Who Speaks for Science?

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Abstract. Ironically, flat-Earthers, anti-vaxxers and climate change naysayers trust in science. Unfortunately, they trust the *wrong* science. That conundrum lies at the heart of scientific literacy in an age of well funded commercial and ideological interests, overwhelming digital information, and social media. In this paper, I describe how teachers can help students learn how to navigate through the treacherous territory of trusting scientific claims, which are inevitably mediated through social networks and various channels of communication. It is a problem of public epistemology, not the epistemology of science itself. I shall survey the role of science ccon-artists and other imitators of science, the role of science media literacy, the roles of evidence versus credibility and expertise in public discourse, the nature of expertise and the problem of assessing an individual's claim to expertise. It begins with distinguishing between the credibility of science (as an institution), the credibility of individual scientists, and the credibility of a *spokesperson* for science. Ultimately, I claim, the core question for the citizen-consumer is not "Why trust science?" (Oreskes 2019), but "Who speaks for science?"

Kewords: epistemic dependence, epistemic trust, credibility, expertise, provenance, science ccon-artist, public epistemology

1. Introduction

The bane of science used to be pseudoscience (e.g., Feder, 1999; Gardner, 1957; Helfand, 2016; Park, 2000; Pigliucci, 2010; Pigliucci & Boudry, 2016). Now it's conspiracy theories, fake news, alternative facts, manufactured uncertainty, misinformation, *dis*information, and the grotesque bending of science by industry, politicians and ideologues (Allchin, 2012a; 2015; 2018; Jackson & Jamieson, 2007; Markowitz & Rosner, 2002; McGarity & Wagner, 2008; Michaels, 2008; Oreskes & Conway, 2010; van Prooijen, 2018). In the 1950s and 60s, philosophers of science were preoccupied with the demarcation problem: trying to characterize what was "special" about science as a way of knowing, thereby privileging its authority (Agin, 2006; Cromer, 1993; McIntyre, 2019; Popper, 1962; Wolpert, 1992; Zimring, 2019). That was all designed to support belief in the cultural authority of science. By now, trust in science has long been well established. It is integral to national and international policy, on everything from the safety of food, drugs and consumer products to defense systems, health care, and managing potential environmental risks. Nowadays, the battle lines have shifted to the struggles about who gets to claim that authority (Gieryn, 1989; Jasonoff, 1990). The critical social question is no longer "why trust science?" but "*who speaks for science?*"

The challenge of interpreting who speaks for science is indeed problematic. Someone who is an expert can recognize fellow experts by their claims, their methods, their command of background knowledge, their ingenuity and technical competence, and so on. However, a non-expert has no such epistemic leverage. They are adrift in a sea of trust. Not moral trust, or contractual trust, but epistemic trust. The need for trust arises where knowledge is distributed. No one can know everything. We must trust others (epistemically). The problem is not unique to science. In our society of specialized expertise, we rely on doctors, lawyers, and dentists. As well as accountants, computer techs, meteorologists, electricians, plumbers, masons, bridge welders, road constructors, appliance servicers, and so on. (Maybe even teachers.) They each have specialized knowledge beyond our own. As noted poignantly by philosopher John Hardwig (1985), we are *epistemically dependent* on each other. Steve Norris articulated the corollary conclusions for science educators (Norris, 1995, 1997). Students need to learn the limits of personal knowledge and the nature of trust.

?? “to provide these people the wherewithal to deal intelligently with science and scientists despite their lack of scientific expertise.”

Traditional lore teaches that science is founded on skepticism (e.g., Helfand, 2016; Lange, 2019; McIntrye, 2019; Merton, 1973). However, since the founding of modern scientific institutions in the late 1600s, science has been fundamentally built on *trust* in fellow scientists and in their results (Goldman, 1999; Hardwig, 1985, 1991; Shapin, 1994). Hence, it is important to understand the social architecture of trust (Allchin, 2012b). Likewise, in the public realm the credibility of claims is intimately related to the credibility of the source of the claim. Namely, *who* does one trust, and why?

In addressing how to educate the citizen-consumer, I will consider numerous dimensions of the problem. First, I will address the puzzle of belief in bad science, illuminated from the perspective of the errant believer (rather than the well informed scientist). This student-centered perspective sets an important benchmark for classroom teachers who interact with students and for informal educators or journalists who interact with underinformed citizens. Second, I will review the problem of modern imitators of science, or what I have elsewhere called *science con-artists*. The problem of trust is not defined primarily by the tortuous path of knowledge communicated from professional scientists, but by those who try—as aptly described by Toumey (1996)—to “conjure” science illicitly, seeking to secure all the cultural authority of science with none of the epistemic work. Third, I will elaborate on the dilemma of assessing persons and their expertise versus assessing abstract arguments and their evidence. It is important to establish, as noted above, that ordinary citizens and consumers (even scientists outside their own field of expertise) are limited in their ability to make authoritative conclusions based on the evidence, or even in their ability to know what the complete and relevant evidence might be. Fourth, I will outline the general criteria for assessing expertise. This will open further the importance of the sociology of knowledge and of institutionalized systems for regulating trust, well beyond the now familiar philosophical concerns about social epistemology. Finally, I will return to the problem of the situated consumer of science and their access to scientific knowledge through various communication media, including the ever more important social media. Understanding the “ontogeny” of a scientific fact in society is a critical tool for interpreting the reliability of claims which arrive to us mediated. In each section, I will cite examples of classroom lessons that help students develop the relevant understanding through epistemic inquiry.

2. The Enigmatic Belief in Bad Science

Consider, for example, the case of the coronavirus pandemic that emerged in early 2020. Research resources were rapidly remobilized around the globe, aiming to understand the new disease—its transmission patterns, the virus’s genome and its molecular components—with findings in remarkably short time. At the same time, spurious theories about the origin and cause of the virus circulated widely on the internet and on social media. One prominent claim attributed the health effects to radiation from the new 5G telecommunications network. No matter that this view was not endorsed by professional scientists. 5G cell towers were vandalized and burned across Europe (Hamilton, 2020; van Prooijen, 2020; Sorkin, 2020). Given the urgency of solving a shared public health crisis, what guided these individuals to adopt such an ill informed claim? Meanwhile, national leaders in the United States and Brazil touted an untested remedy (a "game changer," one said), even while veteran infectious disease specialists cautioned that there was only anecdotal evidence, at best. (A quickly assembled clinical trial in Manaus, Brazil, was soon halted when fatal side effects emerged.) The covid episode illustrates that a huge gulf has opened now between the consensus view of scientists and what a meaningful proportion of the populace *accepts* as justified science. Ironically, the "scientific" debate thrives largely without scientists. One could equally have cited the case of New Madrid, Missouri, a town that closed schools and prepared for an earthquake on December 3, 1990, based on a spurious prediction by someone with absolutely no relevant expertise and no concrete evidence (Spence, et al., 1993). Or over two million voters in California who approved a 1986 ballot referendum for mandatory HIV testing and quarantining, based on the mistaken belief that HIV could be transmitted by casual contact (Toumey, 1996, pp. 81-95). Or the anti-fluoridationists of the 1950s and 60s who paraded studies about the dangers of fluorosis (Martin, 1991; Toumey, 1996, pp. 63-80). Science and *what counts as* science in the public realm can diverge dramatically (for elaboration, see Allchin, 2012c).

