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Communicating contested geoscience to the public: Moving from 'matters of fact' to 'matters of concern'

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ABSTRACT

Geological issues are increasingly intruding on the everyday lives of ordinary people. Whether it is the onshore extraction of oil and gas, the subsurface injection of waters for geothermal power or the deep storage of waste products, communities across the world are being confronted with controversial geological interventions beneath their backyards. Communicating these complex scientific and technical issues is made more challenging by the general public's unfamiliarity with the geological realm. Cognitive studies confirm a cultural dissonance with the subsurface and highlight lay anxieties about tampering with nature. In addressing those concerns, factual information is argued to be subordinate to values and beliefs in shaping public perspectives on contested geoscientific issues. In this context, scientists' attention to technical accuracy and their emphasis on professional consensus may do little to influence multiple publics whose worries instead root into their sense of place, trust and governance, as well as equity and ethics. With a growing recognition that it is social rather than technical factors that stir public unease and fuel community outrage, geoscientists need to develop new strategies to engage dissonant publics, underpinned by a culture change in geocommunication from conveying 'matters of fact' to brokering 'matters of concern'.

1. Introduction

Few Earth scientists would disagree with the view that reliable and relevant information about the ground beneath our feet is critical for wise environmental decision-making. In any geo-energy or ground engineering project, planners, engineers and other professional practitioners demand rigorous technical knowledge from geological specialists, and expect that geoscientific understanding to be conveyed in ways that allow robust analysis and appraisal by other technical experts. Yet, any major development project also involves consultation with a far wider constituency of stakeholders, many of whom lack substantive scientific grounding or technical know-how. Engaging with these wider 'publics', particularly over geoscience issues that are socially contested (Fig. 1), requires styles and strategies of communication that are different from the peer-to-peer exchanges in which most scientists have been trained. Recognizing that a better understanding of how to communicate scientific knowledge effectively to lay audiences is emerging as a critical skillset for those working at the public interface, this paper explores the basic principles and practices of communicating 'contested geoscience' to the general public.

Disseminating technical information to non-technical audiences is a difficulty facing all applied science specialists (e.g. Nisbet and Scheufele, 2009; Groffman et al., 2010; Somerville and Hassol, 2011), but is arguably particularly challenging for geoscientists. After all, the sub-surface geological realm lies out of sight and, for most people, out of mind. Consequently, many of the underground geoscience issues that directly confront society - unconventional oil and gas exploration ('fracking'; Fig. 1), carbon capture and geological storage, geothermal exploitation, and nuclear waste disposal - are not only scientifically complex, they are unfamiliar, perhaps even alien. In this regard, the geological specialist and the average citizen are separated by a comprehension gap that is not simply technical but also deeply cultural (Moores, 1997). Most geologists recognize the public's endemic lack of understanding and broader dissonance with what lies deep beneath their feet and acknowledge the difficulties that poses for lay understanding of geological principles. And yet, for the most challenging near-surface geoscience activities - those with the largest scientific uncertainties and highest technical risks - the views of the public are often mandated as part of the democratic oversight process. The paradox then is that, in seeking public approval for such novel ventures, geoscientists are frequently compelled to engage with lay stakeholders who are generally unknowing of the basic science and often distrustful

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Fig. 1. Geological issues are increasingly intruding on the everyday lives of ordinary people, as exemplified by protests against hydraulic fracturing ('fracking') for unconventional hydrocarbon extraction at a climate change march in London.
Photo credit: authors own.

of where it leads.

At first glance, wider social acceptance of geoscientific interventions would seem to hinge on confronting the public's poor grasp of the geological realm. With only a tiny fraction of the population exposed to Earth science through formal education, many geoscientists perceive a need to improve 'geo-literacy' so that ordinary people have the knowledge base necessary to evaluate the information presented to them. Schemes such as the Earth Science Literacy Initiative (2012) make a start on this task, setting out the fundamental geoscience ideas and concepts that the average 'geo-literate' adult ought to be aware of. Carrying the endeavour further are those geoscientists who engage in public outreach, and appreciate that serving up geological knowledge for popular consumption requires the science to be simplified, stripped of technical jargon and presented in more appealing forms (Liverman, 2008; Donnelly, 2008). Digestion can be made easier by adopting journalistic devices of framing more compelling narratives and indulging in more imaginative storytelling (Bubela et al., 2009; Somerville and Hassol, 2011; Stewart and Nield, 2013; Dahlstrom, 2014), devices that geoscientists already unconsciously employ in reporting research to their peers (Phillips, 2012). And geo-communicators can be still more savvy by learning how to reach multiple audiences through a mix of 'old' and 'new' communication channels, particularly social media (e.g. Brossard, 2013; Drake et al., 2014; Schäfer and Schlichting, 2014; Newman, 2016). In this complex and rapidly evolving public information sphere:

> '…scientists need to re-evaluate the way that they interact with society. …To do this, we must engage with our audiences in new ways, frame our results in ways that resonate with these audiences, and use new communication tools that can reach a wide range of target groups.'
>
> (Gosselin et al., 2013, p.290)

Across academia and industry, training courses are springing up to ensure that the next generation of scientists is more prepared and better able to explain themselves to lay audiences (Warren et al., 2007). But becoming better interlocutors is not just about the means of communication, it is also about the message. Many scientists still regard the public's scientific 'ignorance' as being essentially an 'information deficit' (Durant et al., 1989), as evidenced in a study on public acceptance of geosciences in Ireland in 2016 (GSI, 2016). Science communication studies, however, have long rejected the over-reliance on factual information as the principal currency of communication (Burns et al., 2003). After all, the 'facts' around scientific developments are often themselves contested and the same technical problem can be presented in very different ways to elicit markedly contrasting responses. Most people appear concerned about the socio-economic consequences of implementing novel scientific technologies, but these cannot be judged from a factual point of view (Wallquist et al., 2009). Moreover, 'many environmental claims …are about moral and aesthetic choices. They are about equity and ethics' (Oreskes, 2004, p.381). In this context, even '…compelling scientific information often runs aground almost as soon as it is launched into the choppy waters of public discourse' (Weber and Word, 2001, p.488). As a result, despite several decades of applying the so-called 'deficit model' of science communication:

> '…providing information about the need for, or characteristics of, controversial developments has not notably delivered acquiescence on the part of local communities; on the contrary, it can fuel distrust (especially if information comes from the developers), and further polarise opinions. When key considerations such as need, impacts, risks and economics are genuinely contested, 'providing the facts' is problematic.'
>
> (Owens and Driffill, 2006, p.5)

So, if conveying factual information has failed to convince people of the central role of geological knowledge in wise environmental decision-making, how do we communicate socially contested geoscientific issues? This paper explores this question, drawing its motivation from those sectors in which the public are most directly exposed to geological activities, namely mining, hydrocarbon extraction and geo-waste disposal. Its basic premise is that learning how to better translate unfamiliar geoscience information into the public (and policy) sphere requires geoscientists to better understand how people receive, perceive and process information. For several decades, beyond the fringes of Earth science, social scientists have built up a robust research base on the human and behavioural aspects of communication, and yet little of this empirical science finds its way into geocommunication thinking. Instead, all too often, geoscience professionals who routinely demand and apply evidence-based decision-making forego the 'mind sciences' in favour of ad hoc and intuitive public engagement practices, at times shaped by trial and error or forged by bitter personal experience. In the sections that follow, we outline some of the communication science perspectives that shed light on how non-technical audiences make sense of information to help establish the basis of more effective geocommunication strategies.

