selective use of evidence fosters biased assessments. But without the relevant knowledge, you will be unaware that the evidence is incomplete or unbalanced, and unable to discern which reported evidence is truly reliable. That requires an expert. Pretending otherwise corrupts science.

Most conventional approaches encourage individuals to make critical judgments on their own, as conducive to science. But here, such advice amounts to implicit dismissal of the professional expertise of the Intergovernmental Panel on Climate Change and of all the scientists who have contributed to its consensus. In today's world of specialized knowledge, a skeptical attitude or disrespect toward legitimate scientific expertise amounts to being anti-science.

The challenge, ultimately, is less knowing *what* to trust than knowing *who* to trust. For most socioscientific issues, we need not understand what makes *evidence* credible so much as what makes *testimony* credible. Who are the experts, and why? What is the foundation for expertise? How does one know when someone else can evaluate the evidence effectively? When one can trust their specialized knowledge or judgment? In our world of distributed technical knowledge, understanding expertise and credibility is indispensable to full scientific literacy (Gaon & Norris, 2001). And it poses an implicit challenge for science education.

The principles for what counts as science in the public sphere thus differ strikingly from conceptualizing science itself. Understanding how science works internally is not sufficient for interpreting reports of scientific claims in the public media. One must be familiar with how scientific information flows through the culture, and how it is filtered, shaped, and recast as it goes. That was the primary lesson of mimicking student research on fracking. Of course, even scientists depend on other scientists for their particular expertise. Trust is common. Trust is inevitable. The central challenge, then, is articulating the structure of epistemic trust and the tools for assessing any one person's credibility – a task addressed in the next *Sacred Bovines* essay.

References

Agin, D. (2006). *Junk Science*. New York, NY: St. Martin's Press.

Allchin, D. (2010). First among errors. *American Biology Teacher*, *72*, 390–392.

Brownlee, S. & Lenzer, J. (2011). The bitter fight over prostate screening – and why it might be better not to know. *New York Times Magazine*, 9 October, 40–43, 57.

Conway, E.M. & Oreskes, N. (2010). *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. New York, NY: Bloomsbury Press.

Duyff, R. (2002). *American Dietetic Association Complete Food and Nutrition Guide, 2nd Ed.* New York, NY: John Wiley.

Freedman, D.H. (2010). *Wrong: Why Experts Keep Failing Us – And How to Know When Not to Trust Them*. New York, NY: Little, Brown.

Gaon, S. & Norris, S.P. (2001). The undecidable grounds of scientific expertise: science education and the limits of intellectual independence. *Journal of Philosophy of Education*, *35*, 187–201.

Gardner, M. (1957). *Fads and Fallacies in the Name of Science*. Mineola, NY: Dover.

Gardner, M. (1981). *Science: Good, Bad, and Bogus*. Buffalo, NY: Prometheus Books.

Gilovich, T. (1991). *How We Know What Isn't So*. New York, NY: Free Press.

Goldacre, B. (2010). *Bad Science: Quacks, Hacks and Big Pharma Flacks*. New York, NY: Faber and Faber.

Goodnough, A. (2011). Scientists say cod are scant; nets say otherwise. *New York Times*, 10 December, A20, A27.

Griswold, E. (2011). The fracturing of Pennsylvania: situation normal all fracked up. *New York Times Magazine*, 17 November, 44–52.

Hallinan, J.T. (2009). *Why We Make Mistakes*. New York, NY: Broadway Books.

Hardwig, J. (1991). The role of trust in knowledge. *Journal of Philosophy*, *88*, 693–708.

Harris, G. (2011). Some doctors launch fight against advice on prostate cancer testing. *Star Tribune*, 9 October, A21.

Huber, P.W. (1991). *Galileo's Revenge: Junk Science in the Courtroom*. New York, NY: Basic Books.

Kahneman, D. (2011). *Thinking, Fast and Slow*. New York, NY: Farrar, Straus and Giroux.

Lehrer, J. (2009) *How We Decide*. New York, NY: Houghton Mifflin Harcourt.

Martin, B. (1991). *Scientific Knowledge in Controversy*. Albany, NY: State Univeristy of New York Press.

McGarity, T.O. & Wagner, W.E. (2008). *Bending Science: How Special Interests Corrupt Public Health Research*. Cambridge, MA: Harvard University Press.

Michaels, D. (2008). *Doubt is Their Product: How Industry's Assault on Science Threatens Your Health*. Oxford: Oxford University Press.

Mooney, C. (2005). *The Republican War on Science*. New York, NY: Basic Books.

Park, R. (2000). *Voodoo Science: The Road from Foolishness to Fraud*. Oxford, U.K.: Oxford University Press.

Park, R. (2003). The seven warning signs of bogus science. *Chronicle of Higher Education*, *49* (31 January), B20.

Pigliucci, M. (2010). *Nonsense on Stilts: How to Tell Science from Bunk*. Chicago, IL: University of Chicago Press.

Rampton, S. & Stauber, J. (2001). *Trust Us, We're Experts!: How Industry Manipulates Science and Gambles with Your Future*. New York, NY: Tarcher/Putnam.

Rosenberg, S. A. (2011). Scientists say cod still overfished. *Boston Globe*, 11 December.

Shermer, M. (2002). *Why People Believe Weird Things, 2nd Ed.* New York, NY: Holt.

Sutherland, S. (1992). *Irrationality: Why We Don't Think Straight*. New Brunswick, NJ: Rutgers University Press.

Toumey, C. (1997). *Conjuring Science*. Rutgers, NJ: Rutgers University Press.

Understanding Science. (2012). University of California Museum of Paleontology. Available online at http://www.understandingscience.org.

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