Understanding and Trusting Science

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(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 dismissal 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 factors in our present difficulties, our focus in this essay will be to raise (again) the question of whether we have our priorities for scientific literacy in order — and whether a somewhat different approach might mitigate some of the damaging social–political dynamics that make the consensus gaps we observe so recalcitrant.

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). Our aims in this essay are more programmatic. First, we wish to offer a framework for formulating and evaluating different conceptions of scientific literacy (§§2–3); second, having briefly considered the outlines of a popular conception, finding it wanting when it comes to enabling its possessors to appreciate the epistemic significance of scientific consensus, we will outline a conception that emphasizes certain social dimensions of the scientific enterprise that seem to us undervalued in most discussions of scientific literacy. We call this approach the Social Structure of

Science (SSS) conception of Scientific Literacy and argue on conceptual / epistemic grounds that its possessors will be better positioned to recognize occasions on which the scientific community is appropriately regarded as a source of epistemic authority. To our mind, this makes it an attractive social goal; however, we do not argue here that this variety of scientific literacy is the end-all or universally appropriate minimum standard for the public's grasp of science. Our hope is that this essay will provide STS researchers[1] a useful starting point for engaging in an important and growing area of interdisciplinary research in which their expertise is needed.

2. Varieties of Scientific Literacy

What is scientific literacy and what is it for? Such questions resist univocal answer. This is not overly surprising. Consider other forms of practical competence or epistemic success. What does it mean to be *technologically literate*, for example? Presumably the answer to this question will depend on the context in which judgments about technological literacy are to be made. What is expected and valued will depend on what standards are in play. Standards in turn depend (in part) on goals, which are themselves sensitive to context. Similar comments apply to epistemic competencies. You might say that you understand how a car engine works — unless you were employed in the front office of the local auto shop, in which context we might be disinclined to attribute understanding lest it engender faulty expectations of your capabilities (Wilkenfeld *et al.* 2016).

This strikes us as a productive light in which to consider Benjamin Shen's much cited (1975) three-fold distinction between Practical, Civic, and Cultural "forms of science literacy". Shen thought that practical science literacy — what he defined as "the possession of the type of scientific and technical know-how that can be immediately put to use to help improve living standards" (265) — was the most important. Today, in the democratic, developed world, many might be inclined to think of "civic science literacy" as carrying as much (if not more) significance. Here he defined the aim as "[enabling] the citizen to…participate more fully in the democratic processes of an increasingly technological society" (266). Cultural science literacy Shen explicated (in shades of Snow 1959) by analogy to the sort of competence and familiarity a scientist or engineer might seek to develop by studying ancient history, poetry, or classic: it is "motivated by a desire to know something about science as a major human achievement; it is to science what music appreciation is

[1] Among whom we include historians, sociologists, and philosophers. We note that it is a little surprising, in particular, that philosophers of science and epistemologists have had little to say on this topic (as indeed they have had rather little to say to each other).

to music. It solves no practical problems directly, but it does help bridge the widening gulf between the scientific and humanistic cultures" (267).

Shen's varieties of scientific literacy are thus functionally defined in terms of what they aim to bring about.[2] He says relatively little about what specifically it takes to satisfy each concept.[3] Many proposals have been offered (and criticized) in the intervening decades (Miller 1983; DeBoer 2000; Laugksch 2000; Thomas and Durant 1987; Snow and Dibner 2016; Miller 2010a; Shamos 1995). Before offering our own proposal for a conception of scientific literacy that we think is worthy of being taken seriously, let us take a step back and consider the form that such proposals may usefully take. Very plausibly, scientific literacy centrally involves a certain kind of epistemic success. We interpret this success expansively, potentially to include such states as propositional knowledge, know-how, understanding, and so on. We are not so expansive, however, to include *affective* states — e.g., taking a certain attitude about some aspect of science. Tempting as this might be, doing so has the effect of making analytic what should remain empirical questions about the connection between one's grasp of science and one's attitudes toward it (Thomas and Durant 1987, 10 make a similar point).

Conceiving of such epistemic states as *relations*, a straightforward approach to scientific literacy will start by specifying this relation (or relations) and its (or their) relata. Our framework thus involves answering three questions:

(1) What epistemic relation(s) are at stake? If scientific literacy is a kind of epistemic success, what kind of success is it?

(2) Who or what are taken 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 *content* of this success? For example, what facts or theories are to be truly believed (or known or understood or …) in order for one to count as being scientifically literate (in the given sense)?

Further components may of course be added to accommodate non-epistemic dimensions of a conception that cannot adequately be captured by (1–2). We shall assume in this paper, however, that the epistemic can sufficiently subsume these aspects.

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[2] For this reason, Norris and Phillips call scientific literacy a "programmatic concept" (2009, 271).

[3] Shen's few gestures towards greater specificity tend themselves to be functionally defined: e.g., "the scientifically literate layman knows how to separate the nontechnical from the technical, the subjective from the objective, and to make full use of scientific expertise without being overwhelmed by it" (1975, 266).