2. Geocognition of the subsurface realm

> '…for millenia, man has made use of the subsurface, initially with natural caves for shelter. With time, he created underground spaces for living, storage and disposal by burial, through mining to create space and more recently, by increasing use of the pore space in sedimentary rock to store gas and fluids.'
>
> (Evans et al., 2009, p.302)

Across the world, subsurface space is being exploited in an increasingly diverse set of ways. Tunnels, boreholes, underground disposal facilities and the bulk storage of materials and fuels in natural rock offer society an important resource, and with demands for a more sustainable development of human environments above ground, the 'hidden commons' below ground is likely to be put to ever more use (Evans et al., 2009).

> 'But in the future the subsurface will have greater uses and be more crowded, which will necessitate more integrated and comprehensive planning, regulation and monitoring. This will require more geological research to inform policy and regulation and to gain public engagement and acceptance.'
>
> (Evans et al., 2009, p.314).

The initial signs are that gaining social acceptance for geological activity in 'the land below ground' may be problematical. Geologists are trained to be familiar with the subsurface environment, but non-geologists must draw on very different insights. In a comparative study of the cognitive frames that 'experts' (geologists) and 'non-experts' (non-geologists) use to conceive the subsurface, Gibson et al. (2016) showed that the two groups construct markedly contrasting 'mental models'. Despite examining the lay views of a village community in south-west England with a strong historical association with underground mining, the study revealed common and persistent misconceptions about the subsurface. Local people readily imagined an anthropocentric world of shafts, tunnels and even mine buildings, but the surrounding rock was vaguely conceived, at times simply described as 'dark' or 'hot'. Individuals compensated for their lack of geological thinking by transposing clues from above ground, such as assuming that springs and rivers visible at the surface must connect below to underground rivers. The study suggests that even in a rural region with a strong cultural affinity to the subsurface there is a distinct cognitive dissonance with what lies beneath. In city environments, this discordance might be expected to be even more acute.

In exchanges among geoscientists, the implication from Gibson et al. (2016) that geologists see the subsurface fundamentally differently from lay people is not a problem, but in dialogues with the public our distinctive lens become more problematic. Our expert cognitive models accrue through years of technical training, underpinned by a growing empirical knowledge base (e.g. Bond et al., 2007, 2012), but lay cognitive models are more likely to be fashioned from wider popular culture (e.g. Liverman and Sherman, 1985). That culture – from traditional belief systems to films, literature and the all-pervasive milieu of the internet – often portrays the 'underworld' as unknown, mysterious, and even dangerous.

Although there are no cognitive studies confirming where ordinary people derive their notions about the subsurface, there is evidence that these (frequently misconceived) notions influence their thinking about geological activity. In a study on attitudes to coal mining in Kentucky USA, for instance, it was found that information communicated by mainstream film and popular media about mining is overwhelmingly negative, reinforcing outdated '*canary in the mine*' imagery of mining (Hoffman, 2013). In attitudinal surveys to carbon capture and geological storage (CCS) (Tokushige et al., 2007; Corner et al., 2014; Wallquist et al., 2012; Selma et al., 2014) and radwaste disposal (Skarlatidou et al., 2012; Wallquist et al., 2012), the concept of 'tampering with Nature' consistently emerges as one of the most dominant negative factors in social acceptance (Corner et al., 2011). In relation to CCS, one respondent complains.

> 'this business of meddling with nature, I don't like it at all; it is one thing that you start adopting solutions…that you carry on…examining solutions out here, but this business of storing down there, and that you go on ruining inside'
>
> (Oltra et al., 2010, p.700)

This concern that geological interventions below ground might be 'ruining' the subsurface environment is also encountered in lay perceptions of unconventional hydrocarbon extraction, as this exchange in a focus group discussing seismicity triggered by hydraulic fracturing (Williams, 2014, p.78) reveals:

> Interviewee 1: It's the foundation of this country and if that happens all over the country…it worries me and I think that it would make them very unstable or I'd have that feeling…
> Interviewee 2: Yeah. Well, fracture means break, doesn't it.
> Interviewee 1: Absolutely.
> Interviewee 2: You're breaking something.

A similar sentiment of geological activity inducing underground harm is apparent in investigations of social acceptance for geothermal drilling (Dowd et al., 2011, p.6306), with one participant commenting:

> 'Wasn't there two large mistakes made overseas by geothermal drillers? Didn't they cause an earthquake? That really scares me to think that we are still creating destructive harm to the earth in search of energy'.

These popular conceptions convey a sense of an apparently pristine subsurface that the public would wish to remain 'naturally untouched' or not 'unnaturally disturbed'. It reinforces the idea of a deep-seated comprehension gap between the technical conceptualisations held by geoscientists and the far vaguer imaginations formulated by the lay public (Gibson et al., 2016).

With respect to CCS, Wallquist et al. (2010, p.8561) argue that '…many people lack the basic physical and chemical understanding about CO2 and the natural conditions of the subsurface' (Fig. 2). Their study indicated a particular uncertainty with the concept of a geostatic pressure gradient, with the consequence that half of those questioned considered that CO2 storage would lead to permanent pressure change underground. Visualising underground storage more as filling a big cavern with pure CO2 rather than the more appropriate geoscientific analogy of infusing a 'sponge' of porous rock, lay respondents often envisaged CO2 injection as akin to a balloon inflating. It is a misconception that geological experts too can inadvertently foster. Shackley et al. (2004, p.133), for example, records one focus-group discussion in which a participant picked up upon an expert's use of the term 'bubble' to convey CO2 storage in an underground aquifer:

> Participant: " … you mentioned the world 'bubble' … it's looking for an escape…If it's that large, that much of an area that it's [the CO2] going to be in, it's going to be more than just catastrophic isn't it really? [if it bursts]"
>
> Geologist: "…. Well it's not explosive ……. Underground it's not a bubble and I probably shouldn't have used that word. …. We term it the CO2 bubble but it's not really a bubble because it's not existing on its own … it's actually in the rock pore spaces … there will be dissolving in some of the water, it will be reacting with some of the minerals in the rock".

