# STRATEGIC SCIENCE COMMUNICATION ON ENVIRONMENTAL ISSUES

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A growing number of researchers across social science fields are investigating the factors that influence public perceptions of climate change and other environmental issues, evaluating the implications for effective outreach on the part of scientists. Much of this research has conceptualized communication as a two-way iterative dialogue involving experts, the public, and stakeholders. By way of formal contexts such as meetings and consultation exercises, in this "dialogic" approach, members of the public are invited to be active participants in deciding what is discussed, contributing to the production of expert knowledge and/or the formulation of policy options and decisions (Nisbet & Markowitz, 2015; Dietz & Stern, 2008). A second but distinct area of research has examined "informal learning" approaches to communication across contexts such as science museums, science centers, zoos, and aquariums (Bell et al., 2009).

Over the past decade, there has emerged a third, "strategic" approach to science communication. In this line of research, social scientists examine the social and political context within which science communication and outreach takes place, identifying the factors that influence public perceptions and behavior. Drawing on this understanding, they empirically test specific messages or communication strategies that can be used by scientists and practitioners (Fischhoff & Scheufele, 2013). Research often focuses on attaining specific outcomes such as gaining public attention and generating concern about a problem; maintaining trust and overcoming cognitive biases; responding effectively to false and misleading (mis)information; and/or encouraging the public to discuss an issue and to become involved in addressing a problem.

Yet, to date, few integrated reviews of this rapidly growing field of strategic science communication research exist that clearly emphasize the practical implications for scientists and their organizations. This lack of integration persists despite the fact that many of the studies in this area have the potential to directly inform and enhance the communication and outreach activities of the scientific community. To address this gap, focusing on the U.S. context, we review four evidence-based approaches that are particularly relevant for scientists seeking to communicate with the public about climate change and other potentially contentious environmental issues. These multi-faceted strategies relate to the goals of maintaining trust in politicized debates; countering misinformation and false beliefs; tailoring information to audiences; and promoting informal conversations about environmental problems. Our review is written in a style intended to be accessible and relevant to scientists, communication practitioners, and other non-specialists.

Although not exhaustive of possible options, the four strategies we review are supported by converging lines of evidence across multiple studies, using a diversity of research methods and subjects. Strategies such as framing, narrative, or countering false beliefs have also gained considerable attention and interest from scientists and practitioners. However, as we note in this review, more research is needed on these

strategies and others, as is evaluation across particular social, cultural, and national contexts, and in relation to specific environmental issues.

## MAINTAINING TRUST IN POLITICIZED DEBATES

In forming opinions about climate change, food biotechnology, and other politically controversial issues, research suggests that rather than relying on specialized knowledge, individuals tend to rely heavily on key perceptual short cuts, particularly how much they trust scientists (Snow & Dibner, 2016). Feelings of trust are thought to have at least three key dimensions including: "integrity," the belief that a person or organization is fair and just; "dependability," a belief that an individual or organization will do what they say; and "confidence," a belief that an individual or organization can or will deliver on their promises (National Academies, 2015).

In the U.S. context, leaders of the scientific community hold comparatively high levels of trust. In 2014, 90 percent of the public expressed either “a great deal of confidence” (41%) or "some confidence" (49%) in leaders of the scientific community. Since the 1970s, as public confidence in the U.S. Congress, the presidency, industry, religious institutions, and the news media have plummeted, public faith in the scientific community has remained virtually unchanged (NSB, 2016). On climate change and food biotechnology the U.S. public also believes that scientists should have a substantially greater role to play in policy decisions than either business leaders, NGO groups, or elected officials, and that scientists are more likely to support what is best for the country (NSB, 2014).

Some evidence, however, suggests that trust in the U.S. scientific community varies in important ways across key demographic and social groups (Gauchat, 2012). Political conservatives tend to be more skeptical of so-called "impact scientists," researchers like climate scientists who examine the environmental and health impacts of economic development and technology. In contrast, conservatives tend to hold greater trust in so-called "production scientists," researchers such as engineers or chemists who produce new technologies and marketable products (McCright & Dunlap, 2010). Political liberals tend to doubt scientific advice relative to nuclear energy and natural gas “fracking,” technologies they view as furthering the interest of corporations rather than the public interest (E.C. Nisbet, Cooper, & Garrett, 2014).

