Science Denial, or Science Deceit?

Douglas Allchin

Abstract. This paper explores two widespread assumptions about the current misinformation crisis: (1) Is the rejection of scientific consensus properly characterized as "science denial"? (2) Does the problem arise from a deficit in critical thinking, or individual rationality? It contends that the central problem is deceit, not denial. Polls indicate that trust in science remains high, while analysis of historical cases indicates how distrust is aimed elsewhere (including those who purport to speak for science) and is frequently fueled by various fears. Recent cases of disinformation reflect the regular use of deception, from bogus data and bogus peer review to bogus scientific organizations and bogus consensus documents. Consumers who are tempted by the slogan, "do your own research," seem unable to unravel the lies. Focus must shift, instead, to the liars and their deceptive tactics, which include looks, identity, acting, repetition and skepticism (LIARS). Students need to learn the social practices of science, to appreciate the importance of the consensus of the relevant experts, and inquiry lessons in science media literacy, to understand the dynamics—and potential pitfalls— of media messaging.

This paper explores two widespread assumptions about the current misinformation crisis. First: is the rejection of scientific consensus properly characterized as "science denial"? If so, then science education needs to bolster general trust in science, perhaps to demarcate science, explain the basis for its authority, and articulate just how science works. Second: does the problem arise from a deficit in individual rationality? Are citizens and consumers simply under-equipped to analyze arguments and weigh evidence? Here, the appropriate response would be to teach "all people to think critically and scientifically" (e.g., Agin, 2006; Daempfle, 2013; Dodge, Oshry & Bonetta, 2020; Helfand, 2016; Herrick, Sinatra & Lombardi, 2023; Sinatra & Hofer, 2021). I argue that both assumptions, while plausible, are mistaken.

The central problem, I contend, is deceit, not denial. Most significant misinformation originates as *dis*information. It is artfully designed to resemble science. The purveyors present coherent (but incomplete) arguments, with explicit reasoning and (cherry-picked) evidence, which are rendered persuasively with graphs, statistics, professional style, vivid anecdotal examples and emotional context. Such information is ripe for sharing with peers and for spreading within existing social networks, regardless of the medium. Accordingly, an essential component of science education in the Information Age should be developing skills to diagnose well-crafted deception.

A focus on deceit shifts the analysis from the message to the messenger. From unpacking the complexities of each lie to identifying liars. Namely, who speaks for science? It reorients the consumer from the credibility of the argument to the credibility of the source. From evidence to expertise. From individual claim to critical consensus and scientific institutions.

For educators to appreciate these dimensions of scientific misinformation more fully, historical case studies are an important resource. Retrospect allows clearer understanding of the ultimate outcome of contentious claims. One can typically collect more contextual details and integrate multiple perspectives.

Denial?

Public acceptance of the scientific consensus has been problematic, quite notably in the recent cases of vaccine safety, the causes of climate change, the safety of GMO food, and pandemic control measures. One could also easily include the health effects of cell phone radiation or high-voltage power lines, emissions from a local paper recycling plant, water fluoridation in the 1950s-60s, AIDS quarantining in 1986, earthquake prediction, nutritional guidelines, evolution, and many more. Many commentators interpret this behavior as “science denial”: a wholesale rejection of science and its reliability, or fundamental lack of trust in its practices and conclusions (e.g., Cunningham, 2013; Gorman & Gorman, 2017; Hansson, 2017; McIntyre, 2019, 2021; Sinatra & Hofer, 2021). It is also characterized, variously, as reluctance, refusal, resistance, rejection, repudiation, contrarianism, obstinacy, pathological thinking, doubt, confusion, ignorance, *willful* ignorance, wishful thinking, gullibility, and self-delusion. The deniers “threaten our future” (e.g., Prothero, 2013).

But there is a world of difference between disparaging the victims of misinformation and trying to understand the world from their point of view. Seasoned educators might well adopt a constructivist pedagogy posture instead, and seek to understand the alternative perspectives in order to find appropriate pathways of conceptual change (for example, by contextualizing creationists or by listening to anti-vaxxers—Hausman, 2019; Larson, 2020).

Without denying that there is a problem with science informing public policy and personal decision making, one may wonder whether there is a general lack of trust in science, what has been characterized as a pervasive “anti-science” attitude (Otto, 2016). First, and most notably, there is polling data indicating that the widespread assessment is misconstrued. Since 2016, the Pew Research Foundation has surveyed the American public about their confidence in various professions. Science has consistently ranked at the top, at 76-87% (Figure 1). Scientists rank above the military, police officers, religious leaders, and (sadly for educators) public school principals. Journalists, business leaders and elected officials rank even lower (Funk, 2020; Kennedy, Tyson & Funk, 2022). 3M Corporation (2022) conducts a parallel annual survey internationally. Their 2022 results indicate that 90% trust science, 86% trust scientists (Figure 2). These results — from independent institutions, with consistent findings over several years — seem to belie the assumption that there is widespread “denial,” or distrust in science.

A prime case of sidelining scientific consensus is the spurious prediction of a major earthquake in New Madrid, Missouri, in 1990 (Spence et al, 1993). Earlier, in 1811-12, this locale experienced what still remains the strongest earthquake in American history. The local historical museum commemorates the event in an exhibit, including a seismograph that monitors current seismic activity. Beginning in 1985, a business consultant and self-professed geologist, Iben Browning, predicted another major earthquake — specifically, on December 3, 1990 — based on a high tidal loading on the Earth’s crust. News media shared the story, and full-page ads in local newspapers promoted the sale of Browning's video warning. The U.S. Geological Survey and other professional seismologists dismissed the claims as nonsense. Nevertheless, 10,000 survival kits were distributed. Many schools were closed across a five-state area. The Missouri and Arkansas National Guard staged “earthquake preparedness drills.” $22 million in earthquake insurance was sold. On the day, the television news trucks had their satellite dishes ready to report the event. No earthquake occurred. Here, scientific misinformation spread on a grand scale. But there were no “anti-science” protests. No science “denial.” The episode illustrates how trust in *illusory* science can spiral out of control. Purported “expertise” was misrepresented, coupled with outright falsehoods about credentials. Plausible explanations trumped concrete evidence.

Mainstream media coverage was blindly biased towards alarm and “balanced” news reporting. A single self-proclaimed “expert” eclipsed the consensus of professional geologists. (And all without any internet or social media technologies.)

The pro-science views measured in the Pew Foundation and 3M polls can be found in specific statements by individuals who, like the residents of New Madrid in 1990, do not accept the scientific consensus. Ironically, the naysayers often *endorse* science and empiricism, and appeal to data and evidence for their own views. Consider two women protesting by the roadside in Long Island in 2019, warning against 5G cell towers with placards that read “We Believe in SCIENCE. Wireless Radiation is Harmful to Your Health” (May 16, 2019) and someone else in San Diego, “Have You Heard of SCIENCE? Wireless Radiation is Harmful to Your Health” (May 15, 2019). They display faith in science, but (alas) flawed or mistaken science.

Next, consider a screed lambasting the scientific community for failing to acknowledge the (purported) role of retroviruses in autism and chronic fatigue syndrome, *Plague of Corruption* (Mikovits, 2020). The book is subtitled, ironically, “restoring faith in the promise of science.” The author, a former lab technician and researcher, parades her commitment to “following the data” (p. xxii). She describes her work ethos: “to record our data accurately, compare them with collaborators from around the world, discard outliers, and come to a consensus” (p. 3). She cites extensively the work of her colleagues. In a preface, Robert F. Kennedy, Jr. lauds her credentials, heralding her as “among the most skilled scientists of her generation.” The dust jacket echoes those sentiments: “Dr. Judy Mikovits is a modern-day Rosalind Franklin.” She “has always been on the leading edge of science.” Of course, Mikovits’s “landmark” work on chronic fatigue syndrome, published in *Science*, was retracted by the Editors a few months later. Subsequent research showed that her provocative claims were based on off-the-shelf reagents that had been contaminated with snippets of mouse virus DNA (Cohen & Enserink, 2011). The consensus of the relevant experts found Mikovits’s work to be critically flawed. But she still defends her now discredited work and seems to exhibit trust in science generally.

Other naysayers also appeal to science. Kennedy’s own book declaring vaccines unsafe was ironically subtitled “Let the science speak.” Ira Casson, of the National Football League, dismissed stark evidence of brain injury in football players, declaring repeatedly to a 2007 summit gathering, “I am a man of science” (Fainaru-Wada, 2013, p. 225). Anti-fluoridationists (who opposed the fluoridation of public water supplies in the 1950s and 60s) also appealed to science. They cited research on the dangers of fluorosis, cancer, toxicity, and other side effects (Martin, 1991; Toumey, 1996). Climate-change naysayers have developed sprawling websites (such as CO2science, climateaudit.org, and wattsupwiththat.org) that present reams of scientific data, presented as decisively in favor of their view. The mere volume of information might be enough to impress someone. Of course, it is not the consensus view (more on that later). But they are appealing to science, not rejecting science. Opponents of masking will regale you with *facts* about viral particle size and the dimensions of the holes in N95 masks—clearly indicating that they cannot possibly be effective and that you should be wary of folks trying to persuade you otherwise, *without* the scientific facts! (see https://www.osha.gov/coronavirus/faqs#respirator; Litke, 2020). How can the use of scientific arguments be construed as “denial”—or distrust? Or repudiation? Or resistance?

Consider, finally, perhaps the epitome of science “denial”: flat Earthers. In defending their views, flat Earthers appeal to empiricism (albeit, perhaps, a naive empiricism) (e.g., McIntyre, 2021, p. 3). A 1849 pamphlet explained the “zetetic” philosophy: “to proceed only by inquiry, to take nothing for granted, but to trace phenomena to their immediate and demonstrable causes”

(Weill, 2022, p. 15). Flat Earthers enjoy citing what they must regard as “classic” experiments — for example the Bedford Level test, and its many replications (Garwood, 2007, pp. 133-136; Weill, 2022, pp. 9-11, 27-29, 88; see also https://wiki.tfes.org/Bedford_Level_Experiment). One ardent believer was determined to see whether he could see the curvature of the Earth himself, from a lofty vantage point. He built his own rocket, and died in an ill-fated crash, ironically and tragically affirming his commitment to observational evidence (Weill, 2022, pp. 1-3, 148-170). One flat Earther interviewed by philosopher Lee McIntrye commented, “Well, I don’t distrust science. I distrust pseudoscience” (2021, p. 23). Bold words. But highly informative to an attentive educator.

These various naysayers do not seem to “deny” the value of science. They do not fail to trust the authoritative nature of scientific knowledge. Nor do they seem completely unaware of its core principles, such as the foundation of empirical evidence, replication, data handling, logical reasoning, or even peer review. Rather, they seem to have been misled into erroneous claims masquerading as science. In their sincere view, the conclusions of science, based on their own analysis, differ from what the majority of qualified experts themselves agree on. One may wonder, how did they come to believe that they can make independent scientific judgments themselves? Educators must consider how these persons came to imagine that they could second-guess the experts. Efforts to double-down on teaching about the value of science or the virtues of scientific reasoning seem entirely misplaced. The problem lies elsewhere than in purported “denial.”

Distrust — of What?

At the same time, one should not wholly dismiss the role of distrust in many of these cases. One can find ample distrust. But it is frequently not distrust *of science*. Rather, the distrust is primarily directed at the *social* dimension of socioscientific issues. A critical reading of statements characterized as “anti-science” will typically indicate where the lack of trust lies (see Table 1). In many cases, it is as “simple” as distrust in the government or distrust in authority generally. For example, when the Brazilian government announced mandated vaccines for smallpox in 1904, there were seven days of rioting in the capital, Rio de Janeiro—the now infamous “Vaccine Revolt." What may appear to some as ignorant rejection of science was fueled instead by widespread anti-government sentiment among a populace dissatisfied with brusque public hygiene measures and who felt manipulated by elitist politics (Cantisano, 2022; Cuckierman, 2021). In such cases, scientific knowledge is irrelevant, or of secondary importance at best. (Science advocates may well reflect humbly on how they often exclude these other concerns as irrelevant. By treating a scientific mode of reasoning as exclusively privileged, are *they* engaging in their own kind of “denialism”—namely, eclipsing the relevance of social or ethical reasoning?)

Another major source of distrust is whoever is *reporting* the science. Namely, a key question—embedded in problems of science communication—is: who speaks for science? Access to scientific information is critically *mediated* (Höttecke & Allchin, 2020). The 3M report on trust in science (discussed above) thus also judiciously distinguished between trust in science and trust in *reports of* science. The trust in *news reports about* science drops precipitously, by comparison: from 90% to only 31%. Moreover, 85% agree that “misinformation is widespread across all channels,” but worse on social media. The level of trust varies across sources: from scientists themselves (85%) through teachers (74%) and friends and family members (60%) to company websites (44%), politicians (26%), social media posts (25%) and celebrities (20%) (Figure 3).

Note that government and corporate sources rank relatively low, echoing the analysis above. Namely, the public seems able to crudely rank the credibility of various sources of scientific information. For example, COVID vaccination rates among Somali immigrants in Minneapolis in 2021 lagged behind the general population—until state officials liaisoned with leaders of local faith-based, medical, and community organizations, whom residents trusted (Center for Disease Control, 2021). So, science "denial" may in some cases really be about distrusting who claims to speak for science, not the science itself. Namely, educators must attend the media gap: between science as understood by the community of scientific experts and *what counts as science* in a public realm.

Of course, individuals will be challenged if a non-expert *impersonates* an expert scientist, or an industry *disguises* its website to look like a non-governmental organization (with a dot-org suffix, for example), or a (bonafide) dissenting scientist *fails to acknowledge the consensus* of the relevant expert community. Deceit can stymie normal judgments about who speaks for science. Citizen-consumers may not always be drawing on complete or reliable information. These contexts are addressed in the next section, on "Deceit."

Many science educators focus on how the "anti-science" views are unjustified, and thus, for them, "deniers" inherently exhibit deficient reasoning skills. However, given cultural contexts, the constructivist-minded educator might instead delve into why the proponents view them as *justified* (Carnegie, 1936). That is, rather than cast these positions (and the persons who hold them) as inherently irrational, one should endeavor first to find the orientation in which they seem reasonable. Fear may soon emerge as another key dimension (Table 2). For example, the debate over GMOs is less about food safety than what counts as "natural," as reflected in their rhetoric about "Frankenfoods." Concerns about the MMR vaccine are dominated by fears of childhood autism (even if such fears are unwarranted), while concerns about cell phones and 5G towers are permeated with fears of "radiation" (read "radioactivity") and the specter of cancer. Namely, most philosophers would regard avoidance of a threat as "rational." Of course, it is quite possible that the citizen-consumer may be misinformed or misled in such cases. But that is another matter (more below). Given a cause for alarm, is not alarm an appropriate response?

Socioscientific issues can exhibit multiple dimensions simultaneously. Science is not the exclusive concern for non-scientists. The cultural context in which the science plays out can be equally significant. Those outside the community and culture of professional scientists generally do not embody science as an abstracted pursuit of objective knowledge. Rather, it is chiefly a form of cultural authority. As such, it functions as a significant resource for justifying one's views and for persuading others. This aligns with an evolutionary view of humans as social primates eager to recruit others to their point of view, focusing on justification in a social context rather than an epistemic sense (Mercier & Sperber, 2017). Namely, in social contexts, science becomes a *rhetorical weapon*. In public discourse, it is often not so important what science "says," as what one can achieve by leveraging an appeal to science. Thus, a significant gap can arise between science itself and *what counts as science* in public discourse. For example, even where scientific consensus exists, images of scientific uncertainty have been widely used by corporate interests as a way to effectively stall public policy (Michaels, 2008, 2020; Oreskes & Conway, 2010). A user-centered perspective provides an important interpretive tool to understand how consumers of science (or others trying to persuade them) use "science" and "scientific" arguments in non-scientific contexts—not always towards epistemic ends. Again, a generous constructivist pedagogical posture is needed to inform efforts at conceptual change.

In general, we may expect individuals to align their various beliefs. Our minds tend towards cognitive coherence. It is thus not surprising how people shape (or distort ... or grossly warp) science, as a product, to align with their non-scientific beliefs. Sociologist Brian Martin (1991) documented this tendency in the fluoridation controversy of the 1950s and 60s. The primary concern of the anti-fluoridationists was not science. It was liberty, freedom, and personal autonomy (e.g., Exner & Waldbott, 1957). However, to address the scientific arguments, they essentially needed scientific counterarguments. Thus, rather than argue about balancing the role of government versus individual rights, they appealed to science by inflating minor concerns about overdosing on fluoride (fluorosis) and possible side effects. But these considerations of evidence ended in stalemate. So, their arguments "escalated" to methodology and philosophy of science. How might one adjudicate the conflicting scientific claims? Again, the anti-fluoridationists adopted a position consonant with their libertarian-based conclusions. When that did not work, the criticism shifted to the level of the credibility of the scientists. Fluoridation proponents were supposedly tarnished by conflict of interest, not working for public welfare. Thus, even though the public debate seemed to be about science, science was never treated by the anti-fluoridationists as a neutral arbiter that would settle the dispute. Rationalization was confused with an image of rationality.

In a similar way, arguments about the autonomy and personal beliefs about vaccination have been couched in the scientific terms of adverse consequences (Hausman, 2019). It is in this context that one may also view similar efforts by Ginger Taylor (2023) to articulate (scientifically) how vaccines cause autism, by citing a variety of research. Of course, she is selective about what data or studies she cites, and seems content with incomplete arguments. The goal is not epistemic. It treats science instrumentally, as an argumentative resource. The citing of evidence is more a rhetorical move in a cultural context than an effort to engage is genuine scientific debate or to resolve interpretive disagreements with scientific experts. Imitating science substitutes for authentic science.

The same is true for the anti-climate-change websites mentioned above: unending cherry-picked "evidence," whose primary function is defensive fodder for public debates, not resolution through any scientific discourse. So, too, for Mikovits and her views about autism and chronic fatigue syndrome. In these cases, science is not "science" as scientists conceive it (or as science teachers teach it). Rather, it is hardly much more than an effort to use a heavy-hitting resource in a public contest over something else. Ironically, they nonetheless try to leverage a view that everyone should trust science—"*their*" science—not deny it.

Reasoning about scientific claims happens in a cultural context, not in isolation. Merely bolstering "scientific" reasoning in the classroom will not necessarily address the crux of many socioscientific issues, which often seem inescapably connected to other lines of reasoning. Indeed, some studies have indicated that depth of familiarity with scientific modes of thinking can ironically make things worse. "Smarter" people tend to generate more sophisticated *rationalizations* of ill-informed claims and exhibit more confidence and cognitive resilience in their mistaken arguments (e.g., Shermer, 2002, pp. 279-313). Education can easily foster an unproductive epistemic hubris (see comments on "DYOR" below). We need to foster a form of epistemic trust consistent with epistemic humility.

Who Speaks for Science?

Integral to widespread conceptualizations of science "denial" is the Enlightenment vision of intellectual independence as a standard, or benchmark. Unfortunately, in a culture where intellectual labor is divided, where specialized expertise is pervasive, and expert-level knowledge is widely distributed across the community, this ideal is no longer achievable (Höttecke &

Allchin, 2020). Stephen Norris (1995, 1997) articulated the implications for education over two decades ago. Science educators must abandon the goal of trying to convert everyone into a junior scientist. Students must learn how to cope with their limited knowledge and how to interact with experts who know more than they do. Feinstein (2011) called it being a “competent outsider.” Of course, the roots of that kind of thinking go back even further. Writing in the 1950s, James Bryant Conant (1952) observed, “We live in an age of experts. As a consequence, one of our many problems is how to provide a basis for appraising the expert and his advice” (p. xiii). Namely, as articulated by several philosophers, we are all inescapably dependent on each other epistemically, including relying on scientists for their expertise (Goldman, 1999, 2001; Hardwig, 1991; Kitcher, 1993).

This is true even for scientists. The nearly 300 authors who collectively reported the “Observation of the Top Quark” in 1995 all depended on each other’s expertise. No single person could vouch for the whole. The same is true for the authors of the authoritative IPCC reports on climate change and other scientific endeavors. Following Norris, the era of parading intellectual independence as an educational goal must end. No one has the time or capacity to learn everything. Educators need to adjust their views to an era of epistemic interdependence, humility and informed trust.

This turns out to be the first fundamental error of the non-experts who appeal to science and yet construct their own “scientific” arguments. They are not experts, not as far as the science is concerned. They do not have the technical competence to perform experiments. They do not have the scope of resources, time, or knowledge to conduct large-scale investigations. They do not have the depth of background to recognize all the many possible sources of error, both experimental and conceptual. They do not have the scope of knowledge to know all the alternative hypotheses and potential explanations that must be considered and, in many cases, ruled out. They can only speculate and patch together fragments of evidence collected piecemeal from others. Accordingly, science educators need, at least, to engage students in authentic case studies (possibly from history) where the complexity of science and it many (many!) sources of error (not just logical fallacies) are evident. The nature of scientific expertise needs to be made plain.