Shackley et al. (2004, p.133) report how, when the geologist had left the room, the participant returned to the issue, commenting that:

> "…She scared the living daylights out of me, [saying] there's this bubble..!"

The awkward exchange between the technical specialist and the curious citizen demonstrates how important 'framing' is for public comprehension, and how critically poised social acceptance (or rejection) relies on lay perception of tricky technical detail. A study of perceptions of CCS in Switzerland similarly reported popular notions of an 'exploding balloon' in an over-pressurised storage reservoir (Wallquist et al., 2009). To address this, Wallquist et al. (2010, p.8561) recommended that:

> '…CCS communications should focus on information and images that quickly help non-experts improve their understanding and avoid information and images that might only increase risk

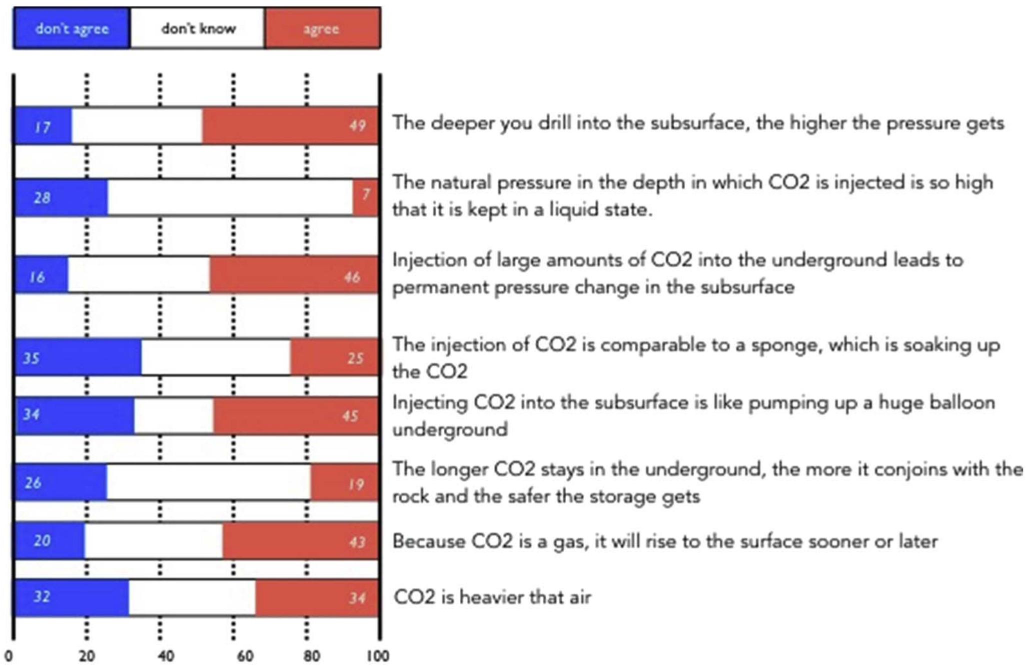

Fig. 2. Percentage of respondents who did not agree, who did not know or who agreed with each technical mental concept and belief about carbon capture and storage (CCS). From Wallquist et al. (2010)

perception without resulting in a better understanding of CCS.'

Exploring how geologists and non-geologists think about the world, especially the subsurface, is at the heart of the burgeoning research field of geocognition (e.g. Manduca and Mogk, 2006; Kastens et al., 2009; Kastens and Manduca, 2012; Manduca and Kastens, 2012; Bond et al., 2007, 2012, 2015; Bond, 2015; Gibson et al., 2016), and a critical part of that research is resolving the natural biases that influence both technical and lay judgements.

3. Bias, subjectivity and the importance of instinct

Even when salient factual knowledge about the subsurface is carefully considered and conveyed, it may not be the magic bullet in gaining informed consent from key stakeholder groups. For example, the experience with public responses to CCS has shown that even after hearing detailed scientific explanations, focus-group participants may develop negative reactions (Palmgren et al., 2004; Shackley et al., 2005; Brunsting et al., 2013). In such cases, the communication of geoscience knowledge and associated technical uncertainty has strengthened social objections among individuals who now can consider themselves 'informed'. The problem, therefore, is not so much about the information that geoscientists communicate, but rather how that information is communicated and made sense of.

An enduring narrative among the scientific community is that there is a sharp distinction between assessment of objective (correct) risks and probabilities by knowledgeable, impartial experts on the one hand and subjective (biased) evaluations by lay people on the other (Pidgeon, 1998). Several decades of social science research have sought to uncover these informal 'rules of thumb' that skew individuals' perceived knowledge. These biases ('heuristics') most commonly relate to overconfidence and neglect of prior information, and it is now generally accepted that they affect both experts and lay people alike (Slovic, 1987).

The recognition that geoscientific experts exhibit systematic biases of judgement has been explored by Baddeley et al. (2004) and Curtis and Wood (2004). The problem is well known in industry where, to temper the tendency for individuals to overly rely on their own judgments, technical evaluations are often undertaken by expert panels, though even this may not eliminate inherent biases. An instructive example is provided by an experiment in an asset-team environment in the hydrocarbon industry (Polson and Curtis, 2010). In the experiment, multiple geological experts assessed the potential of a prospective CCS reservoir. The experts were asked to interpret existing geological data and ascribe levels of certainty to the likelihood of the existence of a specific fault, reservoir and seal scenario (Fig. 3). Those individual levels of certainty were quantified three times: days before the group meeting, just after the beginning of the meeting, and immediately after the end of the meeting. During the meeting, the experts were asked, through reasoned discussion, to reach a consensus position on their joint level of certainty. Expert opinion was found to shift significantly during the process, despite the absence of any additional technical information. In some cases, an individual's expert opinion was shown to disagree with the consensus to which had just been agreed, highlighting the role that subjective judgements due to group dynamics played in the perceived 'objective' process of hypothesis formation.

The inference drawn from this and other geocognitive studies indicate that subjectivity underpins many aspects of professional geological inference. As Curtis (2012, p.96) notes

> "… the existence of subjectivity in forming hypotheses does not necessarily imply a lack of scientific rigour. When recognized explicitly, subjectivity may properly influence scientific inferences, and can also lead to novel hypotheses. Scientists should therefore not be ashamed of subjectivity, but we should strive to develop methods to quantify and sometimes to reduce its effects."

4. The role of values and beliefs

Despite the growing acknowledgement that geoscientific judgement often relies on something more than simply the technical facts, a recurring complaint among experts is that when members of the public are confronted with complex technical questions their recourse to intuitive judgements is inappropriate and misguided. (Often, this is accompanied by a lament about how the public 'don't understand uncertainty', maintaining the illusion that technical evaluations are wholly objective and impartial.) Certainly, informal biases are central to the way that people deliberate about unfamiliar geological activities, as is apparent in this response from a member of a focus group discussing seismicity induced by hydraulic fracturing (Williams, 2014, p.78).

