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Emphasizing uncertainty, celebrating community and valuing values: science communication remedies for the COVID-19 era and beyond

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ABSTRACT

Specific pieces of science communication shape publics' more general impression of science, whether intentionally or not. This, in turn, affects how publics interact with science, acts as citizens in techno-scientific societies, and ultimately has implications for the role of science as an institution in democratic societies. Representations of science that downplay scientific uncertainty, elide the role of the scientific community, and de-emphasize the values which define the institution of science have problematic consequences for science, publics and democracy. Therefore, though increasingly encouraged to communicate research to wider public audiences, scientists must think carefully about their communication practices. Specifically, the epistemic status of research findings, what elements of the process of knowledge creation are foregrounded, and the values which underpin the scientific community all need to be clearly communicated to the public. This article will help Early Career Researchers (ECRs) reflect on their public science communication and begin to develop communication practices of benefit to publics and science.

KEYWORDS
Science communication; uncertainty; scientific community; values; Early Career Researchers (ECRs); practices; publics; democracy

Introduction

Why communicate science to the public? For Early Career Researchers (ECRs),[1] there is a range of answers, which suggest diverse motivations. Science may be communicated for 'instrumental' reasons – because research-funding bodies stipulate it or because experience of 'public science communication' can be a valuable skill to list on a CV. There also

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[1]'Early Career Researcher' (ECR) is a term with some interpretive flexibility, which is strategically deployed by employers, funding bodies and by researchers, often to (dis)qualify certain groups of researchers for funding or employment. UKRI, the UK Government body which oversees government funded scientific research in the UK, defines an ECR as 'a researcher within eight years of their PhD award (this is from the time of the PhD 'viva' – oral test), or equivalent professional training OR within six years of their first academic appointment (the first full or part time paid employment contract that lists research or teaching as the primary functions)' https://www.ukri.org/councils/ahrc/career-and-skills-development/early-career-researchers-career-and-skills-development/. In contrast, the British Academy makes limits eligibility for its Postdoctoral Fellowships (the funding most obviously directed at ECRs) to researchers within 3 years of their viva https://www.thebritishacademy.ac.uk/funding/early-career-researchers/#:~:text=This%20scheme%20is%20aimed%20at,fostering%20long%2Dterm%20international%20collaborations.

exist less instrumental motivations for science communication. A public that knows more and better understands science is a good thing in and of itself is a view that may motivate public science communication.[2] ECRs might also communicate science simply because it is enjoyable – talking about a topic of expertise to a non-expert yet interested, or even uninterested, audience may be a joy in and of itself (e.g. Martín-Sempere et al. 2008). Whatever the motivation, it is important to recognize that how science is communicated – the medium, mode and meter of this communication - has implications for how publics who are audience to science communication understand science. In turn, how science communication shapes publics' understanding of science has implications for the role science plays in public life, both at the individual and societal levels. Done well, science communication can foster a relationship between science and publics that is beneficial to science, publics and to the wider democratic societies of which both form a part. In this article, I provide examples of science communication that does not foster this kind of relationship, explain why this is the case and outline the negative societal impacts of these unhelpful efforts. I go on to provide some guidance for those who would attempt the kind of science communication that does foster a science-public relationship of benefit to democratic societies, and argue for the necessity of attempting these kinds of communications if we wish to maintain the status of science, and our democratic institutions.

What does science communication do?

If success in science communication is measured by increased levels of knowledge in a specific topic area or by the level of enjoyment produced by the communication, issues such as clarity, level of detail and engagement potential for the science being communicated are obvious concerns. This is particularly the case for mass media science communication, where successfully translating expertise in a relatively niche area of scientific research, and repackaging it such that is intelligible and engaging for a lay audience with little knowledge of or interest in the area is a common metric of success (Mason-Wilkes 2018). However, if 'successful' science communication is science communication that fosters science-public relations of benefit to democratic societies, then alongside clarity and engagement is a deeper concern. Namely, what does an audience *take* from even those specific, small-scale bits of science communication ECRs are likely to engage in, besides some specific bits of information on some specific area of science? What *impression* of science, in a general sense, does a piece of science communication foster? This is an important consideration, because whether intentionally or not, individual efforts at science communication, even as they explicitly provide some specific insights into specific sciences, will at the same time contribute to fostering this overall, more tacit, yet nevertheless important, general impression of science.

