Understanding and Trusting Science

MATTHEW H. SLATER, JOANNA K. HUXSTER, JULIA E. BRESTICKER

(under review)

Science communication via testimony requires a certain level of trust. But in the context of ideologically-entangled scientific issues, trust is in short supply — particularly when the issues are politically "entangled". In such cases, cultural values are better predictors than scientific literacy for whether agents trust the publicly-directed claims of the scientific community. In this paper, we argue that the most popular way of thinking about scientific literacy — as knowledge of particular scientific facts or concepts — ought to give way to a second-order understanding of science as a process as a more important notion.

1. Introduction

The state of scientific literacy in America and in other developed nations has been an issue of concern for many decades now (Miller 1983, 2004; Bodmer 1985; OECD 2007). More recently, a palpable anti-science sentiment has become more prominent (McCright and Dunlap 2011; Kahan 2015). This is reflected, in part, by the fact that large portions of the public remain intransigent with respect to their acceptance of policy-relevant science, such as that concerning the risks of anthropogenic climate change (Leiserowitz *et al.* 2016). Given the amount of attention that scientific education and communication have received in the intervening decades, these facts may seem a little surprising. Why have these concerted efforts failed to bring about better outcomes?

A number of plausible explanations could be cited — from the persistence of problematic models of science communication to the increasing prominence of well-funded anti-science groups (Dunlap and McCright 2010, 2011; Brulle 2014). And while we believe that these are indeed relevant, we take a somewhat different focus in this essay: asking whether we science educators and communicators (among whose expansive ranks we count many in the STS community[1]) have been aiming for quite the right goal when it comes to the scientific literacy of the public.

Indeed, it is surprising that philosophers of science and epistemologists in particular have had little to say on this topic (as they have had rather little to say to each other). And while this is not the right forum for a full hearing on the question of how we should conceptualize 'scientific literacy' or 'the public understanding of science' (let alone how to bring about such goods), we wish to sketch a proposal that places greater emphasis on what we refer to as the Social Structure of Science (SSS). We argue that there are theoretical grounds for believing that a lay public with greater understanding of such aspects of science will be better positioned to recognize occasions on which the scientific community is appropriately regarded as a source of epistemic authority.

Before offering this conception and arguing for its merits (§4), we offer a basic framework for

[1] Among whom we also include, of course, historians and philosophers of science.

formulating and evaluating conceptions of scientific literacy (§2–3), arguing that an important desideratum for any credible conception is its enabling of certain social epistemic characteristics of the lay public: primarily their ability to recognize and accord appropriate trust to robust consensus messages of the scientific community. We argue that prominent conceptions of scientific literacy are deficient in this respect. §5 offers some suggestions for how STS researchers might profitably contribute to the interdisciplinary effort to promote greater scientific literacy.

2. A Framework for Conceptualizing Scientific Literacy

Very plausibly, scientific literacy centrally involves a certain kind of epistemic success — a relation between a subject(s) and object(s). Thus a straightforward approach to scientific literacy specifies this relation (or relations) and its relata, leading to three questions: (1) What is the *content* of this success? That is, what facts or theories are to be truly believed (or known or understood or …) in order for one to count as being scientifically literate? (2) Who or what are supposed to be the primary subjects of this success? Is it every individual member of the public, only some, the public as a whole (or some other option)? (3) What is the proper epistemic relation between the agent(s) and the content? These are the three pillars (if you will) of our framework. Further pillars might be added to accommodate non-epistemic dimensions — e.g., affective or practical — of a conception of scientific literacy. We shall assume in this context that the epistemic can sufficiently subsume these aspects, however. Let us say a bit more about these pillars:

Content / Subject Matter

In asking after the *content* of scientific literacy, we are asking what is to be grasped or known (or …?) by the scientifically literate. There will presumably be a contextual or developmental element in any plausible answer to the above. This is characteristic of educational policy documents aiming to outline programs for science education (OECD 2007; NRC 2012; PISA 2012; Snow and Dibner 2016). Suppose we are talking about the non-scientifically-trained laity: what content should they possess? One obvious suggestion to which we will return focuses on basic scientific concepts and theories: e.g., such information as whether the earth orbits the sun, that objects are composed of things called atoms which combine to form molecules, and so on. Another common answer to the content question emphasizes concepts from the so-called "Nature of Science" (NoS): e.g., *theory*, *hypothesis*, *confirmation*, and perhaps other basic methodological ideas in this ballpark.