When presented with information that challenges our preconceptions of the world, rather than responding with an open mind, it is easy for all of us to fall into the trap of reacting emotionally and negatively to that information. We may not only discount or dismiss such evidence; we are also likely to quickly call into question the credibility of the source. Such ‘‘systematic biasing of judgments in favor of one’s immediately accessible beliefs and feelings. . . ," write Lodge and Taber (2013), is "built into the basic architecture of information processing mechanisms of the brain’’ (p. 24). Motivated reasoning is amplified under conditions of politicization, which occurs when

groups or individuals exaggerate uncertainty or make false statements in the service of their own political goals and in an effort to shape the outcome of decision-making (Bolsen & Druckman, 2015).

What strategies can scientists and practitioners therefore use to promote trust and credibility in the face of biased reasoning and politicization? More research on this topic is needed, but in recent reviews of the available evidence, social scientists and others offer a few major principles to follow.

First, scientists are likely to harm their credibility with some audiences if they convey their findings or conclusions in a way that favors a specific policy outcome or political group over another. If the goal is to build trust across audiences with differing political perspectives, scientists should avoid defining for the public a "good" or "competent" decision or policy outcome, recommends Druckman (2015). Rather than arguing on behalf of a specific outcome, scientists should work to ensure relevant science is used or at least consulted in making a policy decision. They should communicate when possible about consensus evidence endorsed by a diversity of experts concludes Druckman (2015), make transparent how scientific results were derived, and avoid conflating scientific information with values that may vary among the public.

Drawing on his personal experience as a scientist, Donner (2014) offers a useful alternative set of recommendations. He argues against a false binary distinction between scientist and advocate, conceptualizing communication efforts as falling along a continuum. Using the example of climate change, at low end of the continuum are efforts focused exclusively on conveying scientific findings and related risks. In the middle are efforts to pair discussion of science with a call for general action, or a range of policy options. At the high end of the continuum is advocacy on behalf of a specific policy action and pursuit of different tactics to achieve that end. There is no single "correct" role for a scientist, concludes Donner (2014). He warns, however, that scientists should expect that more overtly advocacy-focused efforts at the high end of the continuum are likely to lead to a loss of credibility among some audiences. Instead, each individual must weigh where to place themselves on the continuum, taking into account factors such as career stage; intended audience; whether they work for a university, government agency, or non-profit; and their personal strengths and motivations.

Some research (Kotcher et al., 2014) has started to specifically evaluate how communication approaches falling along Donner's proposed continuum might influence perceived credibility with different audiences, and more work is merited. But if the goal is to reduce motivated reasoning and polarization generally, past studies by Kahan (2010) suggest that scientists and their organizations might be best served by adopting the role of "honest broker" (Pielke, 2007). In this case, by way of their organizations they would provide the public and decision-makers with a diverse range of solutions and

options rather than just a few. Such a strategy allows scientists to "present information in a manner that affirms rather than threatens people's values," concludes Kahan (2010).

People tend to doubt or reject expert information that could lead to restrictions on social activities that they value, but Kahan (2010) finds that if they are provided with information that upholds those values, they react more open-mindedly. For example, research by Kahan et al. (2015) shows that politically conservative individuals tend to interpret expert advice on climate change more favorably when they are made aware that the possible responses to the problem do not just include regulation and renewable energy, but also nuclear power and geo-engineering, actions that to them symbolize human resourcefulness (see also Nisbet, 2014 for discussion).

