Dialogue on Science, Ethics, & Religion | Center for Public Engagement with Science & Technology

Scientists In Civic Life: Facilitating Dialogue-Based Communication

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

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Forward

As noted by Dr. Rush Holt, CEO of the American Association for the Advancement of Science (AAAS), "Communication is part of our mission of AAAS…[both] communication among scