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Transforming Science Education in an Age of Misinformation

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Misinformation and disinformation about science, medicine, and public health have reached alarming proportions (e.g., ALLEA 2021; Amara, 2022; West & Bergstrom 2021). In a new report, *Science Education in an Age of Misinformation*, we and others outline what science education can do to address this problem, and, given the urgency, what we must do (Osborne, et al. 2022). Importantly, we highlight the significance of teaching how the social practices of science contribute to a trustworthy consensus and how students should evaluate the credibility of second-hand claims reported in the media or on the internet (Figure 1).

In our work, we brought together a multidisciplinary set of experts. The group included a Nobel Prize-winning scientist, several science educators, experts in educational psychology, online misinformation tactics, and civic online reasoning, a professional fact-checker, and a philosopher of science, as well as an evolutionary biologist and co-author of the popular text, *Calling Bullshit.* We considered the nature of the problem and what can be done in science education.

The problem of misinformation is familiar to university science faculty (Barzilai & Chinn, 2020). For instance, there is widespread denial of climate change — both of the scale of the threat and what has caused it. The safety and efficacy of vaccines have been attacked, aggravating the COVID pandemic through low vaccination rates. While misinformation is a general problem, the threat of displacing the cultural authority of scientific knowledge is especially grave. This challenge cannot be fully addressed in communication arts or the social sciences. Nor can it be fully ameliorated by widespread courses in abstract critical thinking or argumentation (e.g., Chaffee, 2019). Science educators have yet to mount a systematic response in teaching *science media literacy*.

Recent new curricula in science, such as Vision and Change of the American Association for the Advancement of Science (and its K-12 counterpart, the Next Generation Science Standards), offer a much-needed shift in emphasis from conceptual content to scientific practices and scientific reasoning. However, by design, they still tend to follow a model of preparing future scientists. They do not address the competencies needed by citizens and consumers of science. That is, they aim to develop marginal insiders, not *competent outsiders* (Feinstein, 2011). Students do not need to learn how to redo the science for themselves — or how to second guess the experts. Rather, adrift in an ocean of misinformation, they need to know how to find, assess and trust genuine expert consensus. A profound shift in orientation is needed in the goals of general science education.

Most science curricula, including the newest ones, rest on a fundamental premise: that by learning about investigation and scientific reasoning, one becomes competent to judge the evidence for oneself. However, this much touted goal of intellectual independence is an illusion. Expert scientific judgments require extensive disciplinary knowledge, intimate familiarity with methods and their many sources of error, awareness of alternative hypotheses, and more. Even if non-scientists can read the authoritative IPCC report on climate change, they are in no position to (re)evaluate the expert consensus. Even the scientists who authored the report depend on each other for their respective expert contributions. Working with expertise, not just evidence-based thinking, matters (Norris 1995, 1997).

Our modern society, with its specialization, distributed expertise, and mutual interdependence, no longer accommodates the Enlightenment ideal of rationality based on an individual knower. We all depend on the knowledge of others: doctors, lawyers, accountants, airplane pilots, wifi techies, and bridge welders, as much as immunologists and paleoclimatologists. Yet given the immense availability of information on the internet and other digital media, many people readily imagine that they, or anyone, can easily command all the relevant knowledge on their own. However, given the limits of our individual expertise, this is nothing short of epistemic hubris. Students need to recognize the bounded limits of what any one person can know (Hertwig & Kozyreva, 2021). They need to understand the complex social structure of knowledge and their inescapable dependence on experts, including scientists.

The purveyors of disinformation capitalize on the illusion of intellectual autonomy. Individuals who believe that they can rely solely on their own wits are vulnerable to the use of misleading, cherry-picked evidence. They are susceptible to plausible but ill-informed arguments. Such tactics have entered a recurring playbook for spreading scientific disinformation (Kenner, 2015; Michaels, 2020; Union of Concerned Scientists, 2019). In addition to understanding the status of epistemic dependence on experts, students also need to be aware of such deceptive strategies.

Some commentators characterize the problem as one of overcoming “science denial” or a blanket distrust in science (e.g., McIntrye, 2019; Sinatra & Hofer, 2021). Yet recent polls by the Pew Research Foundation and by 3M indicate that public confidence in the trustworthiness of science and its authority remains high (3M, 2022; Kennedy, Tyson, & Funk, 2022). The problem, we contend, is not trust in science itself, but rather *knowing whom to trust*. Unfortunately, the non-scientist lacks precisely the relevant background to assess who is an expert. Only fellow experts have that level of knowledge. Non-experts, by contrast, can easily be misled by strategic disinformation campaigns, charismatic iconoclasts or earnest voices who all claim to know the truth. Accordingly, lessons about the nature of scientific expertise are needed in the science classroom and lecture hall.

Understanding the social architecture of trust is central (Allchin, 2012). How does one establish a scientist’s *credibility* (rather than certify their argument)? Here, the relevant evidence is not in the empirical data or arguments themselves. Rather, the critical information is the media context in which a scientific claim is presented. We recommend emphasizing two basic features for students (Figure 1, “Science-in-the-wild”). First, does the spokesperson have a track record of integrity? Is there a conflict of interest? Are there marked political, economic or ideological biases that betray a lack of objectivity? Even if fragments of authentic scientific evidence are offered, they are of no account if the source of information itself is questionable. However, none of this is addressed by most conventional lessons in argumentation, critical thinking, or media literacy. Those all assume non-experts can participate in discourse at an expert level. Credibility is foundational.