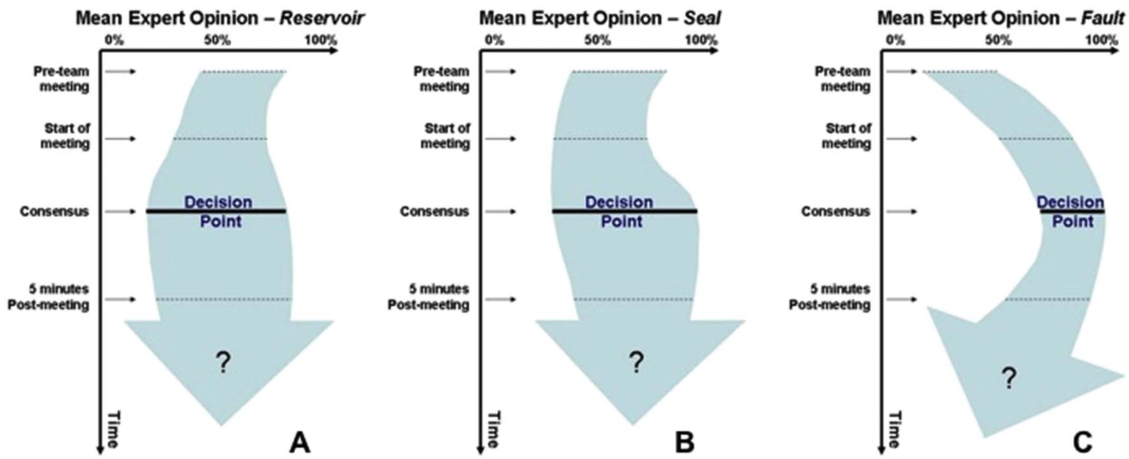

Fig. 3. Evolution of expert opinion during the structured group elicitation process of Polson and Curtis (2010). Horizontal axes: estimated probability of the existence of a specific reservoir (A), cap rock (B), and fault (C). Vertical axes show expert opinion at four points in time. Thin dashed lines show average range of experts' opinions. Bold solid lines show the group consensus on the range of probabilities, representing the decision point in a usual committee of experts.
From Curtis (2012, Fig. 1).

> It's where they're drilling and it like vibrates the Earth and it caused earthquakes and somebody was saying 'Yes it does, it's okay, it's manageable'. That was recently. My instinct went 'Oh, what are you doing? You know, it's not right. It doesn't feel right.'

In the statement above, an individual whose awkward expression suggests a weak grasp of the geotechnical process is not assuaged by the confident reassurance of a presumably expert commentator, but instead draws inwardly on an instinctive anxiety - a gut feeling about the unknown threat - to determine their objection to shale gas exploration. It illustrates how people's attitudes to scientific issues are underpinned by their deep-seated values and beliefs, as well as their lived experience.

Again, a considerable body of social science research has highlighted the importance of values in shaping people's views of socially contested scientific issues. The headline messages of this empirical evidence base are neatly summarised in a recent Commonwealth Scientific and Industrial Research Organisation (CSIRO) report (Cormick, 2014) (Fig. 4). The first message is that when information is complex, people make decisions based on their values and beliefs. The second is that people seek affirmation of their attitudes or beliefs, no matter how strange those views are - a tendency referred to as 'identity affirmation' (Kahan et al., 2011); in contrast, individuals will reject information or evidence that are counter to those attitudes and beliefs. The fact that new information consistent with one's beliefs is more easily seen as reliable and informative than information that discredits one's initial beliefs explains why beliefs change very slowly and are quite enduring in the face of contrary evidence (Nisbett and Ross, 1980). A third contends that people most trust those whose values mirror their own - often known as 'pluralistic advocacy' (Kahan et al., 2011). People tend to look to others around them for social clues on how to act, known as '*pluralistic ignorance*', which can either accentuate or decrease social acceptance of the risk of a given issue. As a consequence, individuals generally make more risky or extreme decisions as part of a group than as an individual (IRGC, 2010). The fourth is that attitudes that were not formed by logic or facts, are not influenced by logical or factual arguments.

The notion that objective analysis and rational thinking may be peripheral to deep instinct and emotional (affective) thinking in the way that people make sense of technically complex issues has important implications for how the geoscience community conveys its unfamiliar science to the public. After all, conventionally, geoscientists tend to build communication strategies around conveying clear, simple

A

B

- When information is complex, people make decisions based on their values and beliefs
- People seek affirmation of their attitudes (or beliefs) no matter how fringe – and will reject any information or evidence that are counter to their attitudes (or beliefs).
- People most trust those whose values mirror their own.
- Attitudes that were not formed by logic (or facts) are not influenced by logical (nor factual) arguments
- Public concerns about contentious science or technologies are almost never about the science – and scientific information therefore does little to influence those concerns

Fig. 4. (A) Geoscience issues relating to oil and gas extraction are a common source of social conflict, such as the protests that disrupted the 2017 Petroleum New Zealand Conference (photo credit: authors own), but (B) social science research emphasises a few headline messages of how people make decisions about complex and contested environmental concerns (after Cormick, 2014).

explanations of the technical detail at the heart of a specific issue of societal concern. They do that because that is what they have been trained to do, because it is that technical understanding that defines their own perspective on the problem and because other crucial stakeholders - regulators, engineers, planners and lawyers - still demand it. Facts and figures, simple graphics and a language uncluttered by jargon are marshalled to address public anxieties. Attention is paid to defining appropriate depth scales and time frames and to the precise explanation of key terms and concepts. The key message emerging from the social science realm, however, is very different:

> It is not enough to assure that scientifically sound information – including evidence of what scientists themselves believe – is widely disseminated: cultural cognition strongly motivates individuals – of all worldviews – to recognize such information as sound in a selective pattern that reinforces their cultural predispositions. To overcome this effect, communicators must attend to the cultural meaning as well as the scientific content of information.
>
> (Kahan et al., 2010, p.23)

The CSIRO report suggests that scientists engaging in public communication have been too reliant on the way that they themselves process information. The study discriminated four 'publics' on the basis of values and beliefs (Cormick, 2014). Most scientists would conform to the values of the most pro-science group - 'the science fans' - who viewed science and technology as important for solving society's problems and creating more social benefit than harm. A second group - the 'cautiously keen' - expressed a high interest in science but reservations on some aspects of it, while a third 'risk averse' group were conservative in their outlook, being less inclined towards science and more concerned with its potential risks. Finally, there was a 'concerned and disengaged' group who were the least enthusiastic about the benefits of science and technology and the most suspicious of its motives. The significance of this social differentiation is apparent when the groups are cross-compared (Fig. 5). The responses from the 'science fans' – arguably the most technically competent cohort – are revealed to be significantly different from the other value groups. Indeed, in terms of fundamental world views and beliefs, the other three value-groups shared more in common with each other than they did with the pro-science group. In other words, those people most keenly disposed towards science - and who see in scientific knowledge and technology the solution to societal challenges - would appear to be a skewed subsection of the wider public. In many respects, in terms of the general population, science fans, including "we scientists", are the social outliers.