In addition, the classroom conception of science must shift from individual knowledge to communal knowledge. Science is not a matter of individual belief. Rather, it is based on *consensus:* the consensus of the relevant experts (Oreskes, 2019; Vickers, 2023; Ziman, 1968).

This is the second fundamental error of the would-be scientist. Their claims are rarely subjected to the “organized skepticism” of the scientific community (Merton, 1973). Their bold claims have not passed muster in the social system of checks and balances that helps expose biases and filter out errors. Regardless of the evidence they cite, the naysayers are not entitled to claim the imprimatur of “science” so important in a cultural context. Alas, their efforts using the tools of rationality may easily devolve into unfruitful rationalization. Everyone — citizens, consumers, and scientists, too — need a healthy dose of epistemic humility. Students must learn who constructs and validates scientific knowledge, and how non-experts may tap into it. Namely, we all must learn how to cope with our epistemic dependence on others and find autonomy without pretending that our own judgment, however sincere, can substitute for an expert one.

Accordingly, science education must teach about the social structure of science (e.g., Ziman, 2000). Teachers need to articulate how scientific claims are vetted, from peer review through ongoing mutual criticism, debate, and follow-up investigations to the resolution of disagreement and formation of a consensus. That will include the role of institutions in helping to structure that critical discourse (journals, conferences, review panels) and in embodying the resulting consensus. That is a significant change to how most science educators currently approach the "nature of science" or "scientific practices."

Whom should we trust? Unfortunately, perhaps, the dependence on others for expertise poses a particular conundrum. Namely, as Conant suggested decades ago, how do we know who is an expert? As non-experts, we are not in a position to directly evaluate (or "calibrate") the expertise of others. As a result, to secure reliable scientific knowledge, we must inevitably exercise trust in others, including those who pass along the knowledge. That inescapable trust, however, opens the way to potential mischief. Others may intervene. We may be deceived by imposters. We may be victims of scientific misinformation, or deliberate *dis*information. This is the challenge of misinformation: not learning to judge the evidence or arguments for ourselves (where epistemic hubris may blind us), but rather learning to manage deceit.

Deceit

Deception abounds in nature. Mimicry is widespread. Carnivorous plants lure insects with the smell of rotting flesh. Bee orchids look like female bees, enticing males, who try to mate with the flower, but end up helping (unwittingly) to transfer pollen. Insect-hunting chameleons are—well, chameleon-like, changing coloration patterns to blend in with their surroundings. The AIDS virus mimics the shape of human cell proteins, enabling them entry into white blood cells, where they compromise the immune system. The biological world is rife with deception (Stevens, 2016; Sun, 2023). It is an adaptive response to opportunity.

So, too, for humans seeking profit, power, or persuasive influence. By imitating science, one can try to leverage its epistemic authority in a cultural context — as exemplified in the cases discussed above. In terms of cultural evolution, disinformation is a perhaps predictable adaptive outcome. Ironically, the effectiveness of scientific disinformation relies on a baseline of trust in science (Figures 1-3). It also relies on a model image of what science is supposed to be or look like. Mimics exploit certain superficial impressions and cultural stereotypes about what science is (or should be). Camouflage, at the social level. Sometimes as easy as donning a white lab coat. As noted by Toumey (1996, p. 6), the purveyors of disinformation "conjure" science "from cheap symbols and ersatz images." In David Michaels' terms, "sound science" competes with its rogue cousin, "sounds like science" (2008, p. xi).

Disinformation about science is found in many forms (Table 3). One can find bogus claims. Bogus data, bogus evidence. Bogus journals, with no genuine peer review. Bogus claims to expertise based on bogus credentials. Bogus "scientific" organizations (some parading authentic non-profit status). Bogus reports of consensus, with long lists of non-expert signatories. Bogus textbooks and museums(!). All exploit the conventional hallmarks of reliability in science. But, like mimicry in nature, it is fundamentally deceit. Cherry-picked evidence passes as evidence. Deliberately truncated or extended study periods may yield favorable results based on biased samples. Statistical significance may seem impressive, but not when it arises from gerrymandered data reanalyses. Arguments may seem plausible on the surface, but fail to rule out relevant alternative explanations. Telltale conflicts of interest may go undisclosed; negative results, unpublished. Bluntly, public media are filled with con-artists seeking profit, power or privilege, all pretending to be "scientific." Deceit, not denial.

How should this analysis of science deceit inform science education? Here, the ideal of intellectual independence becomes relevant again. Many educators want to empower students to apply scientific thinking skills to evaluate the lies for themselves (e.g., Dodge, et al., 2020; NGSS

Lead States, 2013; Sinatra & Hofer, 2021). Under this orientation, the student gathers the evidence, evaluates it and, if the argument seems plausible, the threat of misinformation has apparently been quelled (Herrick, Sinatra & Lombardi, 2023). But plausibility is precisely what the imitators of science produce. Their lies and distortions appeal to the individual's inflated sense of expert competence. Sadly, only an expert can decipher the crafty deception. That is, in part, why non-scientists turn to scientists: to make those very judgments on their behalf, to sort disinformation from genuine science. For example, most of the cases in Table 3 were exposed after months of investigation by journalists (who consulted many experts), or by scientists who documented and explained the critical misrepresentations.

It should be no wonder, perhaps, that purveyors of misinformation often encourage consumers to think for themselves. "Do Your Own Research" — D.Y.O.R. — is the watchword. This advice is promulgated, for example, by a libertarian think tank (the Cato Institute), critical of climate change and research that supports the need for regulations that help ensure environmental, health, and worker safety (e.g., Milloy, 2001; Murray et al., 2001). Steve Milloy promoted "junk science judo," a whimsical motto for debunking. But when applied selectively and superficially, amplifying every limitation of just the scientific conclusions you don't like, it is junk philosophy.

Nowadays, DYOR is interpreted largely as internet search, circumscribed by convenience. Googling contentious topics seems to nurture a misleading sense of escaping the bias of social media — through simple "fact-checking" and rooting out "the truth." Few DYORers seem aware that search algorithms have biases too, posting results that are based more on popularity or profitability than on accuracy. Indeed, in practice, DYOR is susceptible to confirmation bias, with proponents seeking only sources that align with their values and views. They tend to judge the credibility of sources based on their own perceptions of the quality of the information, rather than the other way around. So their views of objectivity are themselves compromised. It is not surprising that DYOR is frequently coupled with a distrust of professional (mainstream) journalists, and even veteran fact-checking organizations like Snopes or PolitiFact (Tripodi, 2022). Alas, coaxing citizen-consumers to DYOR leaves them at the mercy of the disinformation that floods the media—the very opposite of the purported intent. More epistemic hubris.

Studies have now demonstrated that those who adopt the DYOR posture are ultimately less likely to reach conclusions consistent with the scientific consensus (Ballantine & Dunning, 2022). In one study, DYOR-oriented consumers exhibited more COVID-19 misperceptions, and lower levels of trust in science generally (Chinn & Hasell, 2023). In another, mothers who chose not vaccinate their children relied on their self-styled critiques of expert research, substituting their own personal experience in its place (Carrion, 2017). As a third example, flat Earthers frequently report they were unconvinced at first, but changed their minds after doing their own research: namely, binging on YouTube videos (Burdick, 2018; Weill, 2022). Ironically, the individuals here have a misleading impression of their own intellectual authority, while in fact learning less (e.g., Dunning, 2019). Hence, the conventional educational goal of nurturing scientific reasoning skills (yes, helpful in many contexts) may also foster overconfidence in one's own competence in a society dominated by experts and specialized knowledge (Motta et al., 2018). Again, educators must reckon with the discomforting problem highlighted by Norris (1995, 1997): that the ideal of full intellectual independence must be replaced with a model of distributed knowledge and negotiating our way through epistemic dependence and trust.