To get a better sense of how answering these questions can generate different conceptions of scientific literacy, let us consider some potential variety to these answers. We take the questions "out of order" to simplify the discussion; we start with (2).

The Possessors of Scientific Literacy

Who are "possessors" of (a variety of) scientific literacy? We can think of this as a question with normative content (as in who is *expected* to possess scientific literacy for the given conception?) or simply as a factual question of what the target of a certain evaluation is. For now, let us stick with the latter interpretation.[4] A straightforward answer is that when we attribute scientific literacy, we attribute it to individual people. For example, when one is asking after the scientific literacy of the American "lay public" it seems that one typically is interested in the scientific literacy of each member of this group.

But other possibilities are worth considering. Instead of focusing on individuals, 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; Ludwig 2014; Miller 2010b). Perhaps we see hints of this thought in Shen's discussion of Practical Science Literacy, where the focus is on a community's access to scientific knowledge "of health, nutrition, and modern agriculture" that could "improve living standards" (1975, 265). We leave this interesting nuance unexplored in this paper and focus henceforth on the scientific literacy of individuals.

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. Here too we should expect 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). Answers here typically include particular pieces of scientific fact (e.g., that the earth orbits the sun or that molecules are composed of atoms), theories (evolution by natural selection, universal gravitation), or concepts (e.g., radiation, genetic inheritance, and so on). Another common answer to

[4] A further complication that becomes salient when taking up the normative interpretation of this question is that different communities, political contexts, social roles, and so on may carry different expectations for a certain depth and content of scientific literacy; we thank an anonymous reviewer for raising this point.

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 the vicinity. We shall return to the question of content — and the range of answers we see — in greater detail in §§3–4.

The Epistemic Relation

Suppose that we have in mind a conception of both the content of scientific literacy and the possessors of that content. 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).[5]

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. Most widely used measures of it consist in multiple-choice items (Miller 2010a). Sometimes this occurs despite assertions or intimations that understanding is the relevant goal.[6] 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

[5] Shen's initial gloss of it is also typical: it is "in the interest of everybody…to gain a better *understanding* of science and its applications…. Such an understanding might be called 'science literacy'" (1975, 265).

[6] 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 (Huxster *et al.* 2017).

are not themselves understood in any deep way — in addition to a deeper understanding of other matters. Thus, a conception of scientific literacy may plausibly involve a range of different epistemic relations between agents and content. Getting clear on these relations is important for determining how best to bring about more of it via education and communication, as it is not universally granted that understanding can be transmitted via testimony (Hills 2009; cf. Boyd 2017).

So much for describing an approach to filling out a conception of scientific literacy. Clearly other frameworks are possible. Why, for instance, don't we include goals in our framework questions? In part, because we see value in seeking greater specificity in the specification of content, capabilities, or epistemic relations and then asking what more general good for individuals or society scientific literacy so defined might be expected to bring about. Of course, a given conception may be motivated in the first place by an expectation of its social function; it may thus be thought of or labelled in terms of that function. We merely wish to leave it open whether it the specific content of a conception would in fact serve an intended end in a given context. Let us now turn to the more difficult matter of evaluating such conceptions. As before, our aim is not to provide an exhaustive survey of which sorts of scientific literacy are of value (and in what contexts); our discussion will focus on a certain range of evaluations that we hope will provide useful context for evaluating our own conception of scientific literacy.

3. Evaluating Conceptions of Scientific Literacy

We mentioned above the "functional" or goal-directed character of Shen's three conceptions of scientific literacy. An obvious approach to evaluating a given proposal for a particular population could thus be evaluated in terms of, first, whether the goal itself is of value, and, second, whether the proposed answers to our framework questions are poised to bring it about.

What sort of goals might we seek or expect? Without offering an exhaustive typology, the literature on scientific literacy offers various examples of goals purportedly of either practical or intrinsic value. Shen's Practical and Civic forms of scientific literacy are examples of the former, while Cultural scientific literacy is an example of the former: someone who improves the latter does so, he writes, "in the same spirit in which a science student might study ancient history, an engineer read poetry, or a physician delight in classical tragedies…. [It] is motivated by a desire to know something about science as a major human achievement…. It solves no practical problems" (1975, 267). 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). On whether seeking to fulfill the goals of Cultural Scientific Literacy — as opposed to studying ancient history or poetry — we take no position. It does seem doubtful that a univocal case for a purely intrinsically motivated conception of scientific literacy will be in the offing.