Why do people believe claims that scientists regard as utter nonsense? How might we solve this? Many advocates of science conspicuously denounce the popular views as anti-science and place responsibility for them squarely on the shoulders of the individual consumers of science. Beliefs that contradict science, they contend, arise from willful ignorance, gullibility, wishful thinking, self-delusion, pure folly, and the like (e.g., Agin, 2006, Forgas & Baumeister, 2019; Gratzer, 2000; McIntyre, 2019; Youngson, 1998). *If only* non-scientists made an effort to be more rational! Others will target poor science communication. *If only* scientists could learn to speak to the public better and explain their conclusions—and give it a human face—somehow sentiments and deference towards science would be better! Others target deficits in science education. *If only* students learned the "nature of science" and how science worked, they would *understand* science and thus believe only valid, empirically demonstrated conclusions! *If only* students were steeped in "scientific practices," or in argument, logic, and the rules of evidence, they would become independent agents, equipped to address all the controversial claims of science and society themselves on their own and be able to sort bonafide claims from junk! Yet others lay the blame on poor "science marketing." *If only* we did a better job "selling" the benefits of technology and the triumphs of scientific discovery to the public, the skepticism and anti-science attitudes would soon fade away, to be replaced by proper respect! *If only!* If only? Alas, there is little actual evidence that these popular and widely endorsed solutions are actually effective in fostering or instilling functional scientific literacy (that is, in citizen-consumers being able to discern which scientific claims are reliable in a concrete cultural context).

Educators, of course, have learning theory to interpret the challenge. Most notably, all these efforts aimed at bolstering trust in science are developed from the perspective of a science advocate. In constructivist pedagogical terms, they are not student-centered. An instructor hoping to reform thinking must first understand (sympathetically) just how the students or ordinary citizen-consumers think or misconceive a target concept. They must then create an instructional trajectory or learning sequence that will help them notice the flaws in any particular conceptualization, and guide them towards a deeper and more informed perspective. From a constructivist perspective, one can appreciate how utterly counterproductive it is to treat a creationist student as, say, self-deluded or willfully ignorant (for elaboration, see Allchin, 2013a). That is not an effective strategy for achieving conceptual change.

“Getting inside” the perspective of those who reject consensus science is decidedly discomforting. One must risk acknowledging that patently “irrational” views may *seem* reasonable, or even compelling. But if one has the courage to listen sympathetically, one will soon discover that the problem of so-called science denial is plainly not denial of science. Indeed — paradoxically perhaps — the “deniers” often vigorously appeal to science. They *do* trust science. Alas, they trust the *wrong* science. Yet they nonetheless feel that the science is “on their side.”

For example, as evidence for the case of 5G causing covid, one might be advised to compare maps that show the outbreaks of covid and the locations of 5G towers. There’s a striking and unmistakable correlation. One can easily find testimony elsewhere of the harm of cell phone radiation. For instance, an elementary school in California was shut down in March, 2019, after several students were diagnosed with cancer (Carlson, 2019). That echoes an Italian Supreme Court judgment that a plaintiff’s brain cancer was caused by using his work cell phone (Owens, 2012). In 2011, the International Agency for Research on Cancer classified radiofrequency radiation as a Group 2B carcinogen. Thus the anti-5G protestors’ placards proclaim, “Have you heard of SCIENCE?” and “We Believe in SCIENCE: Wireless Radiation Is Harmful to Your Health.” All this evidence is scientifically incomplete and misleading, of course, but it conspicuously indicates that there is no radical dismissal of the authority of science. Rather, it shows how the dissenters seek, ironically, to leverage that authority in favor of their own claims.

Yes—as amazing as it may seem to the “outsider”—the Flat Earth Society advocates empiricism and epistemological reflection. Consult their online wiki (wiki.tfes.org). They assert that:

> there is a difference between believing and knowing. If you don't know something, and cannot understand it by first principles, then you shouldn't believe it. We must, at the very least, know exactly how conclusions were made about the world, and the strengths and weaknesses behind those deductions. Our society emphasizes the demonstration and explanation of knowledge.

They invite you (the naive initiate and skeptic) to find evidence by “relying on ones own senses to discern the true nature of the world around us. ... This is using what’s called an empirical approach, or an approach that relies on information from your senses.” It all resembles rhetoric you might find in an introductory philosophy of science textbook. On their webpage on “Experimental Evidence,” you will find descriptions of what must be regarded as several “classic” experiments: the Bedford Canal Experiments (on water convexity), the Bishop Experiment, and several dozen others, which (they proudly remind you) are reproducible. So, one might take care, perhaps, before prejudicially discounting a flat-Earther as a science *denier* or failing to have *trust* in science.

The same is true in other purportedly “anti-science” cases. Opponents of the MMR vaccine highlight that diagnoses of autism are strongly correlated with the administration of vaccines only months earlier. They will also note the obvious conflict of interest in the for-profit pharmaceutical industry, whose assurances about safety can surely be discounted. Likewise, climate change naysayers have assembled extensive websites that compile and proudly present all the scientific evidence against the (so-called) consensus (for example, WattsUpWithThat.com, climateaudit.com, or CO2science.org). Creationists, for their part, are only too happy to take aim at the least *scientific* flaw in evolutionary theory (e.g., Jonathan Weiner’s *Icons of Evolution*). Intelligent design advocates (such as Michael Behe or William

Demski) despite their caustic criticisms of evolutionary science as "secular humanism," desire nothing more than to establish their own credibility through *scientific* legitimacy. Trust in science is not the issue. Their core arguments, ironically, seem to embody trust in science.