Second, regardless of where a scientist places themselves on Donner's (2014) continuum in terms of policy advocacy, Jamieson and Hardy (2014) would advise that they adopt a "leveraging, involving, visualizing, and analogizing (LIVA)" strategy to communicating about complex scientific findings. In this approach, a scientist conveys that she is "faithful to a valuable way of knowing, dedicated to sharing what she knows within the methods available to her community, and committed to subjecting what she knows and how she knows it to scrutiny and hence, correction by her peers, journalists, and the public." In an initial experiment, Jamieson and Hardy (2014) show that such a strategy has the potential to counter false beliefs about scientific consensus on climate change, even when subjects are also shown a competing news report that challenges that consensus.

Third, Fiske and Dupree (2014) recommend that scientists can maintain trust by emphasizing in communication those motives that the public rates them highly for, such as a desire to educate the public, save humanity, and save the environment. By doing so, scientists may be able to balance already high perceptions of expertise with greater perceptions of warmth, a key factor influencing feelings of trust. In contrast to Donner (2014) and in line with Druckman (2015), they also warn against scientists clearly identifying with political causes or candidates, or engaging in other overt forms of policy advocacy.

Fourth, to further promote trust, scientists should partner with others who can relate more directly to the identity and cultural background of various audiences. On climate change, for example, when audiences encounter complementary messages from military, business, public health, or religious leaders, such strategies are likely to promote a more open-minded consideration of scientific evidence among a broader cross-section of the public (Kahan, 2010).

## COUNTERING MISINFORMATION AND FALSE BELIEFS

Apart from maintaining trust in politicized debates, research has also detailed time and again the challenges that scientists face in effectively debunking myths and misinformation once they have become embedded in the minds of non-experts. If a piece of information is assessed as compatible with our view of the world or something else that we know to be true, it becomes resistant to change, as the consequences of reconciling inconsistent information is mentally uncomfortable, a process that psychologists refer to as cognitive dissonance. We often accept information that "feels right," rather than go through the difficult cognitive work of cross-checking for validity. Information that fits into a larger, coherent story, such as a conspiracy among scientists or corporations to hide the truth, is especially difficult to dislodge. In addition, when false information is consistently repeated by news media, via social media, and in conversations, it is more likely to be accepted as true, in part because hearing something multiple times (from multiple sources) builds a sense of consensus (Cook, 2016; Lewandowsky et al., 2012).

Well-intentioned but ill-conceived efforts to debunk misinformation often have the unintended effect of backfiring, reinforcing false beliefs and fostering distrust of messengers who provide the corrections (Nyahn et al., 2014; Nyhan & Reifler, 2015). Multiple factors create such backfire effects. If people understand complex issues like climate change or food biotechnology by way of the initially encountered misinformation, efforts at correction can leave gaps in understanding that are often not fully replaced. In other cases, even after hearing a correction, memory retrieval failures can lead people to recall the wrong information. Corrections can also sometimes reinforce false beliefs people were exposed to earlier (Cook, 2016; Lewandowsky et al., 2012).

Researchers have begun to identify a number of concrete strategies that scientists and their allies can use to prevent misinformation about environmental issues from being taken up by the public in the first place and that can be employed to correct existing false beliefs.

First, to prevent misinformation from taking hold, the most effective of these strategies involves "inoculating" audiences against intentional efforts to mislead the public. This goal can be accomplished by providing warnings that people may be exposed to misinformation in combination with explanations of *why* misleading information is being promoted. Research suggests that highlighting the motivations of organizations or individuals who are responsible for misleading the public on scientific issues may be particularly effective at preventing false beliefs (Lewandowsky et al., 2012).

In a series of experiments, Bolsen and Druckman (2015) find that if scientists provide warnings about future efforts to politicize an emerging issue early on, such a strategy is likely to significantly reduce the effects of subsequent misleading messages.

In a test specific to the politicization of carbon nanotubes (CNTs), Bolsen and Druckman (2015) evaluated the following warning embedded as part of a larger explainer about the topic: “Some say that it is difficult to assess the benefits of this process because people only point to evidence that supports their position. However, the assessment of CNTs should not be politicized; a consensus of scientists believes CNTs are better for the environment than other energy production methods." In contrast, simply providing a correction to false information someone has already been exposed to in a politicizing message, on its own does not do much to combat the effects of politicization. Only when people are simultaneously motivated by an advance warning to pursue accuracy goals do corrections improve uptake, conclude Bolsen and Druckman (2015). More research is needed on the inoculation strategy, including methods for identifying which emerging issues are likely to be politicized, and therefore require early efforts at inoculation to be pursued.