The Possessors of Scientific Literacy

Who are "possessors" of scientific literacy? The most straightforward answer is that they are simply individual people — members of the public who are not scientists (henceforth, "the lay public" or "laity"). But other possibilities are worth considering. First, one might wish to distinguish between different segments of the public in a way that's relevant to the context relativity mentioned above.

Second, we may wish to countenance *communities* (or other ensembles of epistemic agents) as the relevant possessors of scientific literacy. In a recent report of the National Academy of Sciences (Snow and Dibner 2016), the Committee on Science Literacy and Public Perception of Science acknowledged the concept of "community-level science literacy" as the idea that certain knowledge or abilities might be possessed not by individuals but by groups of people (cf. Bird 2010). We leave this interesting nuance unexplored in this paper.

The Epistemic Relation

Suppose now that we have in hand a conception of both the content of scientific literacy and the possessors of that concept. We have, in other words, two relata. What is the *epistemic relationship* between them? This is a question that seems to us surprisingly neglected in the existing literature. There are a number of straightforward options here: one might *know* something about science, one might merely truly believe it (perhaps without reasons good enough to count as knowing), or one might *understand* something about science. What is the relationship we should favor in our conception of scientific literacy? The answer might seem obvious: the reason why *literacy* has seemed an apt label for this quality stems in part from the comparison with grasping — or *understanding* — a language (Norris and Phillips 2003). One is not literate in, one does not understand, a foreign language when one merely knows what some words mean; literacy is more flexible and holistic, expressing a kind of grasp or mastery. In the epistemic context, it involves seeing how things "hang together" (Zagzebski 2001; Elgin 2006; Grimm 2012). The fact that "scientific literacy" is usually discussed under the rubric of "public *understanding* of science" in Europe further corroborates this suggestion (Laugksch 2000, 71).

We are sympathetic to this line of thought, but it is too simple as stated (and thus the question deserves a place in our conceptual framework). First, as a matter of practice, scientific literacy is often treated as boiling down to agents' knowledge (indeed, their mere true belief) of some facts. Sometimes this occurs despite assertions or intimations that understanding is the relevant goal.[2] Second, even if understanding takes a prominent role in a conception of scientific literacy, knowledge may yet be involved. Whatever the precise relationship between knowledge and understanding (Kvanvig 2003; Grimm 2006), it is credible that an understanding of a subject matter often incorporates various bits of propositional knowledge. Even the richest understandings are ultimately based to some extent on the say-so of others (Coady 1992; Lipton 1998; Goldman 2001). Moreover, a conception of scientific literacy might also involve a certain range of rote knowledge — even of propositions that are not themselves understood in any deep way — in addition to a deeper

[2] Our previous research has shown that epistemic success terms like 'knowledge' and 'understanding' are often left undistinguished from one another or even conflated in the scholarly literature on scientific literacy and the public understanding of science [REFERENCE OMITTED FOR BLIND REVIEW].

understanding of other matters. Thus, a conception of scientific literacy may plausibly involve a range of different epistemic relations between agents and content.

3. Evaluating Conceptions of Scientific Literacy

Let us turn now to the question of how one might evaluate conceptions of scientific literacy in the context of this framework. For each of the above "framework questions," there will be a corresponding justificatory question of why a given answer is preferable to another. Some of these questions are more difficult and contentious than others, some having received much discussion and which are still hotly debated, while others have not received much attention at all.

We can think of potential answers to the justificatory questions as falling into two basic categories: practical and intrinsic. On the latter count, perhaps scientific literacy (somehow conceived) should be seen as intrinsically valuable to its possessors. As Michael Strevens put it at the outset of his book on scientific explanation, "If science provides anything of intrinsic value, it is explanation. Prediction and control are useful…but when science is pursued as an end rather than as a means, it is for the sake of understanding — the moment when a small, temporary being reaches out to touch the universe and makes contact" (2008, 3). While we find this thought compelling, we leave aside the question of intrinsic justification for favoring a conception of scientific literacy.

A natural way of approaching the practical justification (or criticism) of an approach to scientific literacy is goal-oriented: how does it contribute to certain relevant ends that are deemed important? This in turn raises a further set of questions of value — whose ends? why those? — that would need to be defined as the relevant ends. Once again, these may exhibit a contextual aspect; pluralism and relativity to social role may also be expected to apply. We take no position on these questions here.

