Science, Values, and Citizens

Heather Douglas

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Abstract: Science is one of the most important forces in contemporary society. The most reliable source of knowledge about the world, science shapes the technological possibilities before us, informs public policy, and is crucial to measuring the efficacy of public policy. Yet it is not a simple repository of facts on which we can draw. It is an ongoing process of evidence gathering, discovery, contestation, and criticism. I will argue that an understanding of the nature of science and the scientific process should be the central goal for scientific literacy, rather than a grasp of specific (often disciplinary) facts. With this understanding of science as a backdrop, the paper then turns to modes for citizen engagement with science. This paper articulates different ways citizens can engage with science, including four avenues for legitimate contestation of scientific claims. I then look more closely at contestation of science on the basis of values. That science can be legitimately contested by non-experts on a range of grounds means that science communication should not just aim at getting citizens to accept scientific claims, but rather to engage in a more robust two-way conversation about science.

Introduction

Science is an important, often crucial, aspect of contemporary society. But its relationship to citizens is fraught. Even though scientists are among the most trusted professions generally (Smith & Son 2013), controversies about science in the public realm abound and scientists frequently lament the lack of scientific understanding the public exhibits.

Given this complexity, how should the public understand science and how should they relate to scientific endeavors? And, what kind of relationship with the public can scientists reasonably expect? In the realm of science communication since Sputnik, the predominant concern has been couched in terms of scientific literacy. Within the frame of scientific literacy, the central problem is that the public simply does not know enough about science, particularly scientific facts, and so is perpetually unable to grapple with scientific issues of public import. The “deficit” model (named for the deficit in scientific literacy extant in the public) is pervasive; it has also sustained substantial critiques in the past two decades. (Miller 2001; Bauer, Allum, & Miller 2007) Nevertheless, the prevalent attitude among scientists is that the public does not have a sufficient grasp of the underlying science to deal adequately with science-related policy issues. (Pew Research Center 2015)

Critics, however, suggest that instead of deficits and one-way communication, there should be more two-way communication and more collaborative practices between scientists and citizens, to improve the conduct of science and public engagement with science. Such two-way communication can alert scientists both to the concerns of the public and to potentially erroneous assumptions in scientific work. It can allow for increased mutual understanding and respect among scientists and citizens. It can provide avenues for effective engagement in the practice of science and for deeper understanding of science among members of the public. But it can also open science up to scrutiny and critique by the public.

The possibility of a public willing to both engage with and critique science may be worrisome to many scientists. After all, such a description seems apt for perpetual thorns in the side of the scientific community, such as creationists and vaccine deniers (in particular, those who believe vaccines cause autism). Thus, we must have a way to assess whether a public's criticism of science is legitimate. What are the legitimate bases for being critical of science? And how can the public come to understand what the limits are on what is, and is not, a legitimate critique of science?

Here I provide an overview of the bases on which a citizen, in particular a non-scientist, can engage with and even criticize a scientific community or finding. While scientists might not want to open themselves to increased criticism, this is the price of genuine dialogue and engagement. If you want to talk to someone, you should expect that they might want to talk back. But there must also be a clear understanding of the basis on which a citizen can talk back to a scientist. What are the legitimate (and illegitimate) issues which can be raised? Delimiting these might help scientists see both what can be gained from engagement with the public and assuage concerns about what is on the table for contestation.

To see where the public can legitimately engage with and critique science, we need first a general account of what science is. This is not just useful for the particular philosophical project of finding the legitimate avenues of public contestation of scientific claims. It is also essential for the public to have this understanding of the nature of science and of the scientific enterprise, so that they can know what to reasonably expect from science and scientific experts. If we are to have two-way lines of communication, citizens need this understanding.

This paper begins with what we should think the nature of science is and what we should teach the public regarding science. The paper then presents various avenues for engaging with and, in some cases, critiquing scientific claims. Delving more deeply into those bases, the paper then turns to the role of values in science. Understanding the *legitimate* roles for values in science is important because if the public holds different values, particularly social and ethical values, from scientists, then where and when these values play a role in scientific practice shows important ways that the public can legitimately contest scientific claims.