The task for the citizen or consumer of science is not to wade through the morass of evidence themselves, by evaluating the arguments or weighing the relevance of evidence on their own. Rather, we must teach students how to find (and trust in) the consensus of the relevant experts (the benchmark discussed in the previous section).

But how does one identify a spokesperson that faithfully conveys that consensus? The science con artists (Table 3) seem to lurk everywhere. How can educators help individual consumer-citizens distinguish a credible source from an artful imitator? The NGSS (Lead States, 2013) refers repeatedly to the need to use "reliable media" (12 times), but never addresses how students will actually ascertain reliability. How does one detect an effort at deceit, in order to jettison the junk?

Here, one needs to extend focus beyond the content and include the context and practices of messaging: from "scientific practices" to science media literacy (Höttecke & Allchin, 2020). What are the methods of persuasion and deception? How (and perhaps why) do they work? It all happens at the level of rhetoric and presentation—in how the media garners our attention and nurtures belief. How do we sort genuine scientific claims from the dreck made to look like science—and intended to deceive?

Many defenders of science have developed checklists to help the naive user. Many such guides, however, have limited usefulness. Educators already know about the importance of a student-centered approach (e.g., TEAL Center, 2010). While many of the consumer guides provide important insights about the flaws in misinformation, they often fail to adopt an effective user-centered orientation. For example, a popular website for classroom users, Understanding Science (2023), offers students several diagnostic questions for "evaluating scientific messages" (Table 4). They rightfully point out that science and the relative confidence of scientists may not be accurately portrayed (#2-3); that controversies may be blown out of proportion (#4); and that the evidence may vary in strength (#6). But we cannot expect students, as non-experts, to make these very assessments. They do not yet know the science as the comparative benchmark. That is the conundrum of the outsider. These questions do not get at the heart of the problems of trust or of dodging deceit.

SkepticalScience.com offers its own alternative, under the acronym FLICC (Table 5) (Cook, 2020). This scheme has been widely publicized and adopted (e.g., Hansson, 2017; McIntyre, 2021, pp. 33-57; Schmid & Metsch, 2019). Yet here, too, the consumer must be wiser than the deceiver. Only someone familiar with all the evidence is positioned to know whether the evidence someone presents has actually been cherry-picked (Table 5, "C"). A non-expert may be familiar with a few logical fallacies ("L"), but for the most part, on their own they will unlikely be able to see through all the many possible errors in reasoning. So, too, for knowing by oneself whether a purported expert is a fake or not ("F"). Yes, conspiratorial thinking ("C") is a major pitfall—but what conspiratorial thinker recognizes themselves as such?

The core problem is that the imitators of science are clued into, and thus mimic, all the features we normally associate with science. So detection based on those criteria—many of the educators' familiar warning signs of pseudoscience, for example—becomes relatively ineffective in practice. As the founders of FactCheck.org note, the challenge, instead, is to separate substance from spin (Jackson & Jamieson, 2007).

A fruitful approach will thus follow the biological strategy of counteradaptation. That is, learn the various tactics of deception to strip them of their efficacy. Alert users to recognize the various strategems used to game their systems of belief. The toolbox of persuasive methods has been the subject of *decades* of concerted research by advertisers and public relations firms (e.g., Bernays, 1923; Cialdini, 1984; Fennis & Stroebe, 2010; Goldstein et al., 2008; Heath & Heath, 2007; Sharot, 2017). There is now substantial evidence that a core set of such persuasive strategies constitutes a shared "playbook" used by those who wish to derail the role of scientific consensus in the public sphere (Kenner, 2015; Markowitz & Rosner, 2002; McGarity & Wagner, 2008; Michaels, 2008, 2020; Mooney, 2005; Oreskes & Conway, 2010; Shrader-Frechette, 2014; Union of Concerned Scientists, 2007, 2020; see also Table 5). In a sense, the educational goal is to develop and hone our "BS alarms" and identify the liars (rather than unpack their lies).

There are various ways to express and organize the many persuasive tactics.[1] One set is encapsulated in the concise and descriptive acronym "LIARS": Looks, Identity, Acting, Repetition, Skepticism (Table 6). Looks (L) refers to the superficial appearance of success and intelligence: expensive style, easy going and confident manner, handsome, beautiful or charismatic speakers, or a glitzy, ad-free website. Identity (I) is about manipulating social emotions: establishing in-group identity (and perhaps an out-group foe), or appealing to such dimensions as common background, political affiliation, gender, race, nationality, or other identity category. Acting (A) denotes false claims of expertise (perhaps even a misleading "dot.org" URL?). Repetition (R) is about efforts to project an image of majority opinion by sponsoring multiple (apparently independent) messages: flooding the media and creating a false impression of "the wisdom of the crowd." Skepticism (S) is about amplifying a healthy cautionary attitude into outright doubt, fostering uncertainty and confusion, as well as other efforts to dismantle the legitimacy of an established scientific consensus, especially by triggering fears (e.g., cases listed in Table 2). These are all warning signals to probe motives and intent (or the persuasive context) more thoroughly. That is, by themselves, they do not establish the truth or falsity of any particular claim. They help trigger yellow warning flags. They signal the need to seek more reliable expertise.

Namely, educational strategy needs to be oriented to the tools for exposing deceit: leveraging trust in science and articulating the difference between authentic science and bogus imitations. Science "denial" is a misleading red herring.

The Biases of Social Learning

It may be helpful to remember, here, that the very possibility of disinformation is an ironic consequence of our evolved sociality and our cognitive adaptations for social learning (Mercier & Sperber, 2017; O'Connor & Weatherall, 2019). Our social learning heuristics have certain "biases" in who we follow or choose to listen to (Forgas & Baumeister, 2019; Kendal et al., 2018). Unfortunately, these filters have "loopholes," which leave us vulnerable to inaccurate information gathering. The deceptive tactics commonly found in media misinformation tend to capitalize precisely on these inherent tendencies: (1) prestige bias (e.g., Jiménez & Mesoudi, 2019); (2) in-group bias (Zou & Xu, 2023)' (3) conformist bias (e.g., Muthukrishna, Morgan & Henrich, 2016); (4) following the majority (Kendal et al., 2018); (5) discerning domain-specific expertise (e.g., Pornpitakpan, 2004). These correspond to the most widespread persuasive tactics, as indicated in the final column of Table 6. Namely, the purveyors of misinformation effectively hijack our psychological dispositions for social learning.