Let us put the above frameworks to more concrete use by considering some examples. This discussion — which is necessarily partial[3] — will ultimately motivate our outline conception of scientific literacy in the last two sections. Consider what might be called a "foundational conception" of scientific literacy that focuses on an agent's grasp of *basic scientific facts and concepts*, such as whether the earth orbits the sun or what lasers do (Snow and Dibner 2016, 15). As noted above, additional content falling under the heading of the "Nature of Science" (NoS) are often added to this foundation: one might include, for example, a range of conceptual and methodological aspects of science such what scientific theories are, their status as revisable and provisional, how they may be tested and confirmed, and so on.

Such a package loosely corresponds to Miller's conception of science literacy. He wrote that the scientifically literate should possess (1) "a basic vocabulary of scientific terms and constructs" and (2)

[3] For a more comprehensive historically-oriented survey of conceptions, see Laugksch (2000); Duschl (2013) provides a philosophically sophisticated discussion of different ways of representing the Nature of Science. Due to space limitations, our focus will be on the Content question over the other questions.

"a general understanding of the nature of scientific inquiry…sufficient to read and comprehend the Tuesday science section of *The New York Times*" (2004, 273–274). Note how Miller essentially defines the content of scientific literacy in terms of its ability to bring about some ability — in this case, the ability to digest a certain range of information.

Defenders of a stronger focus on NoS content do something similar. Why, after all, might it be useful for members of the lay public to know how hypotheses are tested or how a randomized controlled trial works? The usual answer is that this is supposed to equip the layperson to essentially behave like scientists themselves — including determining whether a given scientific claim can be relied upon (OECD 2007, 34). Here we anticipate a connection with Miller's justification: perhaps one thing that is practically useful about being able to competently read science reporting is the ability to know when that reporting is reliable or whether the claims themselves are plausible. This suggests that the epistemic relation centrally in question in these conceptions is *understanding*. As Elgin notes, understanding involves "an adeptness in using the information one has, not merely an appreciation that things are so" (2007, 35; see also Grimm 2012; Zagzebski 2001, 110–111).

The problem with these suggestions is the implausibility that members of the lay public would actually be able to use this very basic content to evaluate scientific claims.[4] As Stephen Jay Gould pointed out in a (1999) editorial in *Science*, this is something that other *scientists* can barely manage nowadays; he wrote that science had then "reached the point where most technical literature not only falls outside the possibility of public comprehension but also…outside our own competence in scientific disciplines far removed from our personal expertise" (cf. Shamos 1995). And note that Gould has in mind only *comprehension*, not evaluation. Nearly twenty years later, this situation has only become more dramatic.

The practical reality is that the public is not — and likely will never be — in a position to vet scientific claims themselves (Anderson 2011, 144; Jasanoff 2014, 24). They must instead rely on the division of epistemic labor and *trust* the scientific community as a source of intellectual authority, relying on the community itself to vet its own deliverances. This latter claim needs to be nuanced if it is to be plausible; what, for instance, is the force of the 'must'? What is the scope and strength of this trust? We address these questions in other work (REF SUPPRESSED, see also Zagzebski 2012; Keren 2007, 2014). For now, let us assume a plausibly conservative general gloss on trust of, and/or deference to, scientific authority. Many, we submit, would find it plausible that the attitudes and abilities that enable such trust are an important desideratum for a conception of scientific literacy. This is shown, in part, by the fact that the public's deviation from scientific consensus is often treated as evidence of the widespread *lack* of scientific literacy.

Supposing we accept this desideratum as important, recent public opinion research should give us further pause concerning the worth (or sufficiency) of the foundational conception of scientific

[4] This is not to deny that there won't be *some* occasions on which an understanding of basic scientific facts and methods will not allow laypeople to reject some theories as ill-defended or pseudoscientific.

literacy discussed above. In a series of papers, Dan Kahan and colleagues have shown that higher levels of scientific literacy — understood as comprising basic scientific facts and methods[5] — do not correlate with higher levels of deference to scientific authority for socially controversial subjects: despite expectations "[a]s respondents' science-literacy scores increased, concern with climate change decreased slightly ($r = -0.05$, $P = 0.05$)" (Kahan *et al.* 2012, 732). Moreover, this effect was greater for those who identify with the political right; the more "scientifically literate" right-leaners are, the less likely they are to accept the scientific consensus about the causes and risks of climate change (733).