Teaching the Nature of Science

For the past several decades, scientific literacy measures have aimed primarily at scientific facts. Although a few questions may address questions of scientific method, most are simple true/false questions that query whether citizens have a grasp of basic facts as science now sees them. Questions regarding the age of the planet, the size of electrons vs. atoms, whether all life has DNA in it, the speed of sound vs. light, and so forth, are the bulk of scientific literacy questions. Citizens have performed steadily poorly on these tests since their inception over 50 years ago, i.e. the public has been measured as being illiterate, and stably illiterate, over decades. (Miller 2004)

Such results create despair among science communicators. The worry is that a scientifically illiterate public can neither appreciate science nor engage in policy debates with scientific components. But what if we are aiming at and measuring the wrong thing when attempting to assess scientific literacy? Our K-12 science courses still aim for a grasp of scientific facts—educational testing in multiple-choice format seems to be on the rise rather than the decline. The "answer in the back of the book" approach, while criticized at the national level in discussions of science education (e.g., AAAS's Project 2061, Schweingruber et al. 2012), does not appear to be on the wane at the level of implementation. Indeed, I have been told by educators that while national educational reform goals are great goals, getting them to be reflected in actual curricula is extremely difficult. The structural inertia seems insurmountable.

I want to argue here that actually achieving educational reform is crucial. And that educational reformers should be willing to jettison the teaching of large areas of facts in science for the sake of enabling citizens to understand *what science is*. If high school students take one course in science, it should not be chemistry or biology or physics, but rather a course in scientific investigation, so that they come to understand what science is like as an epistemic endeavor. It is this understanding they will need as citizens. All later understandings and facts can be built on this basis. If citizens don't have this basis, they will not be able to grapple with new scientific information as it arises throughout their lives.[1]

What should such a course teach? The most important thing to understand about science is its jointly critical and inductive nature. Science is an evidentially based endeavor that seeks to build an empirical understanding of the world. It does so through proposing explanatory theories that encompass the available evidence, and then, further tests those theories to the best of its ability. Because the theories always say more than the available evidence, the evidence provides at best inductive and thus incomplete support for the theories. Even simple claims of regularities have this feature—extending the claim of regularity into the past or future states, or new locations, requires an inductive inference. Similarly, theoretical or causal claims allow one to test such claims in new and different

[1] If this understanding of science can be taught effectively before high school, so much the better. Blackawton et al. 2011 suggests that it can.

settings. These extensions then provide an opportunity to further test the theory. Thus, explanations and theories never have complete empirical support, yet the primary mode of support is empirical. It is in this sense that science is inductive.

That scientific claims are not completely supported by evidence allows for critical and ongoing testing of such claims. Because theories are applicable beyond their base of support, we can push on them, apply them to new contexts, to see if they continue to hold up. It is also this possibility for ongoing testing that makes scientific theories useful. If theories only applied to the already gathered evidence used to construct them, they would not be terribly helpful in making decisions about what to do in new contexts, including in practical policy-relevant contexts. Scientists can (and should) test their theories to see if they continue to predict phenomena accurately in new but relevant contexts. In addition, scientists can propose new theories that they think do better with respect to the available evidence. Because the fit between theory and evidence is never perfect and complete, space for ongoing critical activity is created. This is the work of scientists, to continually test, refine, reformulate, and rework theories and their relationship to evidence. Every claim of science is open to testing and reworking, even possible rejection. Scientific knowledge is, in this sense, all up for grabs.

As social epistemologists have noted, it is crucial that the social conditions of science be conducive for such critical activities. (Longino 1990, 2002, Solomon 2001) There needs to be open forums for critical exchange, open venues for airing ideas and results, expectations that criticisms are responded to, and an encouragement for diverse participants in the scientific community (so that new perspectives on old problems can be employed and so that tacit assumptions can be challenged). If the culture of science were one that discouraged criticism (e.g. that saw criticism as rude), it would not matter that in theory critiques of scientific claims could be offered. They would not be offered much in practice. The practice of science, of rewarding the critic, of encouraging new challenges and tests of old theories, is crucial to science's epistemic robustness.