Yet the "science" that all these would-be scientists try to promote is obviously *not* good scientific practice. For example, they mistake correlation for causation. Yes, of course covid and 5G towers correlate: they both cluster in population centers. This is no evidence for a causal link. Yes, of course autism typically appears after vaccinations. This reflects the normal schedule for medical treatment of infants. The observed association does not indicate causation (as more detailed studies have clarified). Also, cherry-picking of evidence is common. Selective data may suffice to give an *impression* of empirical confirmation. But it is equally important epistemically to be complete, to survey all the relevant evidence, and to rule out alternative explanations. All these problematic naysayers collect and promote information in an effort to *appear* scientific, chiefly because their target audience does indeed trust Science, writ large. But the particular scientific claims are ultimately *wrong*. Not only wrong, but wrong-headed. And more often than not nowadays, deliberately misleading.

Notably, these ersatz "scientific" claims rarely enter professional scientific discourse. They are really not meant to be scientific, only to appear scientific. The ultimate audience is the non-scientific public. They are designed to be believed by non-experts who *trust* science but at the same time are not positioned to *distinguish* good science from bad science. That is why belief in bad science does not indicate a failure to trust science. It is a failure to detect or diagnose authentic, reliable scientific claims in public discourse: a very different problem indeed. Here, again, we encounter the inescapable conundrum of epistemic dependence, originally articulated by John Hartwig (see above). *Who* does one trust? Who speaks for science? How do we know?

Framing the core problem of epistemic trust in this way leads to other fundamental questions. For example, how can someone be successfully persuaded to believe bad science? How, by contrast, does one ascertain expert knowledge, which is inevitably mediated? How, does one identify an authentic (and honest) expert? Several dimensions of this problem are discussed in the following sections: the "art" of the science con-artist (§3); the role of expertise (§4); how a non-expert might effectively assess evidence of expertise (rather than the evidence for any scientific claim itself) (§5); and how one may conceptualize the "ontogeny" or provenance of claims as they are mediated between scientific expert and scientific consumer through various forms of science communication and news media (§6). These topics help map a distinctive domain beyond the boundaries of a critical scientific community (composed of peer experts): namely, a *public epistemology* of science (§7).

3. Science Con-artists

What counts as science in the public realm? Many people will *say* that they speak for science. But that obviously does not mean they are all trustworthy. Some may lie or mislead. Such persons surely want to gain our trust. But they do not try to earn it fairly through epistemic work. Rather, they hope to win our confidence, hence the term "*con*" artist.

Science con-artists are not that different from shills and hucksters in other contexts. They use a familiar suite of stratagems. Most important, they exploit inherent cognitive dispositions and tendencies (Dobelli, 2013; Piatelli-Palmarini, 1994). Advocates of rationality often contend that those who succumb to these wiles are merely gullible. But, ironically, it is often the more intelligent persons—those who imagine that they are purely rational and therefore not vulnerable to such con-artistry—who prove the most susceptible (Shermer, 2002, pp. 279-313). The unconscious habits are deeply embedded in our cognitive structure. Blaming people for being human is not very helpful. Yes, one may regulate these thought patterns. But it requires learning—and then being alert to the particular occasions when one needs to apply such learning. The con-artist tries precisely to dodge that circumstance by developing trust. Their methods are designed to avoid triggering our "BS alarms." Education seems the appropriate response. Here are five widely used common tactics to address (for a fuller account, see Allchin, 2012a, 2018).

First, there's style. Science con-artists need to *appear* trustworthy. They seem amiable and speak smoothly. That quells alerting any intuitive sense of skepticism. It is primarily an emotional response. Feeling comfortable is, ironically, a warning sign of potential vulnerability. They likely wear nice clothes—or maybe a lab coat and eyeglasses, the stereotypical (yet also culturally quintessential) symbols of scientists. Websites look professional. Videos resemble public television documentaries. Books have high quality publication standards. (Interested parties seem quite willing to fund efforts to confound any science that they see as threatening their power, profit, or privilege). To avoid being influenced, a consumer-citizen needs to learn about the power of these unconscious psychological tendencies, and be prepared to cross-check one's emotions (Rampton & Stauber, 2001, pp. 291–294; Freedman, 2010; Kahneman, 2010).

A second tactic is outright disguise. To impress others as scientific, imitators don the markers of good science. For example, because we expect data, they use graphs and charts. They may use — then "graciously" explain — intimidating jargon. To achieve scientific credibility, one begins by enlisting a scientist to make the claim, even if that person does not have the *relevant* expertise (Oreskes & Conway, 2010). But can a nuclear scientist really speak authoritatively about second-hand smoke? And acid rain, too? *And* the ozone layer? *And* climate change? No. Alternatively, if publication in a peer-reviewed journal is the standard of credibility, then one hires ghostwriters from university faculty or medical schools (McGarity & Wagner, 2008, pp. 76–79; Rampton & Stauber, 2001, pp. 200–201). Much like plagiarism, only in reverse. Or one creates whole journals that one can portray as peer reviewed but that do not meet customary community standards (Michaels, 2008, pp. 53–55; Oreskes & Conway, 2010, pp. 244–245). If scientific consensus is important, one enlists a dissenting scientist to provide an illusion of consensus, say, by giving Congressional testimony (see the case of atmospheric scientist John Christy [2013] testifying about climate change). If one needs to appear to disavow bad science, one just calls the good science "junk" or disparages it as tainted by partisan politics (e.g., Steve Milloy's *Junk Science Judo*; Murray, Schwartz & Lichter's *It Ain't Necessarily So*; or Berezow & Campbell's *Science Left Behind*). Layers and layers of subterfuge. It's all a disguise by bogus experts, who aim to subvert good science.

A third strategy in developing trust by science con-artists is exploiting social emotions. That is, our beliefs are shaped by those around us. We sometimes "calibrate" our views against those of our chosen peers. Our minds are motivated by social acceptance, as much as by any standard for reliable knowledge. Thus, psychologically, people tend to align their ideas and values to "fit in" and show allegiance to their group (Kahan, 2013, 2017). For example, in 1999 the South African government denied that a virus caused AIDS. Public Health Minister Manto Tshabalala-Msimang drew on lingering anti-Colonialist sentiments when she denounced antiretroviral drugs offered by developed nations as harmful. Local customs in nutrition, embedded in African culture and history, she claimed, would effectively combat the "alien" disease (Goldacre, 2009). Or a U.S. political leader refers to the SARS-Cov-2 as "the China virus," thereby stoking xenophobic fears as a preamble to unjustified science. The anti-fluoridationists in the U.S. (mentioned above) were united as much by shared anti-government sentiments, as by any science (Martin, 1991; Toumey, 1997). In the same way, anti-vaxxers and flat-Earthers form tight social groups that reinforce in-group agreement and foster exclusion of dissenters. Likewise, communities where neighbors' livelihoods depend on fossil fuel production tend to share deep skepticism about climate change. Social cohesion can be a powerful factor in belief, and science con-artists can evoke in-group sympathy or out-group fear to align with their desired scientific claims. Accordingly, social media have helped amplify the reach of science con-artists, aggravating the problem.