One might understandably object that such results should be regarded as inert with respect to our promotion of the foundational conception(s) of scientific literacy. The present social context for science is politically and culturally charged in a variety of ways. As has been carefully documented by historians and social scientists, a great deal of effort has been expended in recent decades by individuals and organized groups (many industry-funded) to cloud the science on important issues or undercut the trustworthiness of the scientific community at large (Diethelm and McKee 2009; Torcello 2016; Smith and Leiserowitz 2012; Brulle 2014; McCright *et al.* 2016; Dunlap and McCright 2011, 2010; Oreskes and Conway 2010). In contemporary society, such efforts are facilitated by what might be euphemistically dubbed "the democratization of information flow" via social media, which enables the establishment of political/ideological "echo-chambers" (Takahashi and Tandoc 2016; Jasny *et al.* 2015; Carmichael *et al.* 2017; Bernauer 2013; Leiserowitz *et al.* 2013). These phenomena have been thoroughly explored in the case of climate science where, despite a near perfect consensus among climate scientists (and the scientific community at large), major portions of the public remain (Leiserowitz *et al.* 2016).

Thus, as Anderson suggests, perhaps what is missing from the foundational conception is not so much *ability* as inclination; she writes: "While citizens have the capacity to reliably judge trustworthiness, many Americans appear ill-disposed to do so" (2011, 145); perhaps, then, we should focus on changing "the social conditions" that influence the public's *attitudes* about science.[6] We shall suggest in the next section, however, that a somewhat different approach to NoS-style conceptions of scientific literacy may be relevant to laypersons' trust of the scientific community.[7]

[5] Kahan calls his measurement scale "Ordinary Science Intelligence" (OSI), which incorporates questions from the National Science Board's 2010 Science and Engineering Indicators as well as some common numeracy and cognitive reflection items (see Kahan 2016, for discussion and validation).

[6] This presumes, of course, a separation between the epistemic and affective dimensions of scientific literacy that may in real life be quite a bit more blurry. We take no position in this context on how we should respond to this blurriness.

[7] In this effort, space constraints force us to focus on the content pillar of our conception; there is more to say about both the agent and relation pillars that must wait for another occasion.

4. Understanding the Social Structure of Science

Anderson (2011) argues that many of the members of the lay public have the capacity to judge the trustworthiness of scientific authorities, including both individual scientists and the scientific community as a whole: "second-order judgments [of expert trustworthiness] address whose testimony regarding scientific matters should be trusted, and whether the trustworthy agree on the issue in question" (145). This involves making three judgments about authorities' (1) expertise (or competence), (2) honesty, and (3) epistemic responsibility (145–6). Anderson's framework on expert trust thus dovetails closely with work in epistemology on testimony, which, as she and others points out, is ubiquitous in our epistemic lives (Hardwig 1985; Coady 1992; Lipton 1998; Lackey 2008). She amply demonstrates that the resources for making such judgments are available to anyone who can conduct a web search. Again, it comes to the social–cultural conditions — and resultant attitudinal dispositions — that *incline* one to expend the effort to identify appropriate authorities and instances of consensus (Almassi 2012)[REF OMITTED].

We think we can say more on the epistemic side, however. Focus on the lay public's trust of the scientific community (in cases where there is a strong consensus), rather than on individual scientists [REF OMITTED]. It is one thing to be able to recognize cases of scientific consensus. It is quite another to recognize the epistemic significance of such consensus. Why is it that this consensus should interest us? What *kind* of consensus is important (Odenbaugh 2012; Miller 2013)? What is it about the scientific community makes this so? We submit that these are matters for which that public's understanding of science could be improved. The suggestion is that improving them may result in greater willingness to seek and defer to scientific consensus where it exists.

It is clear enough in individual cases of testimony that knowing things about how a potential source thinks, what their motivations may well be, and so on, can be relevant to judgments about the questions that Anderson identifies as important. You will probably be more inclined to trust a source about the quality of a particular car model if you know that they would not benefit from your purchasing the car in question. You can determine this, of course, by finding out whether they are employed by the relevant company or work as an agent for that company in some other way (e.g., as an advertiser). But consider that seeing these facts as relevant proxies for the question of influence (and thus honesty) depends on having a certain amount of background knowledge concerning how individuals might benefit from your purchasing decisions. We sideline such knowledge in talking about this sort of case because it is so obvious and so clearly shared.