Currently, the culture of science is not perfect in this regard. There are worries that there are too few incentives for replication studies (which try to show whether a theory holds up in a new instance), too much pressure for novel claims rather than building on and testing existing claims, too much pressure for winning grants from committees with an aversion to genuinely new ideas. Note that these concerns pull in opposite directions: that science is averse to the new and that science is obsessed with the new. The question in practice is where the balance is struck. More positively with respect to the robust social conditions for science, the scientific community has gotten a bit more diverse in the past few decades. (e.g., Shen 2013) More voices are now able to participate and raise scientific criticisms within the scientific community, even if more needs to be done in this regard.

It is crucial that citizens understand how the culture of science undergirds the practice of science. Raising concerns about the practicing culture of science is one legitimate way in which citizens can critique scientific claims. Citizens can also raise criticisms of scientific claims on the basis of the evidence, or alternative theories of the evidence, but doing so in practice is a challenge, as such criticisms must reflect an effective grasp of the currently available evidence, a grasp few non-experts have. As we will see below, there are other routes through which citizens can raise criticisms of scientific claims.

Courses should teach this understanding of the nature of science starting in grade school. Young students could engage in a community science project, grappling with data collection, controlling for confounders, proposing alternative explanations for phenomena, and seeing the competitive nature of science in practice in their classroom. (See, e.g., Blackawton P.S. et al. 2011) Alternatively, courses could track historical examples of scientific controversies and how they were handled and debated in the scientific community, including discussing the different theories that were proposed and debated, and how controversies were ultimately resolved. Students coming out of such courses would perhaps know fewer facts about a range of scientific topics, but have a deeper understanding of what it means to do science and the epistemic stance required to do it well. This is the understanding citizens should have first and foremost.

Why is understanding the nature of science more important than having a grasp of a range of scientific facts? Why have literacy tests been measuring the least important thing one can know about science? I am presuming that what we want from citizens is to be able to engage effectively with science policy disputes and to be able to assess scientific expertise. If this is the case, then teaching citizens scientific facts as the primary effort in school is not helpful.

Why? First, because the facts can change. When I was growing up, it was a fact that acquired characteristics could not be inherited by complex organisms. Because of new findings regarding epigenetics, this “fact” is no longer true. Science can challenge and change some of its core findings, even supposedly fixed facts. That it has this capacity is one of central reasons it is one of our most effective ways at discovering empirical reality. But that it has this capacity means that no scientific fact should be considered permanently stable. They are all potentially changeable by future evidence and discovery, even as they are also the best empirical account we have at any given time.

Second, if we teach citizens science as if it were a collection of stable facts to which we may add a few more, citizens will be disoriented and disappointed when either experts disagree or experts change their minds. That experts can disagree is to be expected in many cases—scientists disagreeing with each other is crucial to the culture of contestation in science. Experts changing their minds is also evidence of science *functioning properly*, not evidence of experts being fickle or weak-minded. Experts *should* change their minds in face of new findings, particularly if such findings cannot be accommodated by previous theories or are unexpected and replicated. Such changeability may be frustrating to citizens who just want to know what the right answer is, but that citizens have this desire and expectation just indicates how severely our science education system has failed them. Giving us the right answer, forever fixed and true, is not what the practice of science is about. Instead, it is about giving us the best, most empirically supported answer we can have at the time.

Third, when new science policy issues arise, such issues are often based on new scientific findings. Such new findings are not what is taught in school, and thus the schooling does little to serve as a "basis" for understanding the new findings. It might help a bit to have, for example, a clear sense of what a chemical compound is in order to understand what is at issue in a case of a local chemical spill, but more likely the details of the chemical spill, including the various plausible ecological pathways (e.g., uptake by which organisms), fat vs. water solubility, decomposition routes, and different remediation strategies were not part of the school chemistry, biology, or physics curriculum. And those issues not central to school curricula will be the crucial issues in the particular case. It makes more sense for people to be able to learn scientific facts as they need them for the particular case at hand. They will be more motivated to do so (as the relevance is clear) and which facts are important will be clearer as well.