The CSIRO study emphasises the critical importance of cultural cognition - an array of psychological mechanisms that pre-dispose individuals selectively to credit or dismiss evidence of risk in patterns that fit values they share with others (Kahan et al., 2011; Persson et al., 2015; Corner et al., 2014). In this context, scientists' attention to technical accuracy and emphasis on professional consensus may do little to reach or influence much of the concerned public, who have made up their mind about the issue not on the basis of the facts but on the basis of 'gut instinct' – in other words, personal, cultural and social values and experiences reinforced by consultations with friends, family and other trusted individuals around them. Consequently, the overriding message of the CSIRO study is that:

> '…public concerns about contentious science or technologies are almost never about the science - and scientific information therefore does little to influence these concerns.'
>
> (Cormick, 2014, p.20)

5. Social licence and community outrage

A €2.4 billion overrun on the 15-year Corrib gas project, Ireland's single most expensive energy infrastructure project, has been fuelled by a high level of distrust among sections of the Irish public concerning offshore oil and gas exploration, reinforced by a largely antagonistic print and social media (GSI, 2016). The principal advocate, Shell, recognized that better community engagement was required at a much earlier stage in the design process.

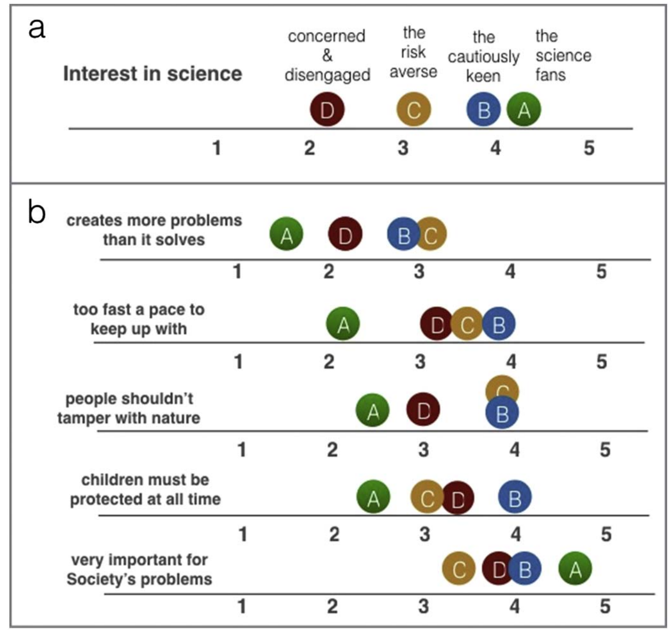

Fig. 5. (a) A recent CSIRO study in Australia discriminated four values-based 'publics' (Cormick, 2014) (1) the 'the science fans' - viewed science and technology as important for solving society's problems and creating more social benefit than harm; (2) the 'cautiously keen' expressed a high interest in science but reservations on some aspects of it; (3) the 'risk averse' group were conservative in their outlook, being less inclined towards science and more concerned with its potential risks; and (4) the 'concerned and disengaged' group were the least enthusiastic about the benefits of science and technology and the most suspicious of its motives. (b) A comparison of the value-based responses indicated that the 'science fans' are significantly different from the other value groups. In terms of fundamental world views and beliefs, the other three value-groups shared more in common with each other than they did with the pro-science group.

> "We underestimated the level of community concern and unrest… Inadequate engagement led to decisions that, in hindsight, were too legalistic in approach rather than really understanding what the concerns were, and in spending some extra time working those through… We didn't have what we might have called social licence".
>
> (Michael Crothers, Shell's managing director for exploration and production in Ireland, quoted in Murtagh, 2015)

The need for dialogue with communities is increasingly recognized by industry and proponents of contentious resource developments. A recent Chatham House dialogue suggested that a wholesale change in corporate culture needs to be undertaken in relation to delivering community benefits from extractive industries (Chatham House, 2013). According to Shell's Michael Crothers, the lesson learnt from the Corrib gas controversy was that as much attention ought to be focused on the "social seismic" up top as on actual geophysical seismic surveying down below (Murtagh, 2015). In this context, social seismic means imaging the hidden human factors that underpin community approval or disapproval for development projects.

Within the geoscience sector there is a growing research literature on securing the social licence (e.g. Thompson and Boutilier, 2011; Anderson et al., 2012; Owen and Kemp, 2013; Moffat and Zhang, 2014), but attention here is directed at lessons emerging from communication science studies. In any development project there are multiple stakeholders to win over. These typically include industry professionals, regulators (at all levels), elected civic officials (at all levels), activists (at all levels), employees, neighbours (everyone who is especially impacted by a particular issue), concerned citizens (everyone

Box 1
Public attitudes to geoscience activity in Ireland: different publics.

A recent survey of public acceptance of extractive activities (quarrying, mining, oil and gas exploration, 'fracking', etc.) in Ireland (GSI, 2016) found a range of opinions among different 'publics'. Adult attendees interviewed at a major science exhibition overwhelmingly (97%) agreed that the State should explore for and exploit as much of its own resource and energy needs as possible in Ireland, versus importing resources. They also overwhelmingly (99%) supported geological research to understand how Earth systems work. Older age groups demonstrated a higher awareness of the role of resources in society.

The science exhibition respondents were generally positively disposed (*74–94% depending on the activity*) to extractive activities, providing that strong regulation and environmental management were adopted. On whether 'fracking' should be allowed, the responses were more likely to be negative (60%) than positive (40%). Qualitative responses focused on energy and ownership of resources, reflecting a wider debate in the national media in Ireland, as well as the need for climate adaptation strategies. Almost all respondents (94%) agreed that community consultation should be undertaken concerning extraction of geo-resources in Ireland.

In a related online survey (GSI, 2016) of public administrators and activists/NGOs in community, heritage and environmental issues, 59% of responses were positive, while 41% were largely negative in their general attitudes to extractive activities in Ireland. In consideration of whether such activity was beneficial to Ireland, this cohort indicated some ambivalence, with 77% saying it had both positive and detrimental effects, and 23% saying it had negative effects. When asked whether Ireland should explore for its own resources in Ireland, a similar ambivalence was reflected with 26.5% in favour, 20.5% not in favour, and 53% saying sometimes. Attitudes to mineral exploration and mining were largely favourable (68%) with strong regulation and environmental management, while 32% were negative. 50% were broadly in favour of exploration and extraction of oil and gas in Ireland with strong regulation, with 50% broadly negative.