The relevant background knowledge in the context of science is considerably less obvious and certainly not widely shared — especially when it comes to the question of scientific consensus, but also in other aspects of judging scientific authority. Consider Anderson's four signs of concern for judging epistemic responsibility: "Evasion of peer-review", "Dialogic irrationality", "Advancing crackpot theories", and "Voluntarily associating with crackpots" (2011, 147–148). However, our previous research (and anecdotal experience) suggests that the concept of peer-review is rarely understood; most members of the lay public, we suspect, do not know that such a process exists (let alone understand the role it plays in the scientific enterprise or avoid common misconceptions about it if they do — e.g., that it is, for the most part blind and unpaid). Moreover, when it comes to the avoidance of "crackpot theories", many members of the public harbor a model of the scientific enterprise that regards such labels as *ad hominems*. This was expressed in a much-quoted passage from Michael Crichton's 2003 speech at Caltech:

> Let's be clear: the work of science has nothing whatever to do with consensus. Consensus is the business of politics. Science, on the contrary, requires only one investigator who happens to be right, which means that he or she has results that are verifiable by reference to the real world. In science consensus is irrelevant. What is relevant is reproducible results. The greatest scientists in history are great precisely because they broke with the consensus.[8]

Many members of the lay public seem to share something like this individualistic model of science — stemming, one can't help but think, from the celebration of individual "Great Men of Science" such as Galileo, Darwin, and Einstein who, it is believed, represented lone voices against an overly dogmatic community of science.

Historians and philosophers of science of course understand that this is a vast oversimplification and that science has changed dramatically in the intervening decades (or centuries). The social structure of science is complex, nuanced, and still contested by researchers but, we argue, represents an aspect of scientific literacy that is both lacking in the lay public and not well represented in measurement instruments for scientific literacy or our thinking about the NoS.[9] But such understanding — for example, of the sense in which scientists are simultaneously competing and collaborating with one another (Kitcher 1990; Kuhn 1962; Strevens 2003; Oreskes and Conway 2010, 272–273) — is, we believe, conceptually important to the recognition of the epistemic significance of scientific consensus and, in general, the recognition of epistemic responsibility.

Why so? A fuller argument must wait for another occasion, but the basic justification is the following. First, we need to recognize that the dominant lay model of science is individualistic. This has some immediate consequences for the public's trust of scientists. Regarding a source as epistemically trustworthy involves seeing that source as being (a) in a position to know and (b) being apt to honestly represent the information in question (Lipton 1998). However, recent research has shown that individual scientists are generally judged by the public as being "competent but cold" (Fiske and Dupree 2014, 13593) — that is, they are generally seen as in a position to know but not

---

[8] A stable and authoritative URL for a transcript of this speech seems to be difficult to come by — one transcript is available at http://stephenschneider.stanford.edu/Publications/PDF_Papers/Crichton2003.pdf — but readers may search for "Aliens Cause Global Warming".

[9] Lombrozo *et al.*'s (2008) instrument for assessing understanding of the nature of science includes two items relevant to the scientific community: "The scientific community is essential to the process and progress of science," and "Unlike many other professions, science is almost always a solitary endeavor" (292).

necessarily to be trusted. After all, individual scientists have been guilty of misconduct of various forms; they are sometimes biased or "pig-headed"; they are, after all, human. Part of the dynamic here, we suggest, is driven by the ways in which science is reported in the media. Journalism, as one seasoned journalist put it to us, is "event-driven"; and reportable "events" in science are typically announcements by individual researchers or labs ("A new study shows that…."). This plausibly contributes to the common perception that "science is always changing its mind", as when a second study casts doubt on the first (and so on). This trickle of information makes it difficult for the laity to perceive the bigger picture — specifically where the consensus lies.

Second, when we move from an individualistic model of science to a communitarian model, one can begin to appreciate how certain forms of consensus (and consensus-forming processes) ameliorate the honesty question (b) above. Less important than trusting scientists as individual testifiers is deferring to the scientific community as a whole — in a sense, treating the *group* as a source of testimony (Odenbaugh 2012). As Roberts and Wood aptly put it: "Kuhn alerts [us] that much that is salutary in the intellectual life is guided and channeled by institutions and social pressures that transcend the character of individuals, correcting for vice and supporting virtues. Aberrations like David Irving and Henry Casaubon are often forestalled or made less pernicious by processes of peer review" (2007, 201–202). But it is not only peer-review and the various vetting processes that are significant in Kuhn's view. It is the fact that, as a loose assemblage of various communities, scientists are at once deeply collaborative and in competition with one another. This is part of the reason why science is seen by insiders as "self-correcting": bad actors are excommunicated, crackpot or badly supported theories are ignored, fruitful theories are pursued until such point as their anomalies encourage certain practitioners to forge out on their own to explore new frameworks. When this haphazard assemblage of more or less independent agents speaks with one voice, prima facie, we ought to listen.