For these three reasons, a curriculum structured towards teaching scientific facts, even scientific theories, for their own sake is inappropriate. The primary aim of science courses K-12 should be to teach what science is and how it works. Disciplinary content, specific scientific claims, facts, and theories, are all secondary to this goal. We should be structuring our science education accordingly.

Citizen Engagement with Science

Suppose we had such a citizenry educated in the nature of science. What would this enable? According to many polls, scientists tend to think that if citizens had a better grasp of science (usually meaning scientific facts), then citizens would agree more with scientists on central science policy issues like whether to pursue stem cell research or whether GMOs are safe. I disagree.[2] Not only do I think that a scientifically literate public (in the sense described above) would not necessarily agree with scientists more, but I also think that such a public could and should raise important challenges to scientists. Citizen engagement with science means more than the public coming to agree with scientists; it means the potential for citizens engaging critically with science, albeit on non-expert grounds.

The most widely understood sense of citizen engagement is through "citizen science" endeavors. (Dickinson & Bonney 2012) In these endeavors, citizens help scientists, usually by collecting data or by attempting to solve puzzles (like Foldit). (A full range of ongoing citizen science projects can be explored at sites like http://www.scientificamerican.com/citizen-science/.) In these cases, the agenda is generally set by the scientist and the citizen agrees to help out, whether by counting birds, keeping track of a temperature measure, or engaging in a constrained search.[3] Clearly,

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[2] Similar concerns are raised by Bauer, Allum, and Miller 2006, who note that there is empirical disagreement on whether "the know you more, the know you love it" or "familiarity breeds contempt." (p. 84)

[3] There are exceptions. See, e.g. Trautmann et al. 2012 for how citizen science can transform education contexts by allowing students to pursue inquiry with their own

understanding the nature of science would help with these endeavors, but because the agenda (and often the methods) are set by scientists, citizens need only do what the scientists ask them to do, and thus an understanding of the nature of science is not actually necessary. Thousands of citizens participate in science through this avenue, but citizen science so conceived does not grapple well the fraught science policy contexts that drive the concerns over science literacy, nor does such an avenue invite a two-way discussion. The possibilities for citizen engagement with science do not end with citizen science.

Of deeper concern to both scientists and policy-makers are controversies regarding science (such as climate change, GMOs, and vaccines) where the scientists and citizens do not seem to agree about what to make of the available evidence. Scientists are perennially frustrated at the lack of concordance between citizen views and scientist views on these issues, and it is here that the deficit model gains the most traction as an explanation for why there remains a gap between scientist understanding and citizen understanding.

But the deficit model is untenable. Not only are deficits of understanding bi-directional, but in the case of controversial science, recent studies have found that increased scientific literacy (in the traditional fact-based sense) does not correlate with increased agreement with the views of scientists. In fact, in some cases, quite the opposite is true. For example both Kahan et al. 2012 and Bolsen et al. 2015 have found that increased traditional scientific literacy does not correlate well with increased acceptance of expert consensus on climate change. For some portions of the public, the more literate the person is, the less they agree with scientists (or the more confident they are in their disagreement).

Much of the social science literature on differences between scientists and the public explain the phenomenon in terms of a “motivated reasoning” model. The argument is that people are less interested in getting at the truth of the matter (to the best of their ability) and more interested in solving practical problems, such as deciding “which stances towards scientific information secure their personal interests.” (Kahan et al. 2012, 733) But the kinds of reasons given under the umbrella of motivated reasoning (e.g. confirmation bias, peer group conformity, ideological commitments, and cherry-picking to fit with worldviews) are hardly the kind of reasons people would want to own up to publicly. It is in this sense that motivated reasoning looks less than rational.[4] Even if such cognitive tendencies explain the patterns of acceptance found, they do not justify them. And pointing to such explanations as reasons for why people diverge from experts

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questions. Such a use of citizen science feeds well into the educational goals articulated above.