One way this more general impression of science is fostered is through the 'framing' used in a piece of science communication (Holliman 2004; Boyce 2006; Nisbet 2009). Here, pre-established media or cultural reference points are employed by communicators to help an audience make sense of some new piece or piece of information. In this vein, Holliman (2004) discusses how, when presenting the cloning of Dolly the sheep, media

[2]See Bultitude (2011) for a discussion of the range of motivations for science communication.

communicators drew on references to Mary Shelley's Frankenstein. The content of these pre-existing frames then shapes how this new piece of information is understood, but, in turn, these frames of reference for understanding science are rendered legitimate or further strengthened. The case of Dolly, the Sheep, for instance, reinforced popular associations between Frankenstein and science and legitimized this general impression of science as, e.g. unnatural or sinister, and scientists as megalomaniacal or immoral. Instances of science communication can thus also cultivate a particular impression by building or adding to existing representations extant in other media or efforts at public communication of science (e.g. Gerbner et al. 1981, 1986; Brewer and Ley 2010)

The kind of tacit impressions of science that science communication might foster are varied. For instance, who is doing the communicating – their gender, their ethnicity, subtle cues as to their class background provided by things like accent – will create or reinforce notions about who *is able to* or who can *legitimately* participate within science, and alongside this who is able to *speak for* or represent science in and to the public (Tuchman 2000). Beyond who is doing the speaking, how a specific bit of scientific information, or a specific science, is communicated, will also shape the more general impressions of science an audience is left with. Presenting scientific knowledge as definitive, without caveat, uncertainty or without reference to error will foster the impression that science produces certain, definitive knowledge (Dhingra 2003). De-emphasizing the complex, serendipitous and unpredictable in scientific knowledge creation will give the impression that creating scientific knowledge involves simple, linear procedures and processes (Tait 2006; Brewer and Ley 2010). Downplaying, or entirely eliding, the role of an expert scientific community in affirming and maintaining scientific knowledge – the fundamental role this community plays in constructing and legitimating what is and what isn't scientific truth – will give the impression that scientific knowledge is producible anywhere, by anyone, without the input of an expert scientific community to legitimate this knowledge (Charney 2003; Hill 2019; Lee et al. 2021).

As is set out below, the impressions of science fostered by science communication have real social and political consequences for how people engage with scientific advice, and more broadly, for how they act as democratic citizens in techno-scientific societies. Communicators, therefore, need to be both aware of the different consequences different kinds of communication *can* have, and more fundamentally, be reflexive of the kinds of social and political outcomes that they *desire* for their science communication. Which outcomes for science communication are desired will rest on the kind of society which we might want to inhabit. Scientists, it seems self-evident to say, would want to live in a society that supports science; where it is possible to do science, where science is a viable career option, where science is valued and taken seriously, and even where science is seen as providing some social goods. It might be the case that this isn't seen as a desirable society, and for any reader for whom this is the case, the rest of the argument outlined here will not be convincing. However, for those who do desire this kind of society, a further practical question arises: how do we help to foster this kind of society through our science communication?