A fourth major stratagem is to manufacture doubt. Where one cannot win a scientific contest, one may still succeed at sowing discord or uncertainty. It is a powerful technique for scuttling any policy based on science, especially regulation of public or occupational health or management of environmental risks (Michaels, 2008; Oreskes & Conway, 2010). "Doubt is our product," one tobacco industry memo noted, "since it is the best means of competing with the 'body of fact' that exists in the minds of the general public. It is also the means of establishing a controversy" (quoted in Michaels, 2008, pp. *x*, 11). You might hear, "But we just don't know for sure! We need *more research* before we can justify any action!" The appeal appears pro-science. But by now, this has become a standard playbook for discounting established science (Kenner, 2015). It is simultaneously a way to disarm the use of the Precautionary Principle, an important resource when science is indeed uncertain (e.g., Harremoës, et al. 2001; World Commission on the Ethics of Scientific Knowledge and Technology 2005). Hence, when some highly predictable engineering "accident" occurs, you may hear industries opine, "We didn't know! How was anyone to know?" (Consider the cases of the Fukushima nuclear plant disaster in Japan in 2011, or several dam failures in Uttarakhand, India in 2013, in Laos in 2018, and in Brazil in 2015—and again in 2019.) More misinformation from science con-artists, here cloaked as uncertainty.

A fifth and final tactic: when all else fails, flood the media. Especially the internet and social media, where lies can spread easily and acquire apparent legitimacy merely through repetition and familiarity. Or multiple websites that host variants of the same disinformation. Talk radio. Twitter and Instagram feeds. When newspaper chains, television networks, or media companies are controlled by motivated individuals, they can easily forsake their traditional role as responsible gatekeepers of public knowledge in order to promote private and ideological agendas. Founts of propaganda. Bogus science can reach far and wide, with con-artists speaking for science, while the voice of authentic science, even if available, is left in a virtual media shadow. Again, the growing popularity of social media has only worsened the problem.

Where science enjoys cultural authority, those seeking power are motivated to imitate science. They may use any of these five tactics (or others) to promote a substitute version of scientific information in their favor. Bad science, but persuasive nonetheless. However, con-artists are less effective when the intended target is aware of the tactics and how they work, enabling them to see through the deception. "Immunity by inoculation" is the apt metaphor. Studies have now shown that students can become more resistant to deceptive practices by learning about them in advance (Cook, Lewandowsky, & Ecker, 2017).

Of course, an instructor can always list the various tactics and provide illustrations. But contemporary pedagogical practice favors active, authentic inquiry activities. Indeed, students can discover many of these strategies themselves through their own explorations, importantly coupled with reflective discussion. One online game invites players to build an imaginary disinformation platform. The player earns points and "badges" as they adopt different techniques and mislead more and more people. That is, the student is learning through experience how someone attracts an audience while spreading lies, although in this case the topic is general news (getbadnews.com). A game oriented more towards science invites students to find unbelievable science news stories and mix them with their own fake stories, which all compete for votes from fellow class members. The goal is to "Bluff the Listener" (as modeled in the American public radio program "Wait, Wait, Don't Tell Me!"). Group discussion and analysis follows: what did everyone seem to find most convincing, and why? Students are thereby sensitized to the rhetorical tactics and scenarios (such as those described above) that can be persuasive, even when they convey false information (Allchin, 2020b). Creative teachers may surely find other opportunities.

4. Credibility vs. Evidence

The prevalence of science con-artists as sources of misleading or false information realigns the question of trust in public scientific claims. As noted earlier, the question is rarely about why we should trust science (writ large), but rather about how we distinguish the authentic voices for science from the imposters. The primary context thus shifts to the dynamics and nature of science communication. Namely, how do consumer-citizens encounter scientific claims and how do they become scientifically well informed (or ill informed)?

One may conceive the relationship in least three ways. Conventional models of science communication are quite simple. Information flows from scientist directly to the consumer (Figure 1a).

Accordingly, the aim would be to encourage scientists to engage with the public, orchestrate press releases, write news and magazine articles, produce television or radio documentaries, and so on. A more nuanced model accommodates the role of problems in communication. Call it the barrier (or resistance) model (Figure 1b).

Here, the apparent challenge is to overcome the inherent barriers: to make science intelligible, simplify complexities, raise interest, and show relevance. These two models are essentially science-centered. They assume that the scientist has knowledge and information and that the goal is to develop an effective link from (knowledgeable) sender to (passive, uninformed) receiver. (It echoes what many call the deficit model of science communication: that citizen-consumers lack information and merely need to be "informed.")

A third model of science communication, however—aligned with constructivist approaches to education—is student-centered, or consumer-centered (Figure 1c).

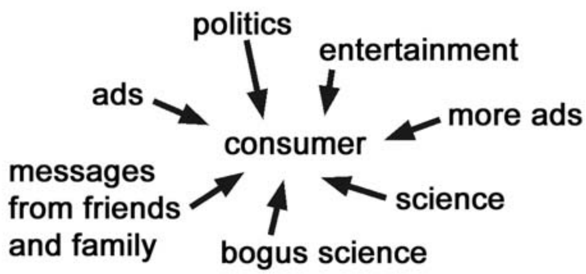

Figure 1(c). A consumer-centered model of science communication, or "science-in-the-wild."

It conceptualizes the consumer in an environment with multiple sources of information, not all of them scientific, and asks why and how a consumer orients to science information. It also highlights how they are exposed to both reliable and unreliable scientific claims from different sources, which vie with each other for attention and authority. This is "science in the wild," where scientists have no editorial control and no mandate to be heard. This is precisely why the other two models of communication cannot adequately inform our understanding of social and media environments where con-artists are found. They simply fail to include any source that reports bad or bogus science, viewing it instead as a version of real science necessarily "corrupted" by impure communication, barriers, or consumer resistance. The consumer-centered model is also important because it acknowledges the consumer of science as a possible agent, actively filtering available information. Media literacy becomes central.

Focusing on the consumer's perspective, then, how should someone encountering a possibly dubious scientific claim "in the wild" assess its reliability? One might initially imagine that they should follow exactly the same epistemic practices and principles as scientists: the very ones that ultimately justify the claims — namely, through evidence and logical argument. Over the years, philosophers have articulated the many possible sources of error and the corresponding methodological remedies—calibrations, experimental controls, statistical analysis of limited samples, peer review, and so forth—the tools the *scientists* use to justify and establish trust in their findings. On this view, science education should be oriented to teaching scientific practices and argumentation. Only in this way, one presumes, can students become truly autonomous agents.