At the same time, the native tendencies can be modulated with education. With training, we can learn to be more aware of them and regulate their influence. (For example, recall the 3M poll, showing how individuals rank trust in various sources of scientific claims—Figure 3.) Good news for science educators, perhaps. However, when individuals are stressed—in conditions of

[1] Here, regretfully, I cleave off conspiratorial thinking, which seems to reflect a separate, deeper problem, akin to religious conversion or cults, or what Fritze (2009), following Colin Campbell, has described as the "cultic milieu" (see also van der Linden, 2023; van Prooijen, 2019; van Prooijen & van Vugt, 2018).

uncertainty, confusion, urgency, or overwhelming information—they tend to resort to the defaults, and their deficits (e.g., Cialdini, 1984; Hausman, 2021; Kahneman, 2011). In these cases, the nuances of adjusting the heuristics will recede. Emotions, too, will assume a larger role in decision-making. Thus, it is not surprising that those who wish to peripheralize the role of science endeavor to generate those very conditions—fear and doubt (Table 6: "Skepticism"; see again Table 2). The rhetorical manufacture of doubt by corporate interests, in particular, has received plentiful attention lately, including the cases of climate change, second-hand smoke, the ozone hole, lead paint, asbestos, industrial chemicals, football brain injuries, and more (e.g., Kenner, 2015; Michaels, 2008, 2020; Oreskes & Conway, 2010; Union of Concerned Scientists, 2019). Another lesson for students to learn about media messaging.

The prospects may seem dismal for the fate of misinformation in our culture. However, humans also seem to be equipped (not inconsequentially) with "B.S. detectors." "B.S. alarms" trigger hesitation. Betrayal of trust also matters, when we discover it. So, one finds that purveyors of disinformation tend to exercise extraordinary caution, and try to avoid setting off any warning signal. That is, they seek to gain our confidence, our trust. They are, literally, confidence artists, or *con* artists. When they succeed, the craft of their persuasion remains invisible. The result is not so much self-delusion as artful deceit. Hence, honing our native skills in detecting deception is an indispensable element in science media literacy.

Ironically, perhaps, while ancestral tendencies in social learning may create openings for misinformation to take hold, social learning itself may also contribute to an effective solution. That is, we need not assess the credibility of sources all on our own. (That image, too, is a legacy of the alluring mythos of intellectual independence.) Social media and other unregulated electronic media (YouTube, commercial websites on the open web, and so on) are surely treacherous sources of misinformation. Yet the internet also provides easy access to "good" information, and informed sources that can help expose the pretenses of the science con artists, or L.I.A.R.S. We can find testimony from others about rogue actors (A). We can assess whether repeated messages (R) reflect true scientific expertise. Is skepticism (S) warranted in the context of the scientific consensus? The strategy is to do an end-run around the limited information provided by a questionable source. That is, one can leverage the power of the web against those who might abuse it (Caulfield & Wineburg, 2023; Pimentel, 2023; Wineburg et al., 2022). We can identify and disregard deceivers without having to unpack every single lie. This is social learning, one layer deeper.

Prospects

What does the analysis of denial and deceit mean for educational curriculum, classroom activities, and performance standards?

First, if the reliability of scientific claims is important for consumers and citizens, lessons in science media literacy become an essential component of conventional scientific literacy (Höttecke & Allchin, 2020; Osborne & Pimentel, 2022). A primary concern for developing "competent outsiders" should be familiarizing students with the challenges of accessing expert knowledge and the potential for mimicry and deceit in messaging about science. Many of the persuasive tactics (LIARS, Table 6) function by being unnoticed, so by making them more visible and less cryptic, they are rendered less effective. Some educators use immunization as an analogy and refer to this approach as "inoculation" (e.g., Cook, Lewandowsky & Erker, 2017; van der Linden, 2023). However (as noted above), in a cultural or ecological context, one may construe the skill simply as a perceptual counteradaptation, or equipping consumer-citizens with a defensive behavior against being hoodwinked.

Because the deceptive methods are already familiar to and addressed by experienced media users, such as journalists and fact checkers, further educational research hardly seems requisite. Instead, educators may need to orient their creative efforts towards crafting lessons that embody the principles of constructivist learning pedagogy. The foremost aim should be to help students *co-develop* the appropriate concepts *from their own experience and analysis*. That is, we should not rely primarily on prepared checklists or on “training” students with teacher-generated templates—the pattern of most currently available media literacy education (e.g., Center for Media Literacy, 2018; National Association for Media Literacy Education, 2007; News Literacy Project, 2012). Rather, the instruction should engage students in authentic cases and samples of deception. There should be open-ended questions about how to detect and disable the adverse effect of persuasive strategies. For example, the teacher might begin by introducing some playful examples that simply invite attention to the problem of credibility (e.g., guessing whether several “fantastic beasts” are real or not).

Next, the LIARS framework (Table 6) may guide the teacher in selecting a handful of concrete cases which help *frame problems to solve* (rather than merely illustrate concepts from a predetermined list) (see Tables 1-3). Students are generally not wholly unfamiliar with ways to mislead or lie, so games that invite them to “play” with persuasive strategies with their classmates, coupled with subsequent analysis, may be appropriate. For example, imagine an activity modeled on the television show, “To Tell the Truth,” or the radio quiz, “Bluff the Listener.” That is, the teacher will ideally guide students in using their own experiences to help (re)construct the LIARS framework (or something similar to it). Students may then apply their list to interpreting real cases in the media. Or they may review more advanced cases (e.g., from the “Disinformation Playbook” case studies, prepared by the Union of Concerned Scientists, 2020). These instructional strategies aim to empower students to recognize and neutralize deceptive tactics in science media: as a counteradaptation.

A second, parallel thread of instruction may focus on how to address individual instances of scientific claims, just as one encounters them on the internet, YouTube, social media, print or broadcast channels, or by casual hearsay. Should one regard *this particular* claim as reliable? Here, the conceptual shift from denial to deceit may help reorient media literacy lessons from the message to the messenger, or from the “argument” to the source of information itself. Namely, it is easier to detect a suspected liar than to debunk each and every lie. Four curricular elements will help, as follows.

First, acquaint students with the ultimate benchmark for reliable knowledge: the consensus of the relevant experts. Explain it. Foremost, as noted earlier, familiarize students with the social practices of science. Historical inquiry cases or narratives can be valuable for conveying these often overlooked dimensions of the nature of science, hard to model fully in student-led investigations. Paradoxically, perhaps, this may involve acknowledging error and bias in science, while clarifying how critical discourse exposes those biases and filters the errors (Allchin, 2012). Learning must underscore the essential roles of: (a) *consensus*; (b) *expertise*; and (c) *relevant* expertise. When appropriate, one might ask if the scientific community is *appropriately diverse*, having developed a consensus across a broad spectrum of relevant critical perspectives (Oreskes, 2019; Solomon, 2001). Lone voices, especially from quasi-experts, don’t cut it — regardless of any plausible argument or fragments of evidence.

Second, in contrast to perpetuating a myth of intellectual independence, teachers should nurture a sense of epistemic humility and an understanding of the challenges of relying on others when they know more than we do. Namely, *do not* “DYOR”! Learn why experts and informe trust matter. This involves exploring the very nature of expertise and the role of credibility in learning from others: the social architecture of trust (e.g., Zemplén, 2009). This marks a significant shift from a focus on individual scientific practices (e.g., NGSS Lead States, 2013).