In what follows, I will outline three aspects of science we should aim to communicate – the importance of uncertainty as an aspiration in science, the role of the scientific community in constructing and maintaining scientific truths, and the wider democratic worth of the set of values which guide and define the scientific community. Ensuring communication efforts effectively communicate these aspects of science will help to build and maintain the kind of impression of science, which, if widespread, will in turn help to foster the kind of society where science is valued, respected and continues to be possible. In contrast, I will discuss the problematic consequence of science communication where scientific knowledge is represented as certain and as producible by anyone with limited expertise working outside the scientific community, and which fails to emphasize the importance of the values which scientific communities aspire to uphold. Communicating science as certain, though potentially attractive in the short term, is likely to result in public intransigence in the face of new scientific evidence, and eventually disillusionment with science, as notions of scientific certainty are repeatedly undermined by the emergence of new scientific claims. Downplaying the role of the scientific community in scientific discovery and knowledge-making in favour of narratives of individual scientific discovery align with models of science identifiable in anti-scientific communities such as 'fringe scientists' and other groups identifiable in the context of COVID-19 such as anti-vaxxers and 'anti-maskers'. De-emphasizing the values that underpin scientific communities risks disguising the alignment of these values with many values central to democracies, and thus the model role science as an institution can play in democratic societies. Indeed, communicating science in these ways is likely to inculcate in publics impressions of science implicated in societal attitudes identifiable in so-called 'post-truth' rejections of science and expertise (e.g. Davis 2017; D'Ancona 2017), which have only been further accelerated under the pandemic conditions of the early 2020s.

Uncertainty

A defining aspect of science is that the knowledge it creates is in principle always open to revision. In practice, of course, scientists work as if many of their theories are as good as fixed (Einsteinian relativity, evolution by natural selection) but science as a communal enterprise is defined by a set of aspirational values, which includes the possibility of overturning any piece of established thinking or knowledge currently held to be true (Collins and Evans 2017). As such, the community of scientists aspire to viewing all pieces of scientific knowledge as essentially uncertain or provisional.

However, for a variety of reasons, public communicators of science often omit this critical aspect of scientific knowledge from their communications. In mass media communication of science, for instance, institutional and professional expectations mean that science communication must be engaging to a mass media audience. There are numerous formats within which science is presented in mass media, with a non-exhaustive list encompassing popular films, newspaper reports, syndicated television shows, long-from documentaries, news reports, magazine programmes, as well as science fiction programmes, educational broadcasts and children's media. Across all these formats, however, similar pressures operate, above all else, the pressure to produce content that engages a mass media audience, either to satisfy commercial or market pressures, or to justify the role of public service broadcasting or communications. Within mass media production, professional norms dictate that a well-established way to make any content engaging, including a piece of science communication, is to structure it around a familiar narrative, with a clear story-arc that resolves neatly and ties up loose ends. Fitting the messy and unpredictable process of scientific knowledge creation into this communication format results in a de-complexifying of these unpredictable and uncertain processes (Mason-Wilkes 2020). Where these narrative arcs are less appropriate, in shorter format content, such as news reports, pressures of time mean that a premium is placed on clarity and simplicity of communication, resulting in the stripping out of what is deemed the superfluous, unnecessary or confounding details, such as the uncertainty surrounding a finding or piece of knowledge.[3] In all instances, professional or institutional ideas about how to engage a mass media audience mean that communication of the complexities of scientific knowledge creation and, importantly, the uncertainty inherent to any piece of scientific knowledge (it's fundamentally provisional nature) is sacrificed to increase the engagement potential of a piece of science-focused mass media communication. New media and online communicators are not immune to the pressures experienced by mass media communicators, e.g. the pressure to engage an audience, and to do so, new media presentations borrow similar communication devices. Rychkova (2020), for instance, shows how Ted Talks use familiar narrative devices to structure their communications, leading to a simplification or eliding of key elements of the process of scientific discovery.

The eliding of the provisional nature of scientific knowledge in public communications of science has problematic implications for public understanding of science. Dhingra (2003) has shown that representations of scientific knowledge as definitive lead audiences to accept scientific knowledge as certain and uncontentious. This, it may be argued, could be seen as a good thing. In the short term, publics who view scientific knowledge as certain and uncontentious may take scientific knowledge, and the scientists who produce it, seriously. However, there are longer-term problems which result from a widespread public perception of scientific knowledge as certain or definitive, two of which I will discuss here and describe as intransigence and disillusionment – intransigence being a perhaps more specific problem, and disillusionment a wider issue.