Second, once false beliefs are already held, dislodging them requires replacing people’s false understanding of how a phenomenon operates, with factually correct and more compelling alternative mental models. Often these alternative models must be simpler than the misinformation they are meant to replace, otherwise there is a risk that the new information will go unused. Alternative explanations must also be plausible, tell a more convincing and complete story than the original misinformation and must also try to explain where the misinformation came from in the first place, including the motivation behind misleading information.

For example, to counter the false belief that there had been an unexplained “pause” in climate change starting in 1998, researchers created an online simulation to refute the myth, emphasizing instead that the Earth in reality had continued to warm at 250 trillion joules per second. Such numeric complexity, however, on its own was unlikely to prove persuasive. So the researchers expressed this information more vividly and simply as the equivalent of four atomic bombs worth of heat released every second. The comparison was made available as an animated widget for embedding at blogs and websites (Cook, 2016; Nuccitelli et al., 2012). In some cases, inducing skepticism or distrust of certain messengers or messages can also help combat misinformation effects. Simple brief rebuttals, fostering skepticism of the misleading messenger, along with reaffirming individuals’ worldviews and personal identities, can also help avoid backfire effects (Cook, 2016; Lewandowsky et al., 2012). More research is needed on strategies to replace false mental models with correct explanations. Additional work is needed on developing decision rules for identifying which false beliefs merit countering, since it is impossible to effectively counter the vast number of false beliefs that exist.

Third, as simple as it might sound, van der Linden and colleagues (2015) argue that correcting misperceptions of scientific consensus can serve as an important "gateway belief," influencing the attitudes that people have about issues like climate change, which in turn, shape policy support and personal decisions. Even for individuals who closely follow an issue like climate change or food biotechnology, it is impossible to

track the latest scientific findings or studies, much less parse the many complexities involved. Instead, people may be more likely to use as a mental short cut what they perceive as the consensus opinion of relevant experts. Yet the problem is that many members of the public are not very good at accurately estimating the true level of scientific consensus.

Recent surveys, for example, find that only one out of ten Americans correctly estimate agreement among climate scientists about the human causes of the problem as greater than ninety percent. As a consequence, van der Linden and colleagues (2015) drawing on preliminary research findings argue that an effective communication strategy would be for scientists and others to emphasize the level of expert agreement on a contentious issue, repeating the emphasis in conversations, social media, presentations, advertising, communication campaigns, and media interviews**.**

Kahan (2015), however, raises doubt about the effectiveness of such a strategy, warning that when put into practice, consensus messaging may actually serve to deepen polarization, rather than erode it. Studies that offer respondents information about expert consensus and then ask them to answer questions about climate change do not correspond to how people are likely to encounter such information in the real world. Recent history suggests that messages about scientific consensus on climate change are often paired with attacks on Republicans elected officials and conservative groups, making it easy for right-leaning members of the public to dismiss such arguments, reinforcing their doubts and antipathy towards proposed policy actions (see also Cook, 2016 for responses to such criticism).

In all, more research is needed on the efficacy of consensus messaging, the conditions under which it is likely to be effective, and strategies for embedding such information within personal conversations, presentations, media interviews, and communication efforts. In the meantime, emphasizing scientific consensus on climate change via talking points such as "97% of climate scientists have concluded that human-caused climate change is happening" is likely to be effective with some audiences, especially those who do not strongly identify as politically conservative. Such a point of emphasis is also a comfortable talking point for most scientists to adopt, since it does not necessitate advocating on behalf of a policy position. Yet in emphasizing such information, like with other communication strategies, it is wise for scientists and their partners to avoid partisan-focused judgments or evaluations.