Thus, given that we believe that the public's *ex ante* trust of the scientific community (when speaking with a consensus voice) is warranted and an important dispositional goal for technologically developed democracies like our own, we submit that a conception of scientific literacy that enables and encourages such a disposition is an attractive candidate for a core conception of scientific literacy. We have argued that an understanding of science as a social enterprise should be expected to bring about these dispositions. For this approach both coheres with recent empirical research on consensus messaging serving as "gateway belief," even for polarizing science (van der Linden *et al.* 2014, 2015) and to a certain extent sidesteps some of the more difficult questions about how expertise should be detected, particularly on contested issues (Goldman 2001; Pettit 2006; Brossard and Nisbet 2006; Almassi 2012; Fiske 2012).

5. Next Steps

Our efforts in this paper have obviously been preliminary; more work is needed. But let us sum up before offering some parting suggestions for where we can go next. First, we offered a way of thinking about different conceptions of scientific literacy, arguing that greater attention to the epistemic properties and the correlative abilities stemming from a given conception is needed. We also argued that a plausible desideratum — ability and inclination to identify and trust robust consensus messages from science — is not credibly met by popular conceptions. Moreover, other desiderata associated with such conceptions are probably not meetable. Finally, we proposed that a greater focus on the social structure of science in a conception of scientific literacy would do better to meet our proposed core desideratum.

This hypothesis stands in need of empirical testing: is it indeed the case that members of the lay public with a good grasp of the social structure of science be more willing to trust consensus messages from the scientific community? Will such an inclination translate to ideologically-entangled issues such as climate change or the safety of childhood vaccines? We are currently pursuing this research;[10] but we hope that others — particularly STS researchers — will also contribute to this broad effort. We conclude by identifying what we take to be several fruitful avenues through which STS (and related) scholars might contribute to this effort.

First, STS scholars can contribute to the effort to characterize a general, consensus picture of what aspects of the social structure of science are relevant to the public's treatment of the scientific community as a source of epistemic authority. This includes both descriptive and normative aspects and requires addressing a highly non-trivial question of the appropriate level of granularity and idealization for how this picture might be described in the context of science education and communication.

Second, and relatedly, STS scholars can contribute to efforts to develop better measurement instruments and frameworks for studying the public's understanding of and trust of science.

Third, epistemologists can provide insight about both the epistemic relation connecting the public to a range of scientific content as well as how the SSS and other aspects of scientific literacy might be successfully communicated — e.g., through education or public messaging and engagement initiatives. If our suspicion that a robust conception of understanding is relevant to scientific literacy, we will need better models of how understanding (in addition to knowledge) may be transmitted (or produced) by testimony or other means.

Finally (but not exhaustively), philosophers can contribute to the project Anderson identified of changing the social conditions under which scientific issues become entangled and recognition of scientific authority becomes problematic.

[10] Our preliminary data suggests that better performance on what we call the "Social Structure of Science Index" (SSSI) correlates with a reduction in political polarization concerning consensus messaging about anthropogenic climate change and correlates more strongly than other measures of scientific literacy (e.g., Kahan's OSI) with measures of one's trust of science in general [REF OMITTED].

REFERENCES

Almassi, Ben (2012) "Climate Change, Epistemic Trust, and Expert Trustworthiness," *Ethics & the Environment* 17 (2):29–49.

Anderson, Elizabeth (2011) "Democracy, Public Policy, and Lay Assessments of Scientific Testimony," *Episteme* 8 (2):144–164.

Bernauer, Thomas (2013) "Climate Change Politics," *Annual Review of Political Science* 16:421–448.

Bird, Alexander (2010) "Social Knowing: The Social Sense of 'Scientific Knowledge'," *Philosophical Perspectives* 24:23–56.

Bodmer, Walter (1985) *The Public Understanding of Science: Report of a Royal Society Ad Hoc Group Endorsed by the Council of the Royal Society*. London: The Royal Society; available online: http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/1985/10700.pdf.

Brossard, Dominique, and Matthew C. Nisbet (2006) "Deference to Scientific Authority Among a Low Information Public: Understanding U.S. Opinion on Agricultural Biotechnology," *International Journal of Public Opinion Research* 19 (1):24–52.

Brulle, Robert J. (2014) "Institutionalizing Delay: Foundation Funding and the Creation of U.S. Climate Change Counter-Movement Organizations," *Climatic Change* 122:681–694.

Carmichael, Jason T., Robert J. Brulle, and Joanna K. Huxster (2017) "The Great Divide: Understanding the Role of Media and Other Drivers of the Partisan Divide in Public Concern Over Climate Change in the USA, 2001–2014," *Climatic Change* DOI: 10.1007/s10584-017-1908-1.

Coady, C.A.J. (1992) *Testimony*. Oxford: Oxford University Press.