Tufecki (2020) highlights both the issues I describe as intransigence and disillusionment in her discussion of mask-wearing during the COVID-19 pandemic. She illustrates how, in the US, early in the COVID-19 pandemic, mask-wearing was initially communicated, with a high-degree of certainty, as having little or no impact on the spread of COVID-19. As the pandemic progressed, the scientific and public policy thinking on this issue developed, and policy-makers, claiming a scientific mandate, announced that mask-wearing did in fact play a significant role in reducing the spread of COVID-19 and advised mask-wearing in various contexts. However, many US citizens rejected this later advice and continued to follow the early advice against mask-wearing.[4] Initially starting with a high-degree of certainty that mask-wearing did not reduce the spread of COVID-19 provided members of the public with the cognitive and rhetorical resources to reject later claims, even those with an apparent scientific mandate. Presenting in public a scientific claim with too much certainty attached to it can mean that if the scientific knowledge or thinking changes (e.g. as more data is collected, or more sophisticated models are developed) it can be difficult to shift public thinking, and behaviour,

[3]Simplicity and clarity of communication are also aimed for in educational and children's broadcasts (e.g. Hall 2021, Chapter 4).

[4]The motivations for this rejection by sections of the US public were of course complex, multifaceted and value-laden and related to, amongst other things, political identification (e.g. Kahan 2015).

because of the certainty attached to the original messaging. Presenting bits of scientific knowledge as certain, then, can in the longer term, harm attempts to inculcate a practical or useful understanding of science in the public, especially around politically charged topics, or areas that intersect with salient value predispositions.

The more widespread, and potentially more socially harmful, threat of disillusionment is another consequence of attaching too much certainty to scientific thinking or knowledge in public communications. Disillusionment is a result of the repeated failures of 'science' in general to live up to the standards of certainty promised by communication efforts where scientific knowledge is presented as certain. Nagler (2014) presents an example of this in action, focusing on the impacts of communication of conflicting messages around the health benefits of different foods and drinks. As an example, she shows how repeated exposure to competing, yet definitive, media messages about the impacts of red wine on health, eventually lead to publics coming to view more general health and nutrition advice with greater scepticism. As this kind of finding shows, if over time scientific knowledge is presented as certain, yet it continues to change, and with each change, the new piece of knowledge is subsequently presented as certain, the consequence of this is a general eroding of trust in science. Disillusionment grows via direct experience of the continued and prolonged failure of science to live up to the perfection promised by representations of scientific knowledge as certain. Under these conditions, publics who continue to place their trust in science can be argued to be, at best naïve, if not potentially acting against their own best interests.

To avoid inculcating this kind of attitude, when doing science communication, the following practical steps can be followed:

- Emphasize the provisionality of findings – e.g. refer to 'current' understandings, or the 'present' state of the field
- Avoid using language that suggests an issue is completely settled, or a piece of knowledge is definitively true
- Present uncertainty as a strength, not a weakness – emphasize that science is the most suitable process for developing knowledge and understanding of the problems societies face, which are complex, multifaceted and evolving and which resist definitive explanations or fixed solutions.

Community

A common narrative of scientific discovery used in science communication is that of the 'Lone Genius' or 'Great Man of Science' (e.g. Charney 2003; Hill 2019). This narrative presents scientific discovery as accomplished by an isolated (invariably male) scientist who makes their discovery single-handedly, unsupported by and often in spite of stiff resistance from the scientific community. Aside from the problematic issues regarding gender representation, this narrative fails to properly represent the vital role the scientific community plays in scientific knowledge creation.

Since its inception, a central insight of sociological analysis of science is the importance of the relationship between individual scientist and scientific community. In his classic text, Kuhn (1962) frames this relationship as the 'essential tension'. For Kuhn, the community provides the framework of knowledge, understanding and values within which the individual works (the 'paradigm') but the individual must be granted the freedom to work in ways that potentially shift this framework of understanding if science is to progress. Without individual freedom, science stagnates, but without the framework provided by the scientific community, the collective assessment and confirmation or rejection of novel findings or ideas cannot happen. Maintaining the essential tension is, therefore, vital for establishing scientific truth, and thus the institution of science. However, in the Lone Genius or Great Man of Science narrative, the essential tension is resolved entirely in favour of the individual, with the role of the scientific community reduced to one of either irrelevance if not outright obstacle to truth. This is problematic, because promoting the ideas that scientific knowledge is the product of individual effort implies that scientific knowledge can be produced anywhere, by anyone. In reducing the role of the scientific community to an irrelevance or obstacle, the narrative emphasizes that new knowledge 'discovered' by maverick outsiders is likely to be met with resistance or derision by the established scientific community, even if it is eventually found to be true.