How might this work in practice? Consider again the claim that 5G caused covid. The astute, well-educated consumer would recognize (as noted above) that correlation does not necessarily indicate causation. One must control for possible confounders, such as population density on the maps. The map comparisons turn out to be coincidence, not evidence. Nor do plausible theories count as proven theories. Policy actions based on limited evidence reflect suspicion, not causal links. So, too, for the case of vaccines. The correlation of vaccination with autism (ostensibly genuine) reflects the timing of the *diagnosis*, not a true physiological effect, as subsequent studies have shown. Learning this level of reasoning seems simple enough, perhaps.

But consider the case of climate change. It is considerably more complex. One may introduce students to the Keeling Curve (showing the steady rise in global carbon dioxide levels) and Mann's "hockey stick" graph (showing the recent history of the planet's temperature) and explain how they are important evidential benchmarks. But even these graphs are complex constructions that require quite a bit of technical reasoning—well beyond what the average citizen might master. In addition, the case for climate change spans numerous fields—paleoclimatology, marine biology, biogeography, atmospheric physics, thermodynamics, plant ecology, and so on. No one person can acquire enough skills in all those fields simultaneously. No one. Not even the scientists who contribute to that immense body of evidence. They trust the conclusions of their fellow scientists not because they have personally reviewed all the evidence themselves, but because they trust their expertise. Not even professional scientists meet the educators' ideal of the autonomous agent. Rather, they exemplify Hardwig's principle of epistemic dependence — and the implicit need for principles guiding epistemic trust.

Yes, the consumer may be able to dissect a simple argument and weigh simple evidence. But most scientific claims relevant to public policy or consumer choices are complicated, like climate science. Without the relevant experimental know-how, the consumer will not know if the evidence, *as reported to them*, exhibits technical competence and can be trusted. Without extensive experience in the field, they will not know if the evidence, *as presented to them*, is sufficiently complete. Without background knowledge, they will not know if there are alternative hypotheses and explanations, and so be able to judge whether the reasoning is trustworthy. That is, an effort to assess the arguments and evidence as communicated via the media, already involves a great deal of implicit trust in information beyond what is formally communicated. Thus, the consumer, as a non-expert, is inherently unable to fulfill the imagined role of an autonomous scientific agent. They don't get the whole story. Indeed, this is why we train scientists through long study and apprenticeship — so that others can trust their conclusions without having to do all the research and epistemic work themselves.

In short, the consumer is not in a position to assess any scientific claim with the same epistemic assurance as the relevant scientific expert. The science consumer, again, is dependent on professional research scientists. Trying to assume the expert's role by assuming that one has all the relevant evidence and background is not prudent. Indeed, that form of trust in oneself, ironically, opens the way to potential mischief (Hardwig, 1985). Science con-artists encourage the illusion that consumers can evaluate the evidence for themselves, while they feed them cherry-picked data and biased arguments (for examples, see Milloy's *Junk Science Judo* and Murray, Schwartz and Lichter's *It Ain't Necessarily So*). They contrive an appearance of science from shards of evidence and contorted plausibilities. It is an effort to short-circuit the communication from the authentic experts and thereby usurp the authority of "trusted" science.

The central epistemic challenge for the consumer, then, is to assess the credibility of those who communicate the science. What matters is their *credibility, not the evidence*. That is, to support functional public scientific literacy, educators need to focus foremost on the epistemics of science communication and of science in public discourse. They cannot rely solely (or even mainly) on the epistemics of evidence and arguments that inhabit "scientific practices" and the discourse among expert peers, wholly within scientific communities.

Surprisingly, perhaps, science communication matters to the consumer as much as the original science itself. Indeed, from the perspective of the consumer who confronts "science in the wild," the first goal must be to "domesticate" the competing scientific claims that crowd the media (see Figure 1c). Namely, the most immediate problem for someone situated amid the information maelstrom is: *Who speaks for science?* And which claims express an expert consensus?

As always, the concepts of science communication and of evidence-versus-credibility are ripe for students to explore through inquiry — here, simply by dissecting any recent public scientific controversy. (Ideally, one balances memories of a recent past, while the historical perspective is still vivid, with enough hindsight that students can identify how the past uncertainties were ultimately resolved.) Again, the pedagogical strategy is to pose epistemic problems for students with concrete, authentic cases. For a complete classroom example, see an inquiry lesson that engages students in the "covid conundrum" of early 2020, a surely familiar case study at present (Allchin, 2020a).

5. Assessing Expertise

How does one assess whether someone who claims to speak for science is credible? To reach a reliable judgment, the consumer needs evidence, yes. But evidence of a different kind than the we typically associate with "scientific practices" (as noted above). Evidence for credibility, here, includes two major components: expertise and honesty. So, first, is the person qualified to vouch for the claim and its justification? Second, might they have reason to misrepresent the facts? One thus seeks data on the person's credentials, experience, background knowledge, and commitment to the scientific consensus, as well as theoretical partiality, bias and motivation for doing science. These are the chief epistemic concerns in the public epistemology of science.

Teachers may explore these concepts with students through inquiry. One possible (and hopefully entertaining) classroom lesson might draw on the television game show *To Tell the Truth* (Allchin, 2020b). (The original show aired in the 1960s and was revived in 2016.) A celebrity panel is presented with three contestants. One has a notable story. The other two are imposters. Through brief questioning, the panel tries to determine who is the real personality. For example, the panelist might know something about the topic at hand and test whether the contestant knows certain obscure facts, too. This is not unlike a scientist calibrating an instrument with a known, standardized sample. It's a system check. In the game, one is calibrating the person's *testimony* by taking a sample statement to compare with an expected answer. The science teacher situates the game in the context of public science. One uses real examples of persons with different claims to scientific credibility, based on their professional and social context, relevant skills, institutional affiliations, and so on. Who can be trusted "to tell the truth"? This analysis helps students think about what matters in determining whether any individual can be trusted or not (see a few examples online: http://shipseducation.net/credibility). As always, explicit reflection after the game helps students elucidate and consolidate the epistemic concepts: expertise vs. celebrity or political status; general scientific expertise vs. specifically relevant expertise; dissenting expert vs. consensus of experts; independence vs. conflict of interest; credentials vs. expertise; and so on.