Diethelm, Pascal, and Martin McKee (2009) "Denialism: What Is It and How Should Scientists Respond?," *European Journal of Public Health* 19 (1):2–4.

Dunlap, Riley E., and Aaron M. McCright (2010) "Climate Change Denial: Sources, Actors and Strategies," in Constance Lever-Tracy (ed.), *Routledge Handbook of Climate Change and Society*. London: Routledge.

Dunlap, Riley E., and Aaron M. McCright (2011) "Organized Climate Change Denial," in John S. Dryzek, Richard B. Norgaard and David Schlosberg (eds.), *The Oxford Handbook of Climate Change and Society*. Oxford: Oxford University Press.

Duschl, Richard A., and Richard Grandy (2013) "Two Views About Explicitly Teaching Nature of Science," *Science & Education* 22 (9):2109–2139.

Elgin, C. Z. (2006) "From Knowledge to Understanding," in Stephen Hetherington (ed.), *Epistemology Futures*. Oxford: Oxford University Press.

Elgin, C. Z. (2007) "Understanding and the Facts," *Philosophical Studies* 32:33–42.

Fiske, Susan T. (2012) "Managing Ambivalent Prejudices: Smart-but-Cold and Warm-but-Dumb Stereotypes," *The Annals of the American Academy of Political and Social Science* 639:33–48.

Fiske, Susan T., and Cydney Dupree (2014) "Gaining Trust as Well as Respect In Communicating to Motivated Audiences about Science Topics," *Proceedings of the National Academy of Science* 111 (4):13593–13597.

Goldman, Alvin (2001) "Experts: Which Ones Should You Trust?," *Philosophy and Phenomenological Research* LXIII (1):85–110.

Gould, Stephen Jay (1999) "Take Another Look," *Science* 286 (5441):899.

Grimm, Stephen (2006) "Is Understanding a Species of Knowledge," *British Journal for the Philosophy of Science* 57:515–535.

Grimm, Stephen (2012) "The Value of Understanding," *Philosophy Compass* 7 (2):103–117.

Hardwig, John (1985) “Epistemic Dependence,” *The Journal of Philosophy* 82 (7):335–349.

Jasanoff, Sheila (2014) “A Mirror for Science,” *Public Understanding of Science* 23:21–26.

Jasny, Lorien, Joseph Waggle, and Dana R. Fisher (2015) “An Empirical Examination of Echo Chambers in US Climate Policy Networks,” *Nature Climate Change* 5:782–786.

Kahan, Dan M. (2015) “What is the ‘Science of Science Communication’?,” *Journal of Science Communication* 14 (3):1–12.

Kahan, Dan M. (2016) “‘Ordinary Science Intelligence’: A Science-Comprehension Measure for Study of Risk and Science Communication, With Notes On Evolution And Climate Change,” *Journal of Risk Research* DOI: 10.1080/13669877.2016.1148067.

Kahan, Dan M., Maggie Wittlin, D. Braman, Paul Slovic, Ellen Peters, Lisa Larrimore Ouellette, and Gregory Mandel (2012) “The Polarizing Impact of Science Literacy and Numeracy on Perceived Climate Change Risks,” *Nature Climate Change* 2:732–735.

Keren, Arnon (2007) “Epistemic Authority, Testimony and the Transmission of Knowledge,” *Episteme* 4 (3):368–381.

Keren, Arnon (2014) “Trust and Belief: a Preemptive Reasons Account,” *Synthese* 191:2593–2615.

Kitcher, Philip (1990) “The Division of Cognitive Labor,” *Journal of Philosophy* 87 (1):5–22.

Kuhn, Thomas (1962) *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Kvanvig, Jonathan (2003) *The Value of Knowledge and the Pursuit of Understanding*. Cambridge: Cambridge University Press.

Lackey, Jennifer (2008) *Learning from Words*. Oxford: Oxford University Press.

Laugksch, Rüdiger C. (2000) “Scientific literacy: A Conceptual Overview,” *Science education* 84:71–94.

Leiserowitz, Anthony A., Edward W. Maibach, Connie Roser-Renouf, Nicholas Smith, and Erica Dawson (2013) “Climategate, Public Opinion, and the Loss of Trust,” *American Behavioral Scientist* 57 (6):818–837.

Leiserowitz, Anthony, Edward Maibach, Connie Roser-Renouf, Geoff Feinberg, and Seth Rosenthal (2016) *Climate Change in the American Mind: March, 2016*. Yale University and George Mason University. New Haven, CT: Yale Program on Climate Change Communication.