Collins, Bartlett, and Reyes-Galindo (2017) identify this kind of attitude among 'fringe' scientists. These are groups who reject key tenets or foundational theories of mainstream science (e.g. Einsteinian relativity), and who therefore work outside of mainstream academic or other scientific fields. Nevertheless, fringe scientists engage in activities analogous to mainstream scientific communities - establishing learned societies, editing their own journals which accept and publish fringe views, and running international conferences with attendance in the 100s. A characteristic of these fringe groups, though they participate in a community of sorts, is that they are committed to what Collins, Bartlett, and Reyes-Galindo (2017) describe as a 'pathological individualism', analogous to the Great Man of Science narrative, which downplays or negates entirely the role of community in establishing scientific knowledge.[5]

More pressingly, this kind of attitude is reflected in more widespread public discourse, around a number of topics, but a current salient example can be found in reference to the COVID-19 pandemic, vaccination and mask-wearing. Individuals or groups arguing against COVID-19 vaccinations, for instance, exhort others to 'do your own research' about the issue rather than trust in the advice provided by established scientific communities and their representative bodies (Hughes et al. 2021; Quinn, Fazel, and Peters 2021). Lee et al. (2021), in their recent analysis, identify another parallel with fringe science groups in the ways in which, in the context of the COVID-19 pandemic, anti-mask groups utilize the same data visualization tools as those used by mainstream scientists to create convincingly 'scientific' looking displays of their own data. This data, however, has been produced outside of, and stands in opposition to, mainstream scientific consensus on the issue of mask-wearing. As with the 'Fringe' scientists, Lee et al. (2021) show that anti-mask movements reject the role of the scientific community and display a commitment to 'pathological individualism':

[5]The extent to which these fringe groups engage with and are influenced by media and popular representations of science which utilise the 'Lone Genius' or 'Great Man of Science' narrative is an empirical question. However, given the ubiquity of this kind of narrative in media and popular culture and its corollary attitudes within these groups, it nevertheless seems plausible that the 'Lone Genius' or 'Great Man of Science' narrative in science communication reinforces pathological individualism amongst fringe scientists.

> While academic science is traditionally a system for producing knowledge within a laboratory, validating it through peer review, and sharing results within subsidiary communities, anti-maskers reject this hierarchical social model. They espouse a vision of science that is radically egalitarian and individualist. This study forces us to see that coronavirus skeptics champion science as a personal practice that prizes rationality and autonomy; for them, it is not a body of knowledge certified by an institution of experts. (Lee et al. 2021)

Fringe or anti-mainstream science movements are able to borrow techniques of data display and communication from mainstream science, to render their own communications aesthetically indistinguishable from those of mainstream science. However, both fringe scientists, anti-vaxxers and anti-maskers, espouse a radically individualistic version of science, which is antithetical to the operation of mainstream science. When members of the established or mainstream scientific community communicate their science, then, a vital aspect of their communication should be foregrounding that it is science, the product of the established scientific community, a community which understands the vital role *community* plays, in the establishing of scientific knowledge.

To inculcate this kind of attitude, when doing science communication the following practical steps can be followed:

- Avoid 'Great Men of Science' or 'Lone Genius' narratives when communicating science
- Stress the role of other researchers or colleagues in the work of science/production of scientific knowledge
- Highlight the continuity of research findings with an established body of work – findings may be novel, but they exist within a framework of previously established theories which evolves incrementally.