50% of the activist/NGO respondents had attended a public meeting pertaining to extractive activity or development in their area. Environmental impacts were of key concern (68%), as well as impacts on the locality (29%) and poor consultation process (21%).

who has indicated a desire to get involved in that issue), experts (everyone who has specialized knowledge of the issue), the media and (through the media), the rest of the public. These publics differ sufficiently from each other that they are generally considered to require targeting with bespoke, individually nuanced communication strategies.

While community engagement strategies focus on the key stakeholders that developers need to reach, conveying technical messages to these disparate groups is complicated by the awkward reality that every stakeholder grouping is itself an amalgam of multiple publics (see Box 1).

Multiple publics not only present very different levels of scientific knowledge, they also show a diverse grasp of what science (and technology) is and how it should be used. In recent years, science communication practitioners have become less interested in people's levels of science knowledge because empirical studies have shown that this 'scientific literacy' often doesn't tell us much about how individuals will engage with science-based issues in real life (Miller, 2001; Sturgis and Allum, 2004; Bauer et al., 2007; Nisbet and Scheufele, 2009). Instead, it is people's attitudes to scientific or technological issues, and their underpinning values and beliefs, that better explain why conflicting, and at times contradictory, views emerge from within the same stakeholder community.

So, if public concerns about contested scientific issues are not about the technical detail for which the scientists have expertise, then what are they about? Again, empirical human and behavioural studies have helped disentangle the social and psychological knots of individual and collective decision making. One of the most influential frameworks has been the psychometric model of risk perception (Fishhoff et al., 1978; Slovic, 1987; Slovic et al., 1991; Slovic, 2000; Fischhoff, 1995), which deconvolves the public view of 'risky' scientific issues. The psychometric appraisal of potentially harmful phenomena (Fig. 6) continues to inform public perspectives on contested geoscientific activity (e.g. Pidgeon, 1998; Frewer, 1999; Singleton et al., 2009; de Groot and Steg, 2011).

The influential 'psychometric risk paradigm' has been popularised by Sandman (1987, 1989, 1993), who contends that most local environmental controversies comprise two competing frames. The first is a technical framing of the problem, involving arguments about the scientific analysis of the hazards that are perceived to threaten a community. The second relates to the 'social risk' - the social context within which those hazards exist and the processes by which a community's concerns about them builds into anxiety, then anger, and finally outrage. The social issues that can build outrage, or reduce it, are outlined in Fig. 7.

According to Sandman (1993), when the experts and the public disagree about the technical aspects (such as the magnitude of a particular threat or its probability of occurrence), the experts are more likely to be correct. And yet, although scientists readily point out how the public often misperceives the hazard, they rarely acknowledge that they themselves pay little attention to that component of the perceived risk that is socially constructed. Public concern is frequently dismissed by technical experts as being irrational, unfounded or manipulated, even though it is evident from community protests that the resulting outrage is arguably more real and measureable than the underlying hazard. In the context of community conflicts, therefore, Sandman proposes that the technical view of risk as a product of 'hazard × vulnerability' is more usefully reformulated as being a product of 'hazard × outrage' (Fig. 8). That, in turn, sets the template for risk-communication strategies…

> 'Two things are true in the typical risk controversy: People overestimate the hazard and people are outraged. To decide how to respond, we must know which is mostly cause and which is mostly effect. If people are outraged because they overestimate the hazard, the solution is to explain the hazard better. But if they overestimate the hazard because they are outraged, the solution is to figure out why they are outraged—and change it.'
>
> (Sandman, 1993, p.9)

The lessons that emerge from a litany of community-centred environmental confrontations are that the public cares too little about the hazard and the experts care too little about the outrage.

> 'The experts, when they talk about risk, focus on hazard and ignore outrage. They therefore tend to overestimate the risk when the hazard is high and the outrage is low, and underestimate the risk when the hazard is low and the outrage is high—because all they are doing is looking at the hazard. The public, in precise parallel, focuses on outrage and ignores hazard. The public, therefore, overestimates the risk when the outrage is high and the hazard is low, and underestimates the risk when the outrage is low and the hazard is high.'
>
> (Sandman, 1993, p.8)

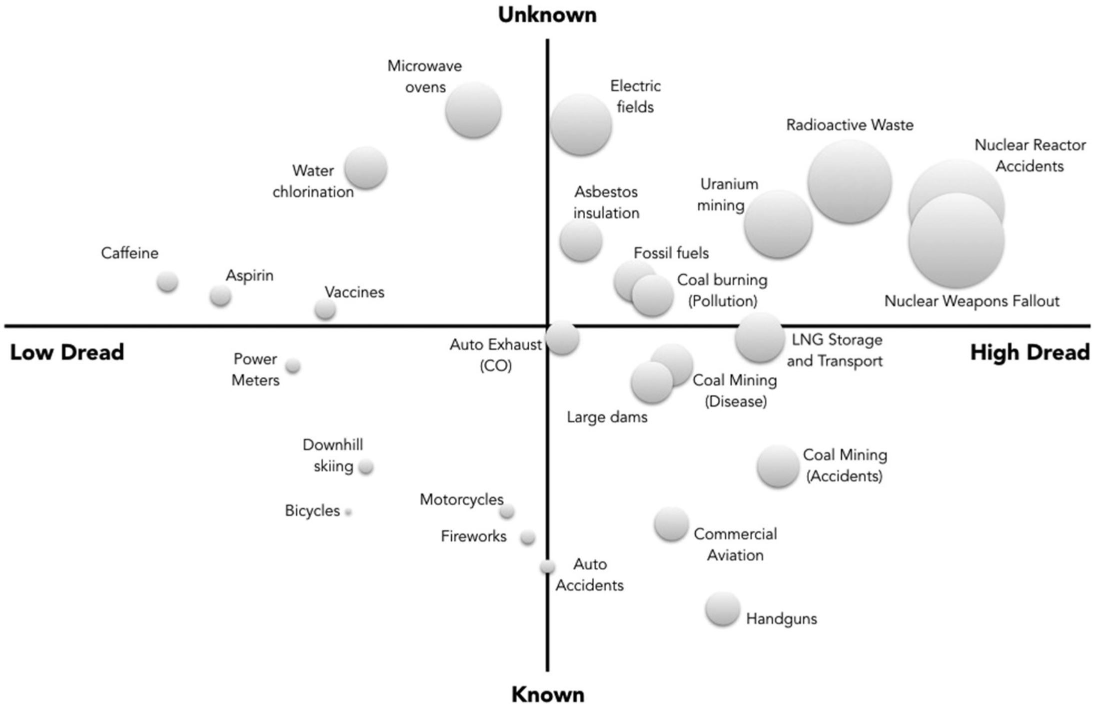

Fig. 6. A graphical representation of how the public perceives risk. This plot shows multiple hazards plotted in the psychometric framework - the amount that the hazard is regarded as ‘dreaded’ or ‘unknown’ is represented on the x- and y-axes, respectively. Based on public responses, the public's perception is indicated by the size of the point. The psychometric model predicts that the public is more accepting of less risky activities (those in the lower left quadrant), and more fearful of those in the upper right quadrant.
Redrawn from Slovic (1987).