[4] A similar taint of irrationality is found in blaming the fragmented nature of the media and the way in which our information searches are structurally being driven to like-minded sources as a reason for why we disagree. Even if the information infrastructure distorts our searches in this way, we should act to counter such trends. (Miller & Record 2013)

is insulting to the members of the public who fit these patterns, precisely because the explanatory causes are not justificatory.

Thus, we currently have two predominant explanations for public disagreement with science, a deficit model and a motivated reasoning model (which explains why those who seem scientifically literate still disagree with experts), both of which tar the public with the taint of inadequacy. Both of these models presume that the goal is to get the public to agree with scientists, that whatever science communication system we have, it is working if we achieve this. But such a presumptions raises the question of whether citizens can disagree with scientists for good reasons. What would good, sound disagreement with scientists look like?

Here I distinguish among four bases for disputing scientific claims. One can reject a scientific claim because 1) one rejects that the claim should be empirically based, i.e., one bases a claim on faith; 2) one disputes the empirical basis of the claim; 3) the scientists who developed the claim were not behaving properly, either individually or with respect to their epistemic community; and 4) one disputes the values that were a legitimate part of the development of the claim.

For the purposes of this paper, I will set aside disputations of claims based on faith. The epistemic stance of faith-based claims is qualitatively different from the epistemic stance of science-based claims. (Douglas 2015) Every scientific claim is open to challenge and rejection as new evidence is pursued, as noted above, whereas the point of many faith-based claims is to hold them above the fray of ongoing challenge and refutation. As faith-based claims are not open to evidential challenge (until, perhaps, the evidence is overwhelming), science has little to say to those who hold such claims. The evidence is largely irrelevant. Whether rejecting science on the basis of faith is rational is far too large of a topic to tackle here.[5] Minimally, what one should not do is conflate belief based on faith with belief based on evidence. This is precisely the error of those who want to teach creationism as science.

For the second basis, the evidence is central. There are cases where citizens have access to particular empirical information that experts do not, and thus disagreement with experts can be legitimately based on a purely empirical matter. (See, e.g. Wynne's classic Cambrian sheep farmer example, where experts had the wrong empirical understanding of grazing habits. Wynne 1996, 26) But such cases are rare, and often if we look at purely empirical bases for disagreement, citizens have anecdotal information whereas experts usually have a more complete empirical picture.[6] This is part of their basis of expertise. A more common source of disagreement concerns whether the right

[5] One classic instantiation of the debate is between Clifford and James. See Clifford (1877) and James (1896).

[6] Rare but often astounding and important, as can be seen in the recent case of Flint water contamination. See the story of Lee Anne Walters covered here http://michiganradio.org/post/mom-helped-uncover-what-was-really-going-flint-s-water#stream/0.

values are at play in the science—in whether the research agenda is pursuing the right questions and in whether what counts as sufficient evidence for the experts is also accepted as sufficient evidence by the public. More on this in the next section.

The third basis is often of central concern to the public. Allegations of fraud are supposed to be caught internally to the scientific community. That Andrew Wakefield's fraud in the case of autism and the MMR vaccine had to be caught by a journalist is something of an embarrassment. (Deer 2011) The scientific community is often not as effective at self-policing as it should be. In addition, the public can be worried that critics of the status quo are not being taken seriously enough within the scientific community. The strong resistance to the idea that bacteria can cause of ulcers is an exemplar of the occasional conservatism of the scientific community. (Thagard 1998) Sometimes, the seemingly outlandish idea is correct. Because of this possibility, the scientific community should address criticisms and alternatives, even if doing so is time consuming.

It is on the fourth basis that I will focus the remainder of the paper.

Social & Ethical Values in Science: Research Agendas and Inductive Risk

Values play a crucial role in scientific reasoning in at least two locations: 1) in the decision of which research projects to pursue (and the details of how to pursue them) and 2) in the assessment of whether the evidence is sufficient to support a claim. Both of these roles are legitimate for social & ethical values in science. Both of these roles also create locations for disagreement with, or contestation of, scientific work. I will illustrate each.