Scholarly work on the nature of expertise, both philosophical and sociological, has grown immensely in recent years. Teachers will ideally enrich their background knowledge (or work alongside the students in doing so). A good concise introduction is provided by Alvin Goldman (2001), who asks "Experts: which ones should you trust?" Other work relevant to science educators includes Goldman's *Knowledge in a Social World* (1999), Selinger and Crease's edited volume on *The Philosophy of Expertise* (2006), Collins and Evans' *Rethinking Expertise* (2007), and Nichols' *The Death of Expertise* (2017), as well as Ward, et al.'s comprehensive handbook (2020). In addition, Eyal (2013) offers an interesting analysis disinguishing the notions of experts (as a social role) and expertise (as an integrated network of resources and skills). Evans (2008) articulates a sociological concept of expertise that does not reduce to cultural relativism. Epstein (1995, 1996) shows powerfully how relevant experience can sometimes be more telling than formal credentials. For a more journalistic perspective, consult Freedman (2010) and Rampton and Stauber (2001), especially on how—or when—experts can be wrong. For an overview tailored to science educators, see Allchin (2012b) on "skepticism and the architecture of trust." All these sources can help provide the educator with the relevant conceptual background.

Once students are primed with some initial concepts and an orientation to the problem of expertise, they are prepared to delve more deeply into the very notion of expertise (see lessons by Zemplén, 2009). In another inquiry activity, students begin with experts in their daily lives—who can fix a cell phone; who can troubleshoot an app; who can help finish the homework. Who is an expert, and why? They reflect on what expertise means and how we can effectively gauge or measure it. Those personal examples can then be expanded to society more broadly, and to the social systems we have for credentialing expertise: licenses for plumbers and electricians; professional exams for doctors and lawyers; certifications for engineers and accountants; and so on. That is, we can use our social system to help us epistemologically by validating expertise using other experts. Finally, science can be identified and discussed as another form of expertise. How is it similar to, how different from those other kinds of expertise? Are students familiar with the scientific institutions that embody expertise? This helps students adopt a more "bird's-eye" perspective of the distribution of knowledge and how we might ideally characterize the reliable transfer of knowledge from expert to non-expert (Höttecke & Allchin, 2020). Note that the pedagogical strategy here is not to teach particular criteria of expertise (in a pre-established checklist, say), but to develop the relevant concepts and assessment tools organically through student/consumer perspectives, addressing successively more complex examples. That is, the *students* should actively participate in developing the checklist criteria. Finally, having reflected on expertise in a social context, students can reconsider science con-artistry as a form of fraud (non-experts claiming expertise where there is none) and answer more clearly, "who speaks for science?"

Consensus is also important epistemically, in contrast to individual expertise alone. That is, scientific reliability relies in part on an organized system of reciprocal criticism. Critiques and responses help balance divergent perspectives and keep individual biases in check (Harding, 1991; Oreskes, 2019; Solomon, 2001). So, when commenting publicly, does an individual expert express the community consensus? Does she or he distinguish properly between her or his own personal view and the collective view of the peer community?

In this section, my primary aim has been to articulate the major parameters in expertise relevant to scientific literacy and science education. Many other issues remain, of course, to be addressed elsewhere. For example, there is a significant tension between establishing expertise through formal credentials (education, institutional affiliations, awards, and professional leadership positions) versus through relevant experience ("hands-on" activities, portfolios, testimonials, and so on). Also, while the chief focus here has been on expertise, honesty is equally important to credible reporting. The notion of conflict of interest as a factor in biased and misleading claims is widespread and thus may be relatively easy to convey in the case of science. (Indeed, this dimension is central to the critics of vaccine safety.) The context of science communication might also open the notion of experts who can vet scientific expertise and "curate" public information on science: namely, media "gatekeepers" (as discussed in the next section).

6. The Ontogeny of a Scientific Fact in Society: Whole Science and Media Literacy

In the preceding sections, I have focused narrowly on particular cases of misplaced trust in public scientific claims as a way to help diagnose the function (and malfunction) of trust. I have identified particular problematic elements and their corresponding remedies, then successively broadened the context of understanding. Here, now, we may now "zoom out" further, and consider the fuller, more comprehensive view: the ontogeny of a scientific fact in society. This tracks the developmental trajectory of a claim, from test tubes to YouTube, from lab book to Facebook, from field site to website, from lab bench to judicial bench (Figure 2). This synoptic view of the provenance of scientific claims and their epistemic structure is known as a *Whole Science* approach in education (Allchin, 2011, 2013b, 2017; Allchin & Zemplén, 2020; Höttecke & Allchin, 2020).

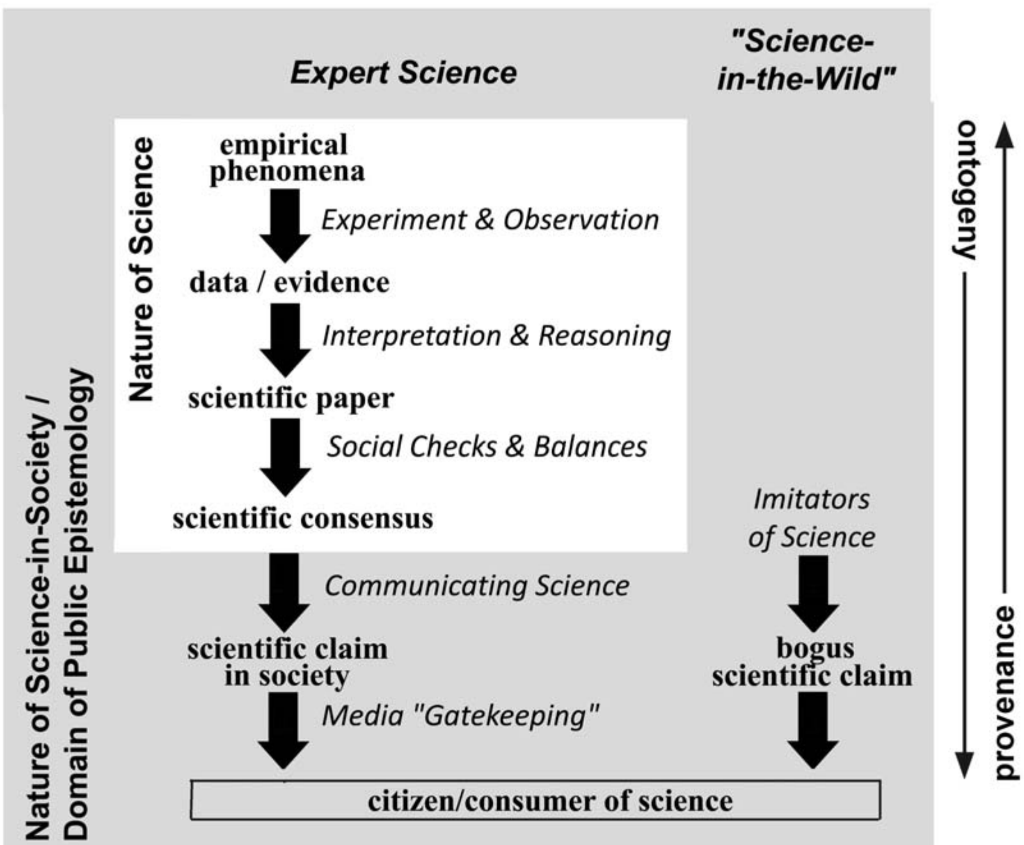

Figure 2. The ontogeny of a public scientific fact. Arrows downward indicate the development of the claim, while tracing arrows in reverse indicates its provenance. Note the contrasting domains of standard epistemology of science ("internal") and of public epistemology of science, "external" to the expert community.