## TAILORING INFORMATION TO AUDIENCES

In many science communication situations, the specific goal is not to counter false beliefs, but more generally to explain a complex subject to a non-expert audience. In the absence of partnerships with social scientists on research to inform such efforts, most scientists will be left to rely on intuition to understand what members of the public want and need to know about a complex topic, or how to tailor that information so that

is understood, relevant, or persuasive (Nisbet & Scheufele, 2009). Drawing on past research, there are at least three major approaches for systematically evaluating and implementing the effective tailoring of information to audiences.

In the first "mental models" approach, researchers begin by identifying what people should know about a complex science topic by conducting a literature review and/or by interviewing experts. The second stage of this method involves interviews and surveys of specific audiences to identify their existing mental models comprised of their beliefs or understanding of a topic and the wording that they use to describe aspects of the topic. Follow-up surveys of a larger, more representative sample of subjects can further refine dimensions of the audience's mental model. Often the differences between how experts and an audience view an issue are represented in comparable conceptual diagrams or maps. By comparing the expert and lay models of the topic, scientists and their partners can identify the decision-relevant information that is missing from people's mental models. Communication materials are then developed that directly address the missing gaps in a target audience's mental model. These materials are then evaluated using focus groups and other methods (de Bruin and Bostrom, 2013).

For example, in mental models research specific to carbon capture and sequestration (CCS), initial interviews suggested that the public equated the risks of burying captured carbon emissions to those of nuclear waste, and as a result preferred investments in wind and solar power. Further, most existing communication about CCS focused exclusively on that technology, without drawing comparisons for the public to other low-emissions technologies. Research showed that the public believed that nuclear power emits $CO_2$ and that solar power was free. Drawing on this research, communication materials that addressed knowledge gaps and misconceptions about CCS and other low carbon energy technologies generated greater openness to CCS as part of a low carbon electricity portfolio (Fleishman, De Bruin, and Morgan, 2010).

Turning to a different application, Cone et al. (2013) working with U.S. Sea Grant programs used a mental models approach to identify the existing beliefs, knowledge, and attitudes of coastal property owners about the risks of climate change and the most effective ways to prepare for and adapt to those risks. The team began by conducting a literature review and interviews with experts to construct an expert model detailing coastal adaptation and resilience strategies. They then developed a local stakeholder and decision-maker model of the same topic using focus groups, meetings, and surveys involving coastal property owners.

Comparing the differences between the expert and lay models, they designed communication materials to address gaps in property owner understanding. A commonly voiced concern of local landowners was their lack of knowledge on how to make their properties less vulnerable to storm surges, sea level rise, and erosion. As a result, subsequently produced online videos shown at meetings and available online

explained how and why structural modifications could be made to a home to reduce its vulnerability to storm surge, sea-level rise, and erosion. Many participants also believed that simply coming together as a community on the topic was productive in its own right, and that the most trusted communicators were not experts, but local property owners who had already started to engage in adaptive behaviors and were skilled at sharing those experiences with others (Cone et al., 2013).

A second approach uses narrative and storytelling techniques to persuasively communicate about complex science issues. Narratives use a particular voice to set up a conflict, unresolved question, or tension relative to a science-related debate and describes action, unfolding over time, to resolve that conflict (Dahlstrom, 2014). Narratives about policy problems like climate change establish a common scientific, legal, political, or ethical framework for understanding the issues, setting the terms of debate for decisions. The narrative features a plot that ties together “characters” as heroes and villains in opposition to each other. The narrative culminates in a resolution in the form of a policy solution or a temporary fix where conflict and/or the problem is resolved (Jones, 2014).

Narratives are particularly persuasive because they describe a specific experience told through the lens of a character rather than general truths, meaning "that narratives have no need to justify the accuracy of their claims; the story itself demonstrates the claim," notes Dahlstrom (2014). "Similarly, the structure of narrative links its events into a cause-and-effect relationship, making the conclusion of the narrative seem inevitable even though many possibilities could have happened." Jones (2014) notes that communication efforts about climate change often lack a clear narrative or storyline, including heroes and villains. Instead, communication efforts have focused on the translation and simplification of scientific concepts or complex statistical trends; an emphasis on a litany of impending risks; and a diffuse set of possible benefits to action.