1. Research Agendas and Vaccines

Members of the public can dispute scientific claims because they think scientists are asking the wrong questions. As noted above, social and ethical values legitimately shape the attention of scientists to certain topics or questions. But if what scientists care about asking does not align with what members of the public care about knowing, statements based on the findings can be greeted with skepticism, because the public thinks the scientists are not answering the crucial questions.

One example of the mismatch between the public and scientists concerns vaccine safety. The Wakefield case and the purported link between vaccines and autism has created a great deal of harmful controversy. Wakefield's research was fraudulent, and there is no evidence for a link between vaccines and autism, despite careful searches for such evidence. (Deer 2011, IOM 2004)

Nevertheless, even among parents who reject the idea that vaccines cause autism there is a hesitancy regarding vaccination schedules. (Goldenberg 2016) There are lingering concerns about side effects of particular vaccines or overwhelming the body with too many vaccines at once. Many public health officials are frustrated by this reluctance among parents to follow vaccination schedules.

One reason for such hesitancy involves the contemporary culture of parenting. As Maya Goldenberg has noted (Goldenberg 2016), parents are told that in general, they should closely monitor their children, that different children have different needs, and that if they are paying attention to their children, they will know their children best. In the face of this individualistic parental expertise culture, parents are asked to set aside their individualized knowledge and follow the herd in the case of vaccination schedules. We should not be surprised that many parents balk at this.

More centrally for our purposes here, many of the questions parents have about vaccines cannot be answered well because they have not been extensively researched. While general safety and efficacy levels of vaccines are studied, what causes the rare serious side effect (which do exist) is not well understood. And many side effects are not tracked well at all. If a child has a response once at home, it is rarely recorded or taken seriously. Such anecdotal evidence is not carefully collected or examined, making the search for harmful side effects of vaccines less than robust. (Stegenga 2016) When parents ask what makes a child susceptible to such adverse effects, physicians have no good answers. It is simply not part of their research agenda. The emphasis in vaccine research has been in producing a generally safe and effective product to produce herd immunity. What causes adverse effects in the rare case is not well understood or studied.

Thus, if parents do see an adverse event in their child at home, they will not receive useful information from their doctors about what it means for the vaccination schedule in general. Nobody knows. It is not surprising that hesitancy to trust the schedule is born out of this mismatch of concern: the physicians with population level trends and the parent with individual response. As a result of this mismatch, parents have good reason to be hesitant placing full trust in the experts—the experts do not have the expertise parents desire.

Similar concerns can be raised regarding the environmental safety of some GMOs and regional climate forecasts. In such cases, what some citizens think are the crucial questions have not been well studied (as of yet). The values of those citizens and the values of the scientists are not aligning, producing skepticism about what scientists are reporting. The scientists are not answering the questions on the topic that are of import to the skeptical citizens.

Neonicotinoids and Inductive Risk

In addition to values shaping the research agenda, there is the issue of whether the evidence we have is sufficient for our acceptance of (and action on) the claim. This is a pervasive yet subtle role for values in science. It is also a crucial reason for why it can be perfectly rational for members of the public to trust experts who share their values.

Inductive risk arises whenever knowledge is inductively based (there is thus a chance of getting it wrong–whatever the knowledge claim is) and there are clear consequences to getting it wrong. In short, inductive risk is endemic in science. In societally relevant areas of science, inductive risk opens the door to social and ethical values in the assessment of what counts as sufficient evidence for a claim. Depending on which consequences of error you find more acceptable, you can be legitimately concerned about some kinds of error (e.g., false positives) more than other types of error (e.g., false negatives). The assessment of the consequences of error is where the values play a role (what I have called an *indirect role*). (Douglas 2009) One must assess such consequences because there is no fixed threshold for what counts as sufficient evidence (e.g., what counts as statistically significant varies among fields).