So let us consider instead conceptions motivated by practical goals. Civic Scientific Literacy will probably be high on the minds of science educators and communicators concerned about the opinion gaps between the lay public (particularly in the U.S. and U.K.) and the scientific consensus on various issues. Shen motivated its value by pointing out how common it was (in 1975) for legislative bills in the U.S., to "have a scientific or technological basis….health, energy, food and agriculture, natural resources, the environment, product safety, outer space, communication, transportation, and others" (1975, 266). Little has changed in the intervening decades — except of course we can add to Shen's list. Consider a recent essay of Miller's:

> Today's political agenda includes a debate over the consequences of and solutions for global climate change, a continuing debate over the use of embryonic stem cells in biomedical research, a spirited set of disagreements over future energy sources, and a lingering concern over the possibility of a viral pandemic. In Europe, the political landscape is still divided over nuclear power and genetically modified foods. No serious student of public policy or science policy thinks that the public-policy agenda will become less populated by scientific issues in the twenty-first century. Yet only 28 percent of American adults have sufficient understanding of basic scientific ideas to be able to read the Science section in the Tuesday *New York Times*. (2010a, 241)

The question, then, is what is needed for citizens to actively participate in the democratic processes that weigh in on such issues. Miller's view has two main components, again indexed to a certain functional competency: (1) "a basic vocabulary of scientific terms and constructs" and (2) "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). Presumably content falling under the heading of the "Nature of Science" (NoS) — 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 — is part of the latter, if not also the former. The former, as judged by Miller's measurement instruments, consists in an agent's grasp such facts as whether the center of the earth is hot or what lasers do (Miller 2010a, 47; see also Snow and Dibner 2016, 15).

While it is certainly plausible that a basic understanding of scientific vocabulary and a grasp in basic facts about the natural world may be a necessary condition for being able to participate in democratic decision making concerning issues informed by or involving science and technology (which is to say a large portion of decision making in developed nations), it is often quite a bit less clear whether — assuming other conditions are met — possession of scientific literacy on conceptions like Miller's credibly put its possessors in a position to participate in an informed and positive way.[7]

Defenders of a strong focus on NoS content sometimes seem to suggest that grasp of this concept will allow members of the lay public to evaluate scientific claims 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). But while it is plausible that such a grasp of basic foundational scientific and NoS content might allow agents to weed out certain obviously problematic content, it seems doubtful that it would allow members of the lay public to evaluate apparently competent but competing claims.[8] As Stephen Jay Gould pointed out in a (1999) editorial in *Science*, this is something that other *scientists* can barely manage; 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. The difficulty, as Shen saw, is that it is sometimes difficult to identify this authority; he wrote of the legislators "who have to decide on [matters concerning

[7] How to define this last idea with more precision is a difficult question; our thoughts here turn initially to work by Kitcher (2001, 2011) on "well-ordered science", though we have no particular account to offer.

[8] 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.

science]" that they "usually do not lack expert advice from contending sides; rather they complain of not knowing which set of experts to believe" (1975, 266). This problem persists.

Many, we submit, would find it plausible that the attitudes and abilities that enable such trust are an important social goal for a conception of Civic 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. But supposing that 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 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[9] — 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 other conceptions 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 skeptical (Leiserowitz *et al.* 2016).

Thus, as Anderson suggests, perhaps what is missing from our conceptions of scientific literacy is not so much *ability* as inclination; she writes: "While citizens have the capacity to reliably judge

[9] 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).

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.[10] 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.[11]

4. Understanding the Social Structure of Science

Anderson 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" (2011, 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 down 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 that there is more to be said 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. 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; Keren forthcoming)? 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

[10] 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.

[11] 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.

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 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). Our previous research (and anecdotal experience) suggests that the concept of peer-review is rarely understood [REF SUPPRESSED]; 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.[12]

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.

[12] 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".

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.[13] 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 one strand of 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 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.

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[13] 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).

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 (Jamieson 2018). When this haphazard assemblage of more or less independent agents speaks with one voice, prima facie, we ought to listen. Supposing that one accepts that the public's *prima facie* trust of the scientific community (when speaking with a consensus voice) is often warranted and an important dispositional goal for citizens of technologically developed democracies, we submit that a conception of scientific literacy that enables and encourages such a disposition is an attractive candidate for at least a core component of Civic Scientific Literacy. We hypothesize that a nuanced understanding of science as a social enterprise — what may be called the "social structure of science" (SSS) — may be expected to bring about this disposition and so argue that further work to (a) fill out the content of the SSS and (b) test this hypothesis empirically are warranted.

We close this section by noting two further points about the SSS conception of Civic Scientific Literacy. First, by focusing on the social-epistemic background for the significance of certain forms of scientific consensus, we are effectively side-stepping 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). It is compatible with our approach that suspension of belief is the right epistemic attitude to take in cases where experts appear to disagree. Second, in support of the empirical plausibility that the SSS conception would contribute broader social goals of rational policymaking, science communication researchers have proposed that consensus messaging serves as "gateway belief," even for polarizing science (van der Linden *et al.* 2014, 2015). But it is worth emphasizing that in our conception of the SSS approach, *understanding* is the key epistemic relation at issue: merely knowing some isolated facts about the way scientists work seems unlikely to form a sufficiently robust and flexible background against which the epistemic significance of scientific consensus — and how to detect it — can emerge.

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 out of reach. Finally, we proposed that a greater focus on the social structure of science in a conception of Civic Scientific Literacy would do better to meet an important 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;[14] but we hope that others — particularly HPS and STS researchers — will also contribute to this broad effort. We conclude by identifying what we take to be several fruitful avenues through which such scholars might contribute to this effort.

First, they 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 and scientific institutions.

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.

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[14] 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].

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.

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