In a series of studies, Jones (2014) has tested specific narratives about climate change as a policy problem that reflect prevailing worldviews in American society. Interestingly, Jones consistently finds that the main effect of these selective stories is to generate emotional identification with the featured protagonists or heroes in the stories, rather than any direct effect on risk perceptions or policy preference. Instead, in those cases where attitudes and preferences are impacted, it is indirectly by way of identification with the hero. The more respondents liked a hero such as a climate scientist or political leader advocating for action, the more they believed climate change was real, that it poses a problem for them individually and society, and the more they supported the policy solution presented in the narrative.

Professional experience and formal research both suggest that narratives are often a more engaging and persuasive format for public communication about science-related issues (see Olson, 2015). Narratives, if properly constructed, can also have the

indirect impact of bolstering identification with scientists as heroes who are working to solve an environmental problem like climate change or to evaluate the risks and benefits of a technology like food biotech (Jones, 2014). But more research and practical work is needed in helping scientists and their partners create, promote, and deliver narratives that create strong character identification, that resonate with the worldviews or background of particular audiences, and as Dahlstrom (2014) notes, the ethical principles that should guide such efforts.

A third approach involves climate scientists working with social scientists to conduct research that informs the effective "framing" of complex problems like climate change. The concept of framing turns on what observers have understood for centuries: when it comes to communicating about complex issues and choices, we can often select from several different roughly equivalent interpretations, with these preferred meanings filtered by way of the background of our audience, shaping their judgments and decisions. There is no such thing as unframed information, and many scientists and science communicators by way of their writing, conversations, presentations, news interviews, social media use or other interactions are already effective at framing their opinions and positions, whether using frames intentionally or intuitively (Nisbet and Scheufele, 2009).

Frames are interpretive storylines that set a specific train of thought in motion, communicating why an issue might be a problem, who or what might be responsible for it, and what should be done about it. Framing, it should be noted, is not synonymous with placing a false spin on an issue, although some communicators do purposively distort evidence and facts. Rather, in an attempt to remain true to what is conventionally known about a complex topic, as a communication necessity, framing can be used to pare down information, giving greater weight to certain considerations and elements over others, thereby making scientific information and advice more relevant, credible, and persuasive (Nisbet, 2009).

Frames are persuasive when they link two concepts, so that after exposure to this linkage, the intended audience now accepts the concepts' connection. Yet in making this linkage, a specific frame is only effective if it is relevant, or applicable, to the audience's preexisting worldviews or identity. Nisbet (2009) proposes that scientists can partner with other professions and societal leaders to frame action on climate change in terms of moral and religious duty, benefiting economic development, or protecting and benefiting public health; such novel storylines about climate change are likely to be engaging to a broader section of the public.

Consider Pope Francis' 2015 Encyclical on climate change. By framing climate change in terms of the religious and moral duty to act, the complex issue was made more personally relevant to many Americans. Following Pope Francis' subsequent visit to the U.S, 17 percent of Americans and 35 percent of Catholics reported that the Pope's position on climate change had influenced their views. Moreover, in comparison

to six months prior to the Pope's visit, significantly more Americans were likely to say that climate change was a moral issue, a social fairness issue, and a religious issue (Maibach et al., 2015).

Effectively communicating about climate change likely requires framing mitigation-related actions in terms of specific societal co-benefits. In other words, not only would addressing climate change benefit progress on the issue but such actions would also bring other societal returns. Controlling for a number of confounding influences, research conducted across countries finds that those individuals who believe that mitigation-related actions will benefit economic development and technological innovation; or make society more compassionate and caring; are more likely to say they are willing to become politically active in support of such actions (Bain et al., 2015).