Values

In the previous section, I argued that it is important for communicators to foreground the vital role that the scientific community plays in the construction of scientific knowledge, to counter the 'Great Man of Science' narrative that aligns with the 'pathological individualism' of fringe scientists and anti-science movements such as anti-vaxxers and anti-maskers. Beyond showing the collective nature of science, there is another important aspect of the communal nature of science that should be emphasized to inculcate an impression of science beneficial to democratic citizens in techno-scientific societies, namely the values that the scientific community aspire to uphold.

As with the work of Thomas Kuhn and the role of community discussed in the previous section, a focus on the role of values of and in science has a long history within sociological analyses. In this vein, Douglas (2016) has traced the multiple ways in which values have been shown to operate in the work of science, challenging the idea that science can, or should, be seen as 'value-free'. Indeed, much sociological work has sought to locate values as central to scientific practice and knowledge creation. Indeed, in one such classic text, Merton (1973) attempts to define science by explicit reference a set of values, the so-called CUDOS norms:

- **Communism/communalism**, or the free and open sharing of knowledge;
- **Universalism**, or the removal of barriers to entry (e.g. race, gender, class, creed) into science and the judgement of work/idea/arguments not on any of these factors but only on the quality of scientific work;
- **Disinterestedness**, or the pursuit of scientific knowledge for its own sake and not for ulterior motives e.g. personal fame, wealth, or glory, and finally;
- **Organized Scepticism**, the collective commitment of scientists to subject novel findings or arguments to rigorous scrutiny before accepting them, and not to let factors such as reputation or standing in a field influence the assessment of findings or argument.

Since Merton, values in and of science have continued to be the focus of sociological analyses (e.g. Mitroff 1974; Longino 1990; Collins and Evans 2017; Oreskes 2021). Collins and Evans (2017), add a number of other values to Merton's CUDOS norms, including observation falsification and corroboration, valuing expertise, maintaining the Kuhnian 'essential tension' (described above), and honesty and integrity (see Collins and Evans 2017, pg. 55 for a full summary). Importantly, Collins and Evans also prescribe a shift in understanding of how these values operate within the scientific community, from the normative understanding forwarded by Merton, to instead viewing these values as 'aspirational'.[6]

The 'formative aspirations' around which the scientific community is organized are important for two reasons. On the one hand, it is good for scientists to aspire to these specific values when aiming to create new knowledge. Aspiring to understand the world, and justify knowledge claims based on observation, corroboration and falsification is a good thing to do if new knowledge of the world is sought (even if in practice observation, corroboration and falsification are not sufficient for establishing scientific truths, or deciding between competing scientific knowledge claims). Likewise valuing expertise, clarity of communication, the essential tension between individual and community, and honesty and integrity in community members are a preferable set of formative aspirations for a community involved in knowledge creation, than an alternative or opposing set of values.

However, alongside this, many of the formative aspirations of the scientific community are good values to aspire to within a wider democratic society more generally. Honesty and integrity are values which are just as worthwhile for citizens of a democratic

[6]For Merton, scientists, when acting as scientists, uphold the CUDOS norms, and if they fail to, they are not acting scientifically. Vitally, knowledge created in violation of these norms is not *scientific*. This somewhat prescriptive view has been met with more recent empirical and theoretical challenge. Later empirical observations of scientists at work by Mitroff (1974) for instance, appeared to show scientists working to a set of diametrically opposed counter-norms, yet successfully achieving scientific work. Longino's (1990) work highlights the importance of the communal aspect of the values of science, downplaying the importance of the behaviour of a given scientist and arguing that scientific 'objectivity', 'disinterestedness' or 'scepticism' operates at the communal level. Oreskes (2021), makes a similar argument, claiming science is trustworthy precisely because the values which operate within the scientific community. As with Merton, Collins and Evans (2017) emphasise the important role values continue to play in shaping the conduct of science. However, they argue that scientific *values* are better understood as 'formative aspirations'; a set of appealed to or aspired to norms, prescriptions for behaviour or templates for going on in the world of science, which are understood collectively by scientists, and a shared commitment to which is a hallmark of membership within the scientific community. On this reading, an individual scientist in some aspects of their behaviour may fail to uphold the values they aspire to (e.g. as in the case identified by Mitroff), yet this would not automatically mean they were not acting scientifically, if they recognised their actions meant they failed to live up to the aspired to value.