One may conceptualize the process of establishing actionable facts in two general stages. The first occurs among the community of expert scientists—what is conventionally called the "internal" dimension of science. For educators, this is the familiar domain characterized by the concepts of "the nature of science" and "scientific practices." The second stage involves science communication (the focus of discussion in the preceding sections), where scientific knowledge is transferred (while being simultaneously transformed) from the scientists to the non-expert public—typically labeled as "external" to science. Namely, what *counts as* science in a cultural context? Educators may call this the *nature of science-in-society* (Höttecke & Allchin, 2020). While the philosophy of science has traditionally focused just on the internal dimension, my discussion has underscored that epistemic questions are relevant to both stages. Namely, epistemic concerns do not end with forming a scientific consensus. *Both* processes must function effectively to achieve reliability of scientific claims in a personal or public context. The ontogeny of a fact constitutes one continuous process (Figure 2). Whole Science, not truncated science.

The internal/external distinction can easily be overstated. However, in one respect it is especially informative. Namely, it highlights the epistemic significance of expertise in interpreting evidence. It also helps delineate who contributes to the system of checks and balances integral to justifying a scientific consensus. Indeed, membership in the scientific community is virtually defined by expertise. As noted in the last section, only within this group will one find the skills and the resources for engaging in the discourse about the quality, completeness, and meaning of the observations and the evidence. Understanding all the possible sources of error, for example, is key to deciding whether a superficially "reasonable" argument is ultimately incomplete or unjustified. Basically, only experts have the epistemic "clout" to challenge other experts, their peers. Hence, the essential value of peer review, both before and after publication. From a normative perspective, the experts constitute the agents competent to engage in mutual criticism. Collectively, they contribute to forming a reliable, even if diffuse and distributed agreement. That is, reciprocal accountability is fundamental to building a robust, trustworthy scientific consensus (a common theme of contemporary social epistemologists).

The relationship of non-experts to experts, by contrast, is decidedly asymmetrical. As noted repeatedly above, individuals outside the scientific community are epistemically dependent on the experts. Accordingly, their knowledge is not direct. Rather, it is inevitably *mediated*. Science *communication* is essential for non-experts (see Figure 2). Thus, we may listen to a scientist lecture, watch them interviewed on television, or read their blog. More commonly, however, we are likely to receive scientific information through standard print and broadcast media: for example, a newscast, a documentary, a podcast, a popular science website, or a museum exhibit. Here, the mediation is typically managed (conventionally, at least) by another group of experts: science journalists. They function as *gatekeepers*. (Shoemaker, et al., 2009; White, 1950). They exercise their particular skills in selecting relevant information, making it intelligible, and shaping it to be entertaining, all while trying to preserve its essential scientific content. Science communication is ubiquitous. Indeed, the mediation is generally so familiar as to commonly escape notice. We consult Wikipedia. We ask a colleague. We read a newspaper. We rarely think about the process of mediation or its implications.[1] However, as the presence of science con-artists indicates, attention to the mediation itself may be warranted if we care about trustworthy scientific information. Understanding the nature of science now notably includes appreciating the nature of science-in-society and science media literacy (for a more extended discussion, see Höttecke & Allchin, 2020).

As one moves from the expert scientific community to the world of non-experts (see

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[1]Science teachers may well reflect that they, too, are professional mediators of scientific knowledge.

Figure 2), communication and mediation become foremost. Epistemic strategies become dramatically reoriented to address the different epistemic problems. To return to our central theme, how does one know that the communicated information is reliable, and when not? It may be clear by now that the implicit task for the non-expert is to discover just what the expert consensus is.[2] But who speaks for science? Trust is not blind, here, but rather involves evidence and justification—of a specific nature. It involves measuring the trust not only in the scientists, but also in the mediators.

Trust in someone whose concrete claims you cannot cross-check yourself may seem difficult, if not inherently impossible. But, ironically perhaps, scientists address the same challenge. That is, they regularly trust each other. They trust the reported results of experiments they have not conducted themselves. They trust technicians to have completed proper experimental protocols and checked all the instruments. They trust collaborators (statisticians, for example). They trust experts in allied fields on whose work they draw. Yet all that trust is measured. And, notably, it is earned from their fellow experts. That is, over time, scientists develop reputations that establish their *credibility*. It is based on their track record and the quality and significance of their findings, as well as their education, mentors, institutions, awards and distinctions—similar to the measures by which one might measure any form of expertise (see inquiry activities and discussions above).[3] Philosophers of science often suggest that reproducibility is what guarantees trust in the reliability of scientific results. But in practice, replication is rare (Broad & Wade, 1982). Scientists, too, encounter a deluge of information, and regularly make judgments about which claims to trust. Accordingly, scientists customarily gauge the trustworthiness of the evidence and the argument based on the researcher's credibility as a proximal indicator (Hull, 1988; Latour & Woolgar, 1979). That is, credibility functions as a *vicarious selector*, a heuristic for trustworthiness (Allchin, 1999; Campbell, 1974). Occasionally, the judgments of trust prove misplaced, and scientists resort to the surer (but more laborious) path of checking evidence directly. But that is relatively rare. Science seems to flourish and succeed using a system of indirect credibility. Here, then, is a model for the non-expert.

Non-experts may appropriately base their epistemic assessments on credibility, also. Both the credibility of the scientist (when available) and the credibility of the source in the media. This is why it is important to know—and respect—the "track record" of a media source. Here (again), credibility — not evidence or argument — is the most effective standard, or benchmark. Can students imagine a social mechanism to rank the credibility of media sources? (And again, the trust here is epistemic trust, not a form of moral trust or personal trust based on identity, ideology or political affiliation.) Ultimately, credibility is how the student, citizen or consumer can most effectively and reliably gauge who speaks for science.