Similarly, studies conducted in the U.S. find that communicating about climate change in terms of its human health risks and the benefits to public health of mitigation-related actions is emotionally engaging to a broad spectrum of Americans (Myers et al., 2012). Other research finds that framing the impact of climate change on ocean ecosystems in terms of human health risks (rather than exclusively environmental risks) generates stronger support for regulation of the fossil fuel industry (Schuldt, McComas, & Bryne, 2016). Importantly, in each of these studies, human health risks and benefits were emphasized in terms of their local impacts, reducing psychological and social distance from the threat that often serves as a barrier to action.

To date, a common weakness in studies on framing and science communication is that they do not compare the effects of strategically designed messages in the context of competing frames emphasizing scientific uncertainty or economic costs. Thus studies may overestimate framing effects on attitude change, since they do not correspond to how most members of the public encounter information about climate change in the real world. By way of the news, social media, or conversations, individuals are likely to encounter multiple, often conflicting or competing frames. Those few studies that have examined the effects of public health or economic benefits frames in the presence of competing frames have found mixed results (McCright et al., 2016; Nisbet E.C. et al., 2013).

In all, the research on competitive framing suggest that efforts to employ novel framing strategies on climate change and other environmental issues will require sustained, well resourced, and highly coordinated activities in which the selected frames are repeated and emphasized by a diversity of trusted messengers. These efforts should also be localized and tailored to specific regions or urban areas and periodically evaluated to gauge success and refine strategy.

## PROMOTING INFORMAL CONVERSATIONS

As an effective public communication strategy, social scientists, scientists, and practitioners tend to overlook the need to promote a greater frequency of informal conversations about environmental issues. Studies show that if people are encouraged to informally discuss science and how it relates to problems like climate change, such conversations help promote more effortful processing of the information that people might encounter in the news media, online, or by way of other sources. This greater level of elaboration in turn can lead to a deeper and more sophisticated understanding of a complex issue, along with a greater ability to apply this knowledge when making decisions or offering an opinion (Eveland & Cooper, 2013).

Research also suggests that discussion of science amplifies concern about problems like climate change. In a study tracking the discussion patterns of a nationally representative sample of Americans across two years, attention to science-related news coverage was associated with more frequent conversations about science, which in turn were linked to higher levels of overall concern about climate change. This heightened concern not only was associated with subsequent attention to news coverage of science but a greater frequency of science-related conversations, which likely helped produce greater levels of worry about climate change (Binder, 2010).

Interpersonal conversations are also a key mechanism by which individuals are recruited into taking action to address a problem (Nisbet, Markowitz, & Kotcher, 2012). For example, two-thirds of Americans say they trust "family and friends" as a source of information about global warming, a proportion higher than any other group except for climate scientists (Leiserowitz et al., 2014a). Given this level of trust, when the public is asked who could convince them to take action to reduce climate change, rather than naming a political leader, expert, or organization, they are most likely to say a person close to them (Leiserowitz et al., 2013). Similarly, if asked by someone they "like and respect," a third or more of Americans say they would sign a petition about global warming, attend a neighborhood meeting to discuss actions to address the problem, or take a pledge to support a candidate that shared their views on the issue (Leiserowitz et al., 2014b).

Studies also suggest that interpersonal discussion in combination with news attention plays an important articulation function relative to public participation, providing individuals with a repertoire of arguments that can be used in conversations, in media comments, and in contacting decision-makers. This articulation function may also boost an individual's willingness to participate in various formal public engagement forums, such as a deliberative meeting, a science cafe, a citizen science project, or science festival (Goidel & Nisbet, 2006), though more research on this possibility is needed.

Given the many potential civic benefits of interpersonal conversations, what strategies are therefore available that can help spark a greater frequency of

conversations about scientific research relevant to climate change and other environmental issues?

Rather than directing their efforts to the broader public, research suggests that scientists should concentrate communication and outreach on gaining the attention of so-called opinion-leaders, individuals who have a stronger motivation for information about environmental issues, and have a special ability as a trusted source to share that information with others. By focusing on opinion-leaders, the hope is that these individuals can then pass on scientifically accurate information to their broader network of peers, talking about the topic in a way that is trusted, persuasive, and personally relevant (Nisbet & Kotcher, 2009).