Now, when considering values and inductive risk, the values do not dictate a result or even provide a reason for choosing a particular result. What they do is provide a reason for setting evidential standards in a particular place. They help to decide whether the evidence is enough. In W.K. Clifford's terms, they help set what should count as "sufficient evidence." (Clifford 1877) Thus, evidence maintains a central place in the reasoning structure (unlike with faith-based belief). Evidence must also be present and substantive (values cannot make up for a clear lack of evidence). But rational people can still disagree about whether the evidence available is strong enough or good enough.

Live science policy debates illustrate inductive risk best. Consider the debate over whether bees are threatened by the use of neonicotinoids. There are some studies which suggest they are. The class of pesticides is immunological and neurotoxic to all insects, and problems with bee colonies correlate with the use of the pesticides (although it takes a few years to show up). But is the dose bees experience in the environment enough to cause them harm? Some have argued that at current levels of use, the dose is not high enough, that studies showing harm have used excessively high doses, and so farmers should be allowed to continue using the pesticides as they have been. (e.g. DEFRA UK 2013) Others argue that controlled studies have been replicating field realistic doses and that critics of the studies have not been taking into account exposure routes like guttation. (EFSA EU 2013)

In short, there is expert debate. What is the public to do? It makes sense in these cases to listen to experts that share your values. This is because experts that share your values will assess the consequences of error and the sufficiency of evidence as you would. If you are particularly worried about bee health, then scientists who are similarly worried about bee health (and thus perhaps willing to see less evidence as being sufficient before taking regulatory action) would be most trustworthy for you. (Wilholt 2013) If you are particularly worried about farmers minimizing pest damage, you should trust scientists with similar values, for they will demand more evidence before accepting the claim that neonicotinoids harm bees.

What science communicators have noted,[7] that sharing core values with an expert increases the uptake of what the expert says, is not just a social bias, an irrationality that we can potentially exploit once we know about it. It is a rational strategy[8] when faced with inductive risks. As inductive risks are pervasive in science, it is a rational strategy when dealing with scientific claims.

In addition, pointing out the values that undergird different assessments of evidential sufficiency help foster good debate within science rather than undermine scientific practice. That such divergent values and divergent assessments can exist should help focus scientists where their efforts should be focused—on seeing if they can produce better, stronger evidence to convince skeptics (both among their colleagues and among the public). And public debates can consider both the available evidence and the arguments for why some values should be more important than others.

Conclusion

There are multiple ways in which citizens can legitimately contest scientific claims, even within an empiricist framework (i.e. setting aside faith-based claims). They can do so on an empirical basis, though gathering evidence for the non-scientist is challenging. They can critique the way in which criticisms are addressed and the interchange of ideas within the scientific community. Finally, they can query whether a research project is well-conceived, whether it has an acceptable (either morally or epistemically) methodology, and whether the evidence gathered is sufficient for the claims being made by scientists. Citizens can rationally and legitimately prefer to depend on the expertise of those scientists who share relevant moral and ethical values.

This means that science will be a site of debate and critique as long as its implications are relevant to the public and to policy-making. Science is not a closer, not a mechanism for bringing about acquiescence or unanimity among the public. Science instead is a resource for debate and a resource for imagining our futures in an already messy public realm.

That does not mean science can and should be used to support any position whatsoever. Scientific evidence places limits on what is empirically plausible, and if we are to care about evidence, those limits must be respected. (Douglas 2014) Scientific integrity still matters, and that the political realm can and does use science as a resource in debates does not mean it should be a resource bent, infinitely flexibly, to the will of the user.

But science is also not an inflexible producer of permanent truth. The conception of science as a fount of fixed facts is as problematic a conception of science as infinitely flexible, as a source of whatever view you desire. Citizens need to understand the

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[7] As Liz Neeley notes Achenbach 2015, 45.

[8] By rational, I don't just mean in one's practical interests. I also mean justifiable publicly, i.e. a reasoned basis that can be stated publicly.

ongoing nature of science, the way in which evidence constrains it, but also the way in which different interpretations of the evidence are also likely. With this understanding, productive and respectful engagement between scientists and the public becomes possible.

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