Increases outrage if…	Reduces outrage if….
PRIMARY	
exposure coerced	exposure voluntary
agent industrial	agent natural
agent exotic	agent familiar
agent memorable	agent forgettable
consequences dreaded	consequences not dreaded
consequences catastrophic	consequences chronic
true hazard unknowable	true hazard knowable
hazard controlled by others	hazard individually controlled
exposure fair	exposure unfair
assurances, control efforts morally relevant	assurances, control efforts morally irrelevant
sources untrustworthy	sources trustworthy
process unresponsive	process responsive
SECONDARY	
affects vulnerable population	affects general population
effects delayed	effects immediate
substantial risk to future populations	no threat to future populations
victims identifiable	victims statistical
not preventable / few benefits	preventable / plenty benefits
substantial media attention	little media attention
opportunity for collective action	no opportunity for collective action

Fig. 7. List of the main factors that increase or reduce the outrage of communities facing an environmental risk controversy, such as fracking.
(From Sandman, 1993)

In the last decade, social psychologists have argued that Sandman's popular “outrage” approach - and the long-held psychometric risk model on which it is based - accounts for only a minor portion of risk perception tendencies and warrants refinement (e.g. Sjoberg, 2000). Nevertheless, Sandman's (1987) basic principles of ‘voluntariness’ (self-imposed risk), ‘control’ (personally managed risk) and ‘fairness’ (equitably distributed risk) continue to elucidate public responses to current geoscience risk controversies (La Bouchardierea et al., 2014; Graham et al., 2015; Thomson, 2015; Wheeler et al., 2015).

6. Beyond NIMBY: place attachment and public trust

The so-called NIMBY (‘Not In My Back Yard’) syndrome is a response to perceived unfairness. NIMBY is a pejorative label loosely applied by those advocating and promoting a controversial

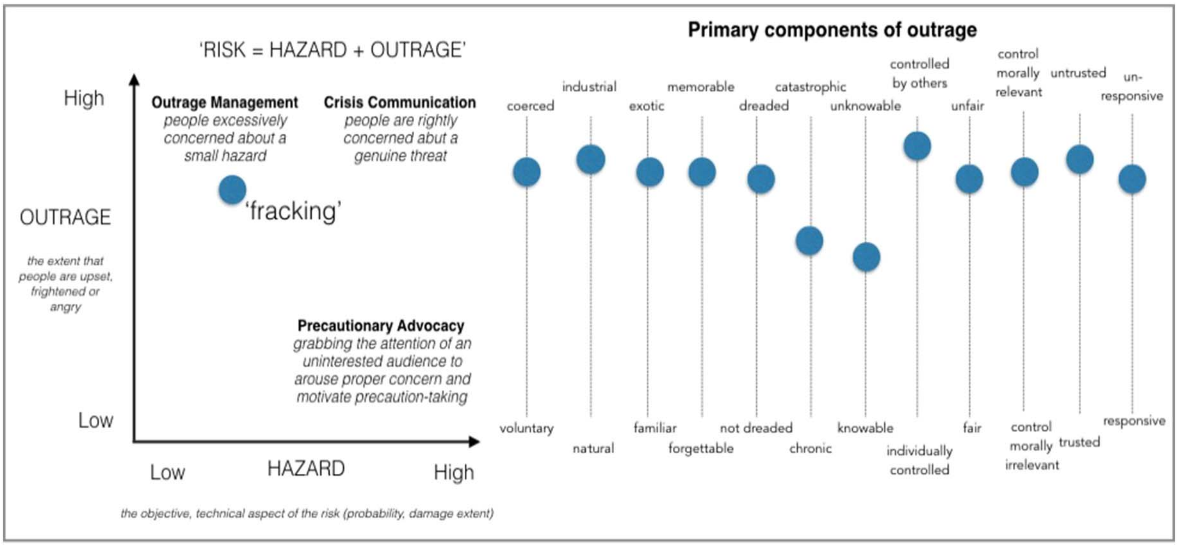

Fig. 8. In the context of community conflicts, Sandman (1993) argues that 'risk' is a product of 'hazard × outrage'. Reducing risk can be achieved by lowering outrage through adjusting the levels of the primary components of community anxiety.

development to those local citizens who oppose it, apparently on groundless safety or socio-economic concerns. Strictly speaking, to be a NIMBY, a person should be generally in favour of a technology or activity but object to it locally. But while geographic proximity to geoscience-related developments can feature prominently in local opposition (e.g. Palmgren et al., 2004), NIMBYism is a blunt and overly simplistic explanation for a lack of community acceptance (Devine-Wright, 2005, 2009). In many cases, an individual's environmental politics means that they oppose a contested geoscience activity, such as radioactive waste disposal, both locally and elsewhere (e.g. Sjoberg and Drottz-Sjoberg, 2009). In surveys of public attitudes to oil drilling in California, for example, Michaud et al. (2008) showed that people's environmental attitudes were a far stronger indicator of opposition rather than simply how close they lived to visible oil wells. Indeed, it is possible for an inverse-NIMBY situation to prevail, such as in the significant relationship evident between residence in a shale play and support for fracking (Boudet et al., 2016). It seems that lack of familiarity with a novel or contested industrial activity, rather than simple proximity, may be a more cogent descriptor of community objection (Boudet et al., 2014).

An individual's relationship with their neighbourhood, however, remains critically important in their environmental decision-making. Emotional attachment to 'place' is highly relevant in discussions of contested space and plays a significant role in the psychological response to any proposed physical change. In northern Sweden, increased forestry and mining activity in recent years has impacted heavily on local communities, including the traditional Sami people, hinging on place attachment, hunting patterns and cultural values. Where communities are already under socio-economic pressure, the imposition of 'outside' activities may induce conflict and cause fragmented communities to cleave further as place values vary among communities. Conversely, where there is strong social capital, communities may be more open to accepting the resource activity (Beland Lindahl et al., 2013). In all instances, an open and deliberative process of engagement is critical to identifying alternative pathways and resolving conflict (Beland Lindahl et al., 2016).