The challenge of ascertaining credibility has one final, important dimension. One of the problems in trusting a mediated claim and in building trust in particular mediators is being able

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[2]One should certainly not brush aside historical cases where expert scientific consensus was wrong. Biases can certainly appear at the community level. Scientists, philosophers and sociologists are continuing work on how to diagnosis such cases and what remedies may be found in the social structure of science, as well as what tools a non-experts might apply to know when a scientific community as a whole may exhibit bias that might qualify their claims (see Harding, 1989; Oreskes, 2019; Solomon, 2001).

[3]Studies of animal behavior are also relevant here. How does cooperation evolve in animal societies? Evolutionary biologists, economists, anthropologists, game theorists, and others have developed the notion of *image scoring*, which corresponds to reputation or credibility, to describe how trust is negotiated in an ongoing and open social network (see Allchin, 2009).

to track down the sources behind the claims. Are the researcher's findings fairly represented? Is the scientific consensus being responsibly and accurately reported? Part of tracing credibility of a particular scientific claim includes being able to check its provenance. Where did the claim originate? Who vouches for it? What are their credentials? For example, in 1995, the Science and Environmental Policy Project, led by noted physicist Fred Singer, issued a document known as the "Leipzig Declaration," apparently signed by 79 scientists who testified that evidence did not support dire warnings of global warming. The document was cited in numerous newspaper editorials and on the floor of the U.S. Senate. However, a reporter for the *St. Petersburg Times* investigated the signatories and found many connections to the oil industry, as well as many others (including a local weathercaster) who had no expertise (Olinger, 1996). Another purported "consensus" document, the Oregon Petition, followed in 1998—this one signed by thousands. Again, its pretensions were debunked, the con-artists exposed. Provenance matters. And thus another important epistemic principle for mediated claims is *transparency*. Even mediated claims demand evidence: here, in the form of full documentation of the sources of information.

How, indeed, do fact-checkers in the media check facts? That is a simple inquiry ripe for students. In subsequent discussion, they might reflect on why (or when) we even need fact-checkers. What do we learn from how they work? (See the guide by the founders of FactCheck.org: Jackson and Jamieson, 2007.) A more adventurous inquiry might invite students to investigate how archaeologists, museum curators, historians, and others establish the provenance of an item, whether an ancient relic, work of art, document, and so on (e.g., Mould & Bruce, 2020).

As the anti-climate change documents illustrate, in the interest of promoting power, profit, privilege or ideology, science con-artists will mimic whatever feature is regarded as essential to the nature of good science (see Figure 2, right column). If data is required, they will present data—but cherry-picked data. If consensus is required, they will imitate a consensus—or (as noted above) manufacture a false one. Therefore, the aim of transparency is not fulfilled by a long list of useless citations. This pattern was exhibited in Immanuel Velikovsky's infamous 1950 *Worlds in Collision*, which alleged that millennia ago a planet-sized comet veered so close to the Earth that it parted the Red Sea and created other mayhem as recorded in the myths of ancient cultures. Many non-experts believed it. They interpreted its numerous references as indicative of a scholarly nature. They did not bother to check the references, assess the author's credibility, or listen to the overwhelming consensus of scientific experts against its wild claims. In a similar way, in 2017 an employee at Google issued a internal memo that cited numerous studies which (he contended) proved that women were not "naturally" fit for creative work or leadership in the software engineering industry. Many who endorsed his claims echoed his cited works as "evidence." They seem to have assumed his credibility without checking the provenance of his various scientific claims. The works he cited were selective, controversial among professionals, and not the consensus of the field. Yet transparency allowed others to articulate the many flaws in his presentation (e.g., Fuentes 2017; Sadedin 2017). Ironically, the author of the now notorious Google memo trusted science. But the *wrong* science. He even discounted his critics as anti-science, sadly biased by political values (citing yet more philosophical works). Yet ultimately, his manifesto has become a vivid example of the need to understand who speaks for science in the public realm of non-experts.

Once students have gained an appreciation of the function of media gatekeepers and the role of credible sources and transparency, they are well prepared to consider another major contemporary form of communication: social media. What is the status of scientific claims posted and forwarded through Facebook, Twitter, and the like? Most students would probably recoil at the idea of lying deliberately, but they may not think twice about retweeting a message that, if properly vetted, they would discover was an utter falsehood. Lies travel exceptionally well on Twitter—faster, farther, and more broadly than truth, unfortunately (Vosoughi, et al., 2018). Students may well find it fruitful to discuss how one determines the epistemic credibility of persons broadcasting scientific claims through social media. How do diffuse social networks affect the ideal of tracking provenance? Are gatekeepers for science appropriate here? How might we envision methods to foster the integrity of scientific information in such contexts? Given the ascendancy of social media in our culture, especially among younger generations, it seems appropriate to invite them to reflect on the epistemic dimension of such media (for a fuller analysis, see Höttecke & Allchin, 2020).

7. *A Public Epistemology of Science*.

In summary, the significant question of trust in science, as contemporary cases indicate, is not broadly about science in general, so much as *misplaced* trust in *particular* scientific claims. More importantly, perhaps, it is about imitators of science who flood the media alongside those who speak for genuine science. The central challenge for the situated consumer of science is thus "Who speaks for science?"

In recent decades, philosophers of science have profoundly transformed epistemology by acknowledging the limits of a centuries-old tradition based on individual rationality. In the new naturalized view, scientists exhibit ineliminable cognitive flaws and biases. Yet these may be regulated and remedied through a further system of checks and balances, notably at the social level, in a community of diverse scientists. The benchmark for reliable knowledge now additionally includes *social epistemology* (e.g., Oreskes, 2019; Ziman, 1968). But epistemic problems remain. A scientific consensus is not always adopted by the society or in government bodies. With the distributed nature of expertise and the dynamics of information flow in our modern age, we need to articulate how to achieve reliable scientific knowledge across the society, even among non-experts. How do we ensure reliable knowledge in our shared public discourse, and especially in public policy? A complete epistemology in such contexts seems to include the roles of expertise, credibility, epistemic trust, deception, communication media, and social systems for certifying or enforcing expertise. That seems to invite a further historical transformation in philosophy: the emergence of a *public epistemology of science*.

In the short term, however, educators should focus on the prevalence of ordinary people who seem confident that their personal judgments are more justified than the consensus of professional scientists. We are witnessing an epidemic of *epistemic hubris*. This is where science educators urgently need to begin. We need to teach about deceptive practices and science con-artists, the natures of expertise and of epistemic dependence, as well as the social structure of epistemic trust, the problems of mediated science communication, and the roles of credibility, provenance, and transparency. Namely, Whole Science. And all that needs to be infused, it seems, with a good dose of epistemic humility and respect for scientific expertise.

Acknowledgments. forthcoming.

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