Opinion-leaders rarely hold formal positions of authority and instead prove influential by way of their greater attention to a topic, their knowledge, their strength of personality, and their experience in serving as a trusted go-between among their large network of friends, colleagues, neighbors, and acquaintances. By way of these traits, opinion-leaders not only help draw the attention of others to a particular issue, but perhaps most importantly, signal how others should in turn respond or act (Nisbet & Kotcher, 2009). In their everyday interactions and via social media, scientists themselves can also serve as trusted opinion-leaders, sparking conversations and sharing information among co-workers, friends, neighbors, and acquaintances.

Specifically targeting opinion-leaders via social media may be a cost-effective and rapid way to spread science-related information, building greater engagement with an issue like climate change, even potentially cultivating new opinion leaders on the issue. In this sense, social media outreach should be conceived of as more than generating "likes" or re-tweets. Instead, involving people in forms of social media recommendation and sharing may actually socialize individuals into thinking of their role as a communicator on a topic like climate change, imparting a sense of efficacy and the skills needed to take part in various other forms of civic engagement and political activism (Roser-Renouf et al, 2014; Vraga et al., 2015).

Across studies, survey measures have been developed to reliably and validly identify individuals who hold opinion-leader traits, and shortened versions can be included in surveys of members of organizations, or distributed among email lists and social media followers. Scores on these questions can then quickly identify those individuals who have strong opinion-leader like traits (see Nisbet & Kotcher, 2009). More informally, scientists as part of their outreach activities, professional lives, and community interactions can observe and identify those individuals who appear to be key influencers and go-betweens.

Scalable models for scientists and their organizations to incorporate opinion-leaders into their outreach activities are needed. One possible example to learn from is The Science & Engineering Ambassadors program. Sponsored by the U.S. National

Academy of Sciences and the National Academy of Engineering, the program has trained and supported close to 40 scientists and engineers in the Pittsburgh, PA area. The goal of the program is to help local community members become more conversant with energy topics, gain knowledge and skills in explaining energy information to others, and improve the ability of community members to assess the validity of others' claims and conclusions. To achieve this goal, scientists and engineers involved in the program specifically target in their outreach opinion-leaders living in the Pittsburgh-area who can serve as valuable community-based go-betweens in spreading knowledge and information. These opinion-leaders span a variety of fields and sectors and include teachers, business leaders, attorneys, policymakers, neighborhood leaders, students, and media professionals. Overall, the program seeks to engage those who "participate and have reach within the local community, as well as those who have a platform for disseminating knowledge and fostering community relationships" (National Academies n.d.).

## CONCLUSION

In coming years, the significance of science and technology to understanding and managing environmental issues is only likely to grow. From the emergence of novel genetic modification techniques to the development of powerful new energy sources to discoveries about the Earth's climate, scientists will substantially contribute to societal decisions either intentionally or not.

Some scientists may prefer to remain focused on research and to let media relations officers and other communication practitioners translate their work. Yet with increasing frequency, given the stakes involved, scientists will be called upon to be the chief communicators about complex environmental problems and issues. They will be the experts who will be giving the interviews, or writing popular books, articles, or blogs. They will testify before Congress and address local community groups. Perhaps even more importantly, as senior decision-makers, many scientists are ultimately responsible for setting communication policy and strategy at scientific institutions, agencies, non-profit organizations, and philanthropic funders. These leaders need to understand how social science research can and should inform effective public communication and outreach (see Nisbet & Scheufele, 2007).

The four evidence-based strategies reviewed in this paper provide a basis and foundation to inform the work of individual scientists and their institutions, though more research is needed, especially in evaluating the activities of specific organizations relative to specific issues. These tools and approaches are by no means exhaustive, nor are they a magical key to promoting public trust, overcoming biased reasoning and false beliefs, or ensuring the use of scientific advice in making decisions, but they are a first step toward developing better informed communication strategies.

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