Understanding and Trusting Science

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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 publicly-directed claims of science. 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.

1. Introduction

The state of scientific literacy in America and in other developed nations has been an issue of concern for many decades now (Bodmer 1985; Miller 1983, 2004; OECD 2007). More recently, a palpable anti-science sentiment has become more prominent (Kahan 2015; McCright and Dunlap 2011). 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 (Brulle 2014; Dunlap and McCright 2010, 2011). 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.

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

Before offering this conception and arguing for its merits (§4), we offer a basic framework for 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 (or subjects) 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 — e.g., what facts 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 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.

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 (NRC 2012; OECD 2007; 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. 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).

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 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.

Some may doubt that this is an important question. Isn't it obvious that any credible conception of scientific literacy should be analyzed as an agent's *understanding* of some scientific content matter? The reason why *literacy* has seemed an apt label for this quality, after all, 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" (Elgin 2006; Grimm 2012; Zagzebski 2001). 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 (Grimm 2006; Kvanvig 2003), it is credible that an understanding of a subject matter often incorporates various bits of propositional knowledge. 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 understanding of other matters. Thus a conception of scientific literacy may involve a number of different epistemic relations between subjects and content.

[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].

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 it possessor. 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.

Concerning practical justification (or criticism), one natural way to approach this is to ask after the tendency of different accounts of scientific literacy to 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 agreed upon as defining the relevant ends.

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) "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

[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.

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 how deeply implausible it is 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. Almost 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 OMITTED, see also Keren 2007, 2014; Zagzebski 2012). 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 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

[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.

[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).

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 (Brulle 2014; Diethelm and McKee 2009; Dunlap and McCright 2010, 2011; McCright *et al.* 2016; Oreskes and Conway 2010; Smith and Leiserowitz 2012; Torcello 2016).[6] So, 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.[7] 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.[8]

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

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[6] 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" (Bernauer 2013; Carmichael *et al.* 2017; Jasny *et al.* 2015; Leiserowitz *et al.* 2013; Takahashi and Tandoc 2016).

[7] 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.

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

out, is ubiquitous in our epistemic lives (Coady 1992; Hardwig 1985; Lackey 2008; Lipton 1998). 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 (Miller 2013; Odenbaugh 2012)? 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 on questions that Anderson identifies. 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) has 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). 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.[9]

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.[10] But such understanding — for example, of the sense in which scientists are simultaneously competing and collaborating with one another (Kitcher 1990; Kuhn 1962; Oreskes and Conway 2010, 272–273; Strevens 2003) — is, we argue, conceptually important to the recognition of the epistemic significance of scientific consensus and, in general, the recognition of epistemic responsibility. Thus, a better understanding of the "social structure of science" may well predict greater levels of trust in the scientific community.

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 correlative abilities of a given conception. 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 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

[9] 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".

[10] 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).

messages from the scientific community? Will such an inclination translate to ideologically-entangled issues such as climate change or the safety of childhood vaccines? Our team is currently pursuing this research;[11] 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 SSS 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.

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[11] 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].

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