According to Wüstenhagen et al. (2007), community acceptance hinges on three factors: a fair decision process allowing for participation from all stakeholders ('procedural justice'); a system for sharing costs and benefits ('distributional justice'); and trust of the community in outside investors and stakeholders ('trust'). Trust has been identified in multiple studies as having a profound effect on environmental decision making by the public (Earle and Cvetkovich, 1995; Terwel et al., 2009; Hall et al., 2013) and recent research on public attitudes to geoscience activity Ireland (see Box 1 above, GSI, 2016) reinforces the central importance of scientists acting for the broader societal good. In procedural terms, public approvals and consents processes must often demonstrate due consideration of place values and environmental concerns. Procedural fairness in project development is requisite for acceptance, with transparent decision making by developers and public bodies, in which community stakeholders can have a valid and timely input. Indeed, the provisions of the 1998 UN Aarhus Convention clearly provide rights to citizens to participate in environmental decision making, including resource developments. Moreover, it includes explicit acknowledgement of the socio-cultural and even emotional dimensions of contested geoscientific issues, aspects that cannot be judged from a scientific point of view. Instead, what is required is the adoption of a participatory and non-adversarial style of community and public engagement.

7. Concluding remarks: towards communicating 'matters of concern'

Engaging with the public in a more egalitarian mode about contentious developments in their locality means seeing communication not as a traditional one-way transfer of information from the technical expert to the 'person in the street', but rather a genuine exchange between various stakeholder groups about what concerns them. In short, it requires a mindset shift from communicating 'matters of fact' to developing dialogues around 'matters of concern' (Latour, 2004). Dialogues are central to meaningful communication - acts of informing and of being informed. Interactive rather than uni-directional flows of information are more likely to promote knowledge and attitude change (Dowd et al., 2011). Scientific and technical information are necessary for this process, but are not the sole basis on which decisions or actions are made. As is evident in other contested interfaces between geoscience and society, simply explaining the technical science rarely motivates meaningful attitudinal or behavioural change among stakeholder communities (Nisbet, 2009; Solberg et al., 2010; Wood et al., 2012; Kirchhoff et al., 2013; Wachinger et al., 2013; Wood, 2014). Whether directed at the public or at policy makers, far more effective communication emerges from participatory engagement and dialogue, where individuals and communities may contribute meaningfully to the decision-making process.

And yet, a more participatory approach raises ethical dilemmas for an 'engaging' geoscientist, particularly around how to avoid persuading communities to accept something that they may not want. After all, geoscientists play a range of roles when engaging with stakeholders (Pielke, 2007); those employed by developers may be actively advocating in favour of a specific development, those working for communities or environmental groups may directly oppose it, and unaffiliated others may be advising as independent technical experts for the regulators. The usual advice is to be transparent about affiliations, but maintaining public trust in scientific advice in the battleground of community-centred politics will be difficult.

Clearly the responsibility of scientists remains the communication of balanced factual information, but the issue of what constitutes effective communication relates to the relative prominence of those facts. In climate science communication, this problem has been labelled the 'double ethical bind' (Schneider, 2002), namely, if you want to convey a scientific message in a way that gains wide acceptance for your argument then you need to assume a simplified message, one stripped of the usual technical caveats. The ethical burden that this bind places on the science communicator is very obvious:

> 'This double ethical bind we frequently find ourselves in cannot be solved by any formula. Each of us has to decide what the right balance is between being effective and being honest. I hope that means being both.'
>
> (Schneider, 2002, p.498)

Despite the obligation to honestly share information, geoscientists may be more effective in their communication by giving less prominence to factual knowledge:

> '…scientists must realize that facts will be repeatedly misapplied and twisted in direct proportion to their relevance to the political debate and decision-making. In short, as unnatural as it might feel, in many cases, scientists should strategically avoid emphasizing the technical details of science when trying to defend it.'
>
> (Nisbet and Mooney, 2009, p.56)

In a similar vein, Pielke (2007) has argued for the notion of scientist as 'honest broker' - the specialist who can integrate stakeholder concerns with available scientific knowledge in order to open up and inform a range of options. In such a context, geoscience communication ought not to be judged effective by securing public acceptance (whether that be active, passive or simply tolerance – e.g. Devine-Wright, 2009), but rather by the more intangible outcome of securing public trust. Ultimately it is more important to build trust than to build technical understanding because trust is used as a surrogate tool for the reduction of cognitive complexity. The provision of more 'information' to the public does not necessarily build understanding or increase the level of acceptance. But when accessible scientific information about a contested energy issue is presented in a well-organized social space in which lay people can form and express their opinions (e.g. citizen juries), the public can actively participate in scientific decision making (Roberts and Escobar, 2015). This supports the view of Slovic (1986, p.170) that…

> 'It appears that people understand some things quite well, although their path to knowledge may be quite different from that of the technical experts…given an atmosphere of trust in which both experts and lay persons recognize that each group may have something to contribute to the discussion, exchange of information and deepening of perspectives may well be possible.'

Critical to acting as brokers of concern rather than conveyancers of fact is the avoidance of any presumption that a good outcome from a geoscience perspective would necessarily be public acceptance of a disputed activity. The final decision about acceptance or rejection lies beyond the professional remit of the geoscientist. Yet those scientific brokers genuinely engaging with affected communities will likely have a particularly privileged place in the deliberative process because, in addition to their grasp of complex technical issues, they will be afforded a high degree of public trust. As a consequence, geoscience communication demands a strong ethical underpinning in order to stay within its remit, and it is perhaps no surprise that with the increased prominence of geoscientific issues being contested in the public realm there has emerged a resurgent research interest in 'geoethics' (Wyss and Peppoloni, 2015; Peppoloni and Di Capua, 2016; Bobrowsky et al., 2017), with an explicit recognition that:

> '…geoscientists's professional duties go beyond scientific and technological knowledge and skills. Ethics is part of their (our) professional responsibility.'
>
> Martínez-Frías et al. (2011, p.257)

For geoscientists to succeed as effective and ethical brokers of knowledge with lay communities they (we) are going to have to become better communicators (Liverman, 2008). But better communication does not simply mean explaining Earth science in plain English instead of geo-jargon, invoking compelling narratives, or using everyday imagery, metaphors and analogues to convey our unfamiliar geological ideas (Liverman, 2008; Stewart and Nield, 2013). It means communicating our know-how in novel social spaces that allow information to be presented in a facilitative, non-gladiatorial environment, while building trust among stakeholders. But it also means hearing firsthand the views of non-experts about their informal (and frequently technically misconceived) comprehension of the geoscientific issues in order to discern the real roots of local concern, and thereby reduce the propensity for community outrage. In other words, as well as having to learn how to 'speak better', geoscience communicators are going to have to learn to 'listen better'.

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