A third curricular element explores the nature of mediated messsaging (the Media; Höttecke & Allchin, 2020). *Who* is purporting to speak for science? And why? What are the motivations and the intent in *reporting* the science? (Recall, again, the 3M poll, Figure 3.) Is the information possibly framed to enlist our belief, not merely inform us? For example, is there a conflict of interest (Table 3)? Here, the toolbox for disentangling deceptive tactics (LIARS) becomes especially significant (e.g., Jackson & Jamieson, 2007). Students should become aware of their subconscious vulnerabilities and the tactics used by con artists (social learning biases in Table 6). Likewise, consumers of science should become familiar with publically recognized scientific authorities and sources that function as reliable spokespersons *on behalf of* the scientific consensus. For less familiar sources, the adept consumer can consult the internet as a convenient reference. For example, even Wikipedia can easily identify the Heartland Institute (sponsor and publisher of the notorious 2009 report, *Climate Change Reconsidered*, from the bogus Nongovernmental International Panel on Climate Change) as a “public policy think tank known for its rejection of both the scientific consensus on climate change and the negative health impacts of smoking” (Caulfield & Wineburg, 2023; Pimentel, 2023; Wineburg, et al., 2021).

Finally, students should learn about the role of their own beliefs and motivations. A preliminary step when addressing any significant scientific claim is, oddly perhaps, monitoring one’s own emotions. If the reliability of the claim is important, students need to learn to shift from experiential (immersive) mode to analytic mode, where one applies epistemic criteria, and does not merely respond intuitively (Table 6). (Think of moving from Kahneman’s [2011] “System I” to “System II”?) That is the first step in escaping from the invisible tactics of deceit that, often by design, play on those emotions.

That is, numerous competencies are relevant to addressing misinformation (e.g., Author). Ideally, all the lessons should, again, be framed as bottom-up exercises, rather than as top-down checklists. For example, guide students in revisiting the in-situ interpretive challenges in the early history of the coronoavirus pandemic, now with the added benefit of hindsight or situate students in the 18th-century dilemma of whether to use smallpox variolation on their children.

Ironically, an appropriate learning sequence (as sketched above) may present these skills *in reverse order* to how they are actually applied in practice. Namely, procedurally: (1) Monitor emotions; (2) Ask who and why?; (3) Ascertain the basis for trust; and (4) Seek the consensus of the relevant experts (e.g., Osborne et al., 2022). The learning series, however, functions by gradually introducing a larger scope of view and a deeper sensitivity to context.

Managing misinformation can indeed be done, and science education may have a major role. But it may begin by acknowledging that the core problem is deceit, not denial.

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Figure 1. Results of Pew Research Foundation survey on public trust (adapted from Kennedy, Tyson & Funk 2022).

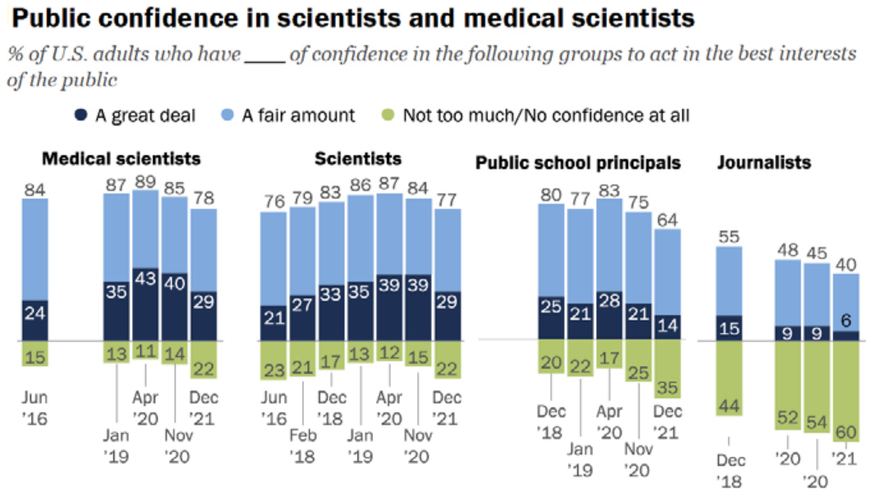

Figure 2. Results of the 2022 3M State of Science Index report on trust in science.

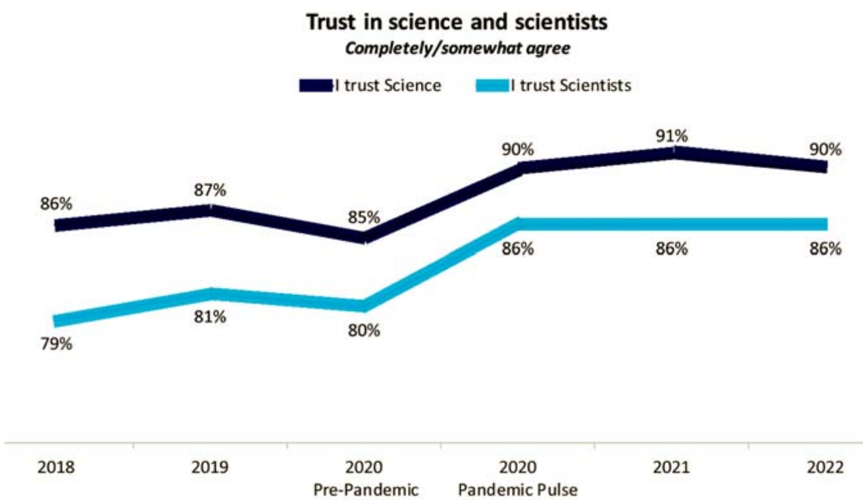

Figure 3. Trust in different sources of scientific information (3M, 2022).

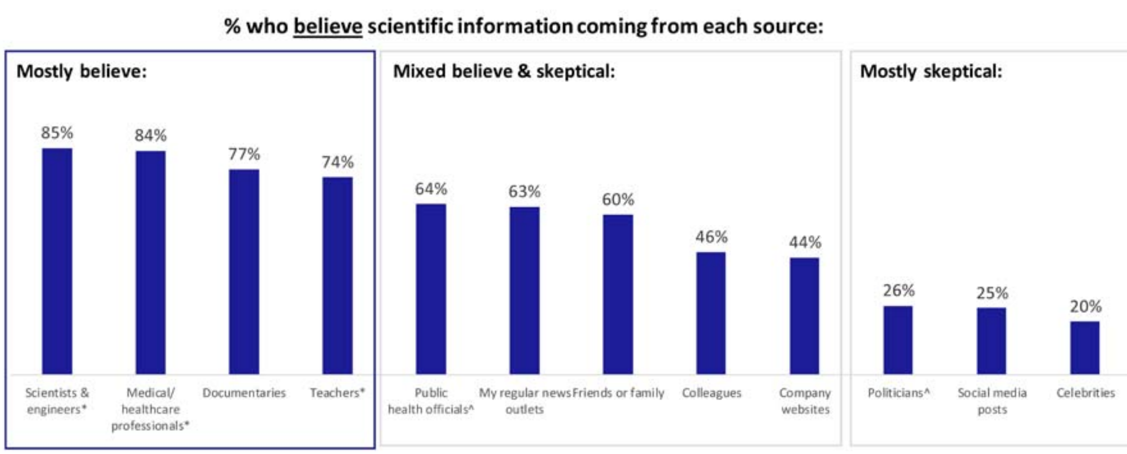

Table 1. Where trust is lacking on some socioscientific issues.

Case	*Where trust is lacking*	*Ref.*
vaccine safety	"Big Pharma" (conflict of interest in the pharmaceutical industry)	e.g., Mikovits (2020); Hausman (2019)
GMO safety	"Big Ag" (conflict of interest in agricultural biotech)	
water fluoridation	government welfare	Exner & Waldbott (1957); Martin (1991); Toumey (1996)
vaccine mandates (e.g. Vaccine Revolt of 1904, Brazil)	government welfare	Cantisano (2022); Cuckierman (2021); Larson (2020)
pandemic masking mandates	government welfare	
HIV as the cause of AIDS (South Africa, 1999-2008)	Post-Colonial Western powers / racism	Nattrass (2007)
flat Earth	most conventional authorities	Garwood (2007); Weill (2022)

Table 2. Fears and nature of threat in various socioscientific issues.

Issue	*Fear/threat*	*Reference*
climate change	loss of comfortable lifestyle	Jylhä, et al. (2023)
GMOs	unnaturalness ("Frankenfoods")	Allchin (2014)
vaccine mandate	loss of autonomy	Hausman (2019); Larson (2020)
MMR vaccine	childhood autism	
evolution	loss of moral standards; immoral society	Allchin (2009, 2013). Toumey (1996)
cell phones/3G/4G/5G towers	"radiation," cancer, mutation	
fluoridation of water (1950s-60s)	poisoning; loss of autonomy	Toumey (1996)
AIDS quarrantining (1986)	deadly infection, moral contamination	Toumey (1996)
New Madrid earthquake prediction (1990)	natural disaster	Spence et al. (1993)

Table 3. Forms of mimicking science and sample cases of deceit. * indicates undisclosed conflict of interest or other hidden corporate sponsorship. (In addition to cited references, many cases are summarized on Wikipedia, with additional citations.)

Deception (Deceit)	*Case example*	*Reference*
bogus claims	• vitamins & AIDS (Matthias Rath)	Goldacre (2010)
	• nutrition & AIDS in S. Africa (Manto Tshabalala-Msimang)	Nattrass (2007)
	• safety of flame retardants (Citizens for Fire Safety*)	Callahan & Roe (2012); Roe & Callahan (2012)
bogus data	• asbestos litigation	Union of Concerned Scientists (2019); Michaels (2008)
	• Andrew Wakefield*/MMR vaccine & autism	Deer (2011)
	• brain injuries of football players (NFL Mild Traumatic Brain Injury Committee*)	Fainaru-Wada (2013); Schwarz et al (2016)
	• Univ. of Texas* / environmental effects of oil fracking	Augustine, et al. (2012)
bogus expertise,	• Weather Channel co-founder, on climate change	Peterson (2023)
bogus credentials,	• Iben Browning, New Madrid earthquake prediction	Spence, et al. (1993)
bogus peer review	• Didier Raoult / HCQ treatment for COVID	Bloom (2020)
	• Editor,* *Neurosurgeon* / football concussions	Fainaru-Wada (2013)
bogus journals	• *Journal of Regulatory Toxicology & Pharmacology**	Michaels (2008, pp. 53–55)
	• *Journal of Physicians and Surgeons**	Oreskes & Conway (2010, pp. 244–245)
	• *Indoor and Built Environment**	
bogus textbook	• *Beryllium: Biomedical and Environmental Aspects**	Michaels (2008, pp. 131-132)
bogus professional or research organizations	• Tobacco Institute Research Committee* (smoking)	Michaels (2020)
	• Foundation for Clean Air Progress* (soot pollution)	Center for Media & Democracy (2012)
	• American College of Pediatrians* (transgender care)	Cameron & Mehrotra (2023)
bogus review articles and reports	• sugared beverages and health*	Michaels (2020)
	• *Climate Change Reconsidered* (Non-Intergovernmental Panel on Climate Change)*	Ball (2014)
	• Jonathan Wells / *Icons of Evolution*	National Center for Science Education (2016)
bogus consensus	• Leipzig Declaration* (global warming)	Olinger (1996)
	• Oregon Protocol* (climate change)	Angliss (2010)
misleading evidence (cherry-picked)	• ecological benefits of lawns (Lawn Institute*)	Allchin (2023a)
	• anti-fluoridationists	Martin (1988)
	• Merck* / truncated “VIGOR” study of Vioxx painkiller	Krumholz etl al. (2007)

misleading study ("red herrings")	• need for vitamin D testing*	Allchin (2017)
	• dietary sugar vs. exercise in causing obesity (ISCOLE study; Coca-Cola/Global Energy Balance Network*)	Nestle (2018); O'Connor (2015)
	• dietary sugar vs. fat in causing obesity (Sugar Research Foundation*)	Michaels (2020); Union of Concerned Scientists (2019)
	• health (vs. environmental) benefits of organic foods*	Yudell (2012)
misleading statistics	• data reanalysis on chromium-6 toxicity & worker safety*	Michaels (2008); Union of Concerned Scientists (2019)
	• data reanalysis of safety standards for benzene exposure*	Michaels (2008, pp. 71-78; 2020, pp. 243-244)
	• health of meat diet*	Harvard School of Public Health (2019); Parker-Pope & O'Connor (2019)
misleading arguments (plausible, incomplete)	• sea ice expansion and global warming	Mooney (2015); Wolchover (2012)
	• N95 masks & virus particle size	Litke (2020)
	• oxygen production by lawns* (gross vs. net)	Allchin (2023a)
misleading publication (selective or suppressed data)	• dangers of tobacco smoke*	Michaels (2008); Oreskes & Conway (2010)
	• risk of polyfluoroalkyl substances (PFA) chemicals*	Union of Concerned Scientists (2019); Michaels (2020)
	• Purdue Pharma* & opioids	Union of Concerned Scientists (2019); Michaels (2020)

Table 4. "Your Science Toolkit: Evaluating Scientific Messages" from the popular website Understanding Science (2023).

- Where does the information come from?
- Are the views of the scientific community accurately portrayed?
- Is the scientific community's confidence in the ideas accurately portrayed?
- Is a controversy misrepresented or blown out of proportion?
- Where can I get more information?
- How strong is the evidence?

Table 5. Techniques of science denial, according to the acronym FLICC (Cook, 2020).

F — Fake experts
L— Logical Fallacies
I — Impossible expectations
C — Cherry picking
C — Conspiracy thinking

Table 6. Persuasive tactics and their basis in social learning heuristics, organized around the acronym "LIARS" (adapted from Allchin, 2022a).

	Persuasive tactic	*Related strategies*	*Social learning heuristic*
L	Looks	style, ease, imagery of success, charisma, self-confidence	prestige bias
I	Identity	in-group/out-group, peers, social emotions	in-group bias, conformity bias
A	Acting	expert disguise, false credentials	expertise-based judgment
R	Repetition	false consensus, normalization	majority bias
S	Skepticism	imaging doubt, uncertainty, fostering fear	identifying & avoiding threats