society to aspire to uphold in their society as they are within the scientific community, likewise universalism. Placing a higher value on the opinion of those who 'know what they're talking about' (i.e. experts) when they speak on a topic of their expertise is a good thing to aspire to outside of the scientific community as well as within it – the value of any specialized occupation, from mechanic to lawyer to sports coach resides in recognizing this. Science, because of the constellation of values members of the scientific community aspire to uphold, should be viewed as an exemplary institution in modern democracies. Those values that scientists as a community aspire to in many respects overlap with values preferable in democratic societies, and democratic citizens could do far worse than viewing the scientific community as a normative example in modern democracies.[7]

Ophir and Jamieson (2021) offer a parallel line to this argument, showing that communicating the values of science actually increases public confidence in science. They analyse the differential impacts of various storytelling devices in science communication, and specifically a device they call the 'problem explored' narrative. This narrative emphasizes the values that underpin scientific practice, specifically, treating findings as provisional, applying careful scrutiny in observation, and subjecting new findings to an organized scepticism. Ophir and Jamison find that in contrast to narratives such as the 'honourable quest', which elide the importance of science's communal values and as a result have the potential to increase public scepticism toward science, the 'problem explored' narrative instead serves to increase public confidence in and attitudes towards science:

> [the] problem-explored narrative could ameliorate those detrimental effects [of the 'honourable quest' and other narratives] and yield more positive beliefs and attitudes about science and scientists, by better communicating scientific norms of continuing exploration, scrutiny, and skepticism. (Ophir and Jamieson 2021, 13)

Communicating the formative aspirations of science in public then, is both beneficial to science, in that it increases public trust and confidence in it, and beneficial for society as a whole, as citizens come to view the scientific community as guided by a set of values which are in many cases good values to live by as democratic citizens.

To inculcate this kind of attitude, when doing science communication the following practical steps can be followed:

- Use devices that communicate the aspired to values of science, e.g:
  - Communicate 'universalism' by diversifying who can and does speak for science in and to the public(s)
  - Communicate 'disinterestedness' and 'honesty and integrity' by declaring conflicts of interest, and avoiding presenting science as neutral which is carried out on behalf of interested parties[8]

[7]This is not to say that science should be viewed as the *only* legitimate source of normative guidance in modern societies – other sources of normative guidance include religious traditions and secular moral treatise - nor as one which provides a totalising moral or existential framework; science, for instance should be seen as offering little insight into the ultimate value of human or animal life, or of the creative arts. The claim here is rather that, alongside their role in facilitating production of knowledge of the natural world, the formative aspirations of science mean that science's worth as an institution in democratic societies resides in the normative example it provides.

[8]e.g. the Tobacco or Fossil Fuel Lobby as discussed by Oreskes and Conway (2010)

- Communicate 'respect for expertise' by having scientists present science on which they are knowledgeable, but deferring to others (including to non-scientists) in areas outside their expertise.

Discussion and conclusion

Communicating science to the public is increasingly on the agenda for Early Career Researchers (attested to by, amongst other things, the focus of this Special Issue). Beyond simply disseminating information on a scientific topic, public communication of science shapes the impression of science the public receives. The impression of science held in public will shape both how publics interact with science, and more widely, the kind of society that we inhabit. I have outlined three facets of science it is important to communicate to foster an impression of science in publics of benefit to the flourishing of both science and society.

Scientific knowledge is provisional. Internal scientific controversies arise, scientists disagree on the outcome of experiments or the meaning of new data, and novel findings disrupt established ways of thinking. This has been made clear during the COVID-19 pandemic, with scientifically mandated public health advice evolving as understandings of, e.g. the vectors of transmission and the best methods to prevent the spread of the disease have developed. The consequences of attaching too much certainty to communication of this fundamentally provisional knowledge have also been made visible - communication of science which inculcates the expectation that scientific knowledge is certain has led to public intransigence or disillusionment when scientific knowledge has failed to live up to this expectation. To counter this, public representations of science must therefore convey the aspirational uncertainty of all scientific knowledge.