Lipton, Peter (1998) “The Epistemology of Testimony,” *Studies in the History and Philosophy of Science* 29 (1):1–31.

Lombrozo, Tania, Anastasia Thanukos, and Michael Weisberg (2008) “The Importance of Understanding the Nature of Science for Accepting Evolution,” *Evolution: Education and Outreach* 1:290–298.

McCright, Aaron M., Meghan Charters, Katherine Dentzman, and Thomas Dietz (2016) “Examining the Effectiveness of Climate Change Frames in the Face of a Climate Change Denial Counter-Frame,” *Topics in Cognitive Science* 8:76–97.

McCright, Aaron M., and Riley E. Dunlap (2011) “The Politicization of Climate Change and Polarization in the American Public’s Views of Global Warming, 2001–2010,” *The Sociological Quarterly* 52:155–194.

Miller, Boaz (2013) “When is Consensus Knowledge Based? Distinguishing Shared Knowledge From Mere Agreement,” *Synthese* 190:1293–1316.

Miller, Jon D. (1983) “Scientific Literacy: A Conceptual and Empirical Review,” *Daedalus* 112:29–48.

Miller, Jon D. (2004) “Public Understanding of, and Attitudes toward, Scientific Research: What We Know and What We Need to Know,” *Public Understanding of Science* 13:273-294.

Norris, Stephen P., and Linda M. Phillips (2003) “How Literacy in its Fundamental Sense is Central to Scientific Literacy,” *Science Education* 87:224–240.

NRC, The National Research Council (2012) *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.

Odenbaugh, Jay (2012) “Climate, Consensus, and Contrarians,” in William P. Kabasenche, Michael O’Rourke and Matthew H. Slater (eds.), *The Environment: Philosophy, Science, and Ethics*. Cambridge: MIT Press.

OECD (2007) *PISA 2006: Science Competencies for Tomorrow’s World*. Vol. 1: Analysis. Paris: Organisation for Economic Co-operation and Development.

Oreskes, Naomi, and Erik M. Conway (2010) *Merchants of Doubt*. New York: Bloomsbury Press.

Pettit, Philip (2006) “When to Defer to Majority Testimony – And When Not,” *Analysis* 66 (3):179–187.

PISA (2012) *Results from PISA 2012: United States*. Paris: Organisation for Economic Co-operation and Development.

Roberts, Robert C., and W. Jay Wood (2007) *Intellectual Virtues: An Essay in Regulative Epistemology*. Oxford: Oxford University Press.

Shamos, Morris H. (1995) *The Myth of Scientific Literacy*. New Brunswick: Rutgers University Press.

Smith, Nicholas, and Anthony Leiserowitz (2012) “The Rise of Global Warming Skepticism: Exploring Affective Image Associations in the United States Over Time,” *Risk Analysis* 32 (6):1021–1032.

Snow, Catherine E., and Kenne A. Dibner, eds. (2016) *Science Literacy: Concepts, Contexts, and Consequences*. Washington, D.C.: The National Academies Press.

Strevens, Michael (2003) “The Role of the Priority Rule in Science,” *The Journal of Philosophy* 100 (2):55–79.

Strevens, Michael (2008) *Depth*. Cambridge: Harvard University Press.

Takahashi, Bruno, and Edson C. Tandoc (2016) “Media Sources, Credibility, and Perceptions of Science: Learning About How People Learn About Science,” *Public Understanding of Science* 25 (6):674–690.

Torcello, Lawrence (2016) “The Ethics of Belief, Cognition, and Climate Change Pseudoskepticism: Implications for Public Discourse,” *Topics in Cognitive Science* 8:19–48.

van der Linden, Sander L., Anthony A. Leiserowitz, Geoffrey D. Feinberg, and Edward W. Maibach (2014) “How To Communicate The Scientific Consensus on Climate Change: Plain Facts, Pie Charts or Metaphors?,” *Climatic Change* 126 (1–2):255–262.

van der Linden, Sander L., Anthony A. Leiserowitz, Geoffrey D. Feinberg, and Edward W. Maibach (2015) “The Scientific Consensus on Climate Change as a Gateway Belief: Experimental Evidence,” *PLOS One* 10 (2):e0118489.

Zagzebski, Linda T. (2001) “Recovering Understanding,” in Mathias Steup (ed.), *Knowledge, Truth, and Duty: Essays on Epistemic Justification, Responsibility, and Virtue*. Oxford: Oxford University Press.

Zagzebski, Linda T. (2012) *Epistemic Authority: A Theory of Trust, Authority, and Autonomy in Belief*. Oxford: Oxford University Press.