Second, does the spokesperson or institution advancing the claim have the relevant expertise? For other forms of expertise, our society has established various forms of credentialing — professional licenses, accreditation, certifications, and so on. No such public markers exist for science. Scientists, of course, learn about their professional peers — indicating whose work they should esteem and whose might be open to question. There is an implicit system of credibility. But this familiarity, too, generally circulates only among fellow experts. Students must thus learn how one can establish that a purported expert scientist has a track record among their professional peers (those uniquely positioned to assess shared competence). Good science journalists, for example, usually take note of such credentials and peer reputation. Again, the critical lessons about gauging expertise are virtually absent from current science curricula (Figure 1, shaded area).

Purveyors of disinformation, of course, try to convey a false image of their own expertise (Rampton & Stauber, 2001). For example, they may list affiliations with institutions or organizations that sound grand but are not accredited or generally respected. They may cite publications, but not from reputable peer-reviewed journals. They may rely on their expertise in one area to make pronouncements in another. But being an expert in nuclear physics, say, does not make one an expert in virology. Students have much to learn about subterfuge and deceitful tactics.

Expertise is essential. However, a single expert is insufficient. Experts may differ in their verdicts, at least initially. Science differs from many other forms of expertise in striving for consensus as the ultimate marker of reliability (Figure 1, "Expert Scientific Community"). Scientific knowledge is developed through a distinctly collective enterprise. For example, peer review occurs both before publication and after. Methods are scrutinized. Assumptions are reviewed. Possible errors are probed. Where there is disagreement, further research is done, towards resolving ambiguities or residual uncertainties. Science exhibits a powerful social system of checks and balances that helps to filter out error and bias. The resulting consensus is stronger epistemically than that which any individual can typically achieve. Thus, the consumer of science as a competent outsider must seek, "what is the *consensus* of the relevant scientific experts?" (Oreskes, 2019). Again, this understanding of the social practices of science is absent from nearly all science classrooms and even the recent model curricula.

Consensus is not formed by snap judgement. While textbooks and most lecture styles focus on settled facts, scientists spend the vast majority of their time grappling with unsettled matters. During these periods, there may yet be no scientific consensus. Multiple hypotheses may fit the data and scientists may legitimately disagree about how to interpret the evidence. In some cases, rival camps may advance mutually incompatible models and explanations. When members of the public observe this happening in real time, as they did early during the COVID pandemic, they sometimes imagine that science is in disarray — or worse, corrupted by political or financial interests. Science teachers need to help students recognize that uncertainty is an ordinary part of science-in-the-making. They need to appreciate the lively dynamics of science-in-progress. Resolving uncertainties takes work, and it does not happen overnight.

Science teachers should also explain how and why scientific consensus is not a process of collective self-interest or groupthink, as some naysayers purport. Scientists earn credit for exposing past errors, while making revelatory new discoveries. The rewards for conformity are limited. Indeed, reciprocal criticism is the norm (Ziman, 1968). Nor is the discourse just a political free-for-all. Evidence and expertise are essential currencies in shaping acceptance by others. Investigators must frequently go back to the lab or field to collect additional data that will address alternate points of view and, ultimately, persuade their colleagues. Consensus in science is not easy. It is hard won. This is why scientific consensus can be considered so trustworthy and proves so resilient over time.

Our chief concern, however, is how scientific information reaches individuals, not just how it is produced or validated (Figure 1). What is the essential know-how for navigating the treacherous ocean of information now available on the internet and social media? In our report, we include some sample lessons, highlighting a set of basic heuristics that can benefit all students. They echo the methods of professional fact-checkers (Neuvonen, Kivinen & Salo, 2018). We argue that when individuals encounter unfamiliar websites or receive tweets (or worse, retweets) from remote sources, they should begin by "taking bearings." Like an experienced navigator, they ought to ask "where exactly am I?" They should open new tabs in their web browser and research the credibility of the author or sponsor — a technique known as lateral reading (Wineburg, et al., 2021). This leverages the very power of the internet against those who would seek to abuse it. As a foundation, students will need to be familiar with a few trustworthy, independent benchmarks, such as professional scientific institutions, established fact-checkers, and veteran science journalists.

Everyone can benefit from science — but only if they can access reliable scientific information. For typical consumers and citizens, understanding a set of scientific concepts or practices acquired through formal education will be of minimal help. Rather, the science that matters most to their personal choices and to public decision-making will most likely be new, complex, and possibly incomplete. Moreover, it will be mediated through second-hand reports. For the information to be useful, the critical question will be whether the source at hand can be trusted. Lessons in science media literacy are essential. Our full report, which we have only summarized in brief here, provides the rationales and guidelines for meeting this urgent challenge to science in the public domain and to supporting the informed discourse that sustains our democratic societies.

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Figure 1. The pathway of scientific information "from test tubes to YouTube." Shaded area represents scope of current curricula aimed at developing "marginal insiders." The remainder indicates competencies required to be a "competent outsider": (a) understanding the social practices of developing a consensus within the expert scientific community; and (b) assessing the credibility and expertise of sources of scientific claims in the public media, in order to differentiate reports of the scientific consensus from misinformation ("science-in-the-wild").