The scientific community is vital in producing and maintaining scientific knowledge. Individuals who work within the scientific community must be able to shift the boundaries of knowledge, but the scientific community establishes what is legitimately within those boundaries. This is the 'essential tension' which must be maintained for scientific knowledge to progress. Fringe scientists and other anti-science groups, however, buy into a 'pathological individualist' version of science, where the established community of scientists is at best an irrelevance and at worst an impediment to scientific truth. This version of science is promoted in representations of science such as the 'Great Man of Science' narrative. Public communication of science must therefore resist these narratives, and those simplifying narratives that reduce the complex and messy world of scientific knowledge production, and communicate the foundational role that the scientific community plays in the creation of all scientific knowledge.

The values that scientists aspire to uphold within their community (the 'formative aspirations' of science) are good values to uphold when attempting to create new knowledge, and are synonymous with many of the values that should inform a democratic society. Science can therefore act as an exemplary institution in modern democratic societies because of its 'formative aspirations', and this should be made clear when communicating science in public.

Public science communication of course takes place in a variety of forums, through various media and to audiences at different scales, and this in turn impacts on the influence science communication can have. Similarly, the extent to which ECRs are able to 'tailor' there message to include or exclude the kinds of representational devices I have described, will depend upon the kinds of media in which they are communicating, its institutional norms and pressures, and pre-established methods or practices of communication to and engagement with audiences (e.g. Peters 2008; Peters 2013). Clearly, this is a complex issue, which can involve the interaction of complex and sometimes opposing professional and institutional norms, and differential power relations. Tasking ECRs with negotiating these various pressures to ensure those aspects of science I highlight are included in their communications, when already they are disempowered in multiple ways, may appear to be focusing critical attention in the wrong place.

However, this important work must be undertaken in multiple ways, by multiple actors at all levels, particularly when communicating science in the ways outlined here offers such tangible benefits, to both ECRs, more established scientists and society as a whole. As has become more and more evident, first in what was described as the post-truth political climate of the second half of the 2010s (D'Ancona 2017; Davis 2017), and more recently in during the COVID-19 pandemic, the negative consequences, both for science and our society, of failing to communicate these aspects of science to the public are very real.

These include the above-described intransigence, disillusionment, and the misrecognition and propagation of fringe or anti-scientific beliefs. In turn, some of the serious social and political consequences of these attitudes have already been felt, as others continue to emerge, including in such high-profile recent events as the Brexit campaign in the UK (Sky News 2016); in decisions taken by the Trump administration to drastically limit funding and support for government scientific agencies such as the EPA (Smith 2017); or in the mishandling of the COVID-19 pandemic on both sides of the Atlantic (e.g. Islam 2021).

Clearly, the felt impacts of these attitudes have already been quite severe. The longer-term consequences, for science and society, of failing to counter these trends by fostering an impression of science that foregrounds its value in and too democracies are potentially no less stark. Widespread public attitudes which fail to recognize the value of science may lead to questions about its usefulness. If science's practical utility appears reduced, its social necessity can be questioned, with a reduction in public and financial support for science potentially to follow. In the longer-term, this could adversely impact the scope and quality of scientific research, the viability of science as a career, and the ability of science to address itself to empirical, theoretical and social problems. If this occurs, the role that science can play as model institution in democracy, will in turn be increasingly limited.

Indeed, we can already see science being targeted by populist regimes seeking to undermine or overturn established checks and balances on their power (e.g. Collins et al. 2020). Against such a backdrop, the guidance offered here, aimed as it is at ECRs with currently only limited scope to (re)define science communications practices, may seem poorly targeted. However, as has been suggested above (e.g. Ophir and Jamieson 2021) methods for communicating science in democratically beneficial ways already exist. The next generation of scientists and science communicators (increasingly one and the same) must reflect on their communication practices, and what, beyond meeting institutional demands or providing personal satisfaction, their science communication does in the world. Todays' science communicators have a unique opportunity to develop communications which emphasize science's value in and to democratic society, and by doing so support both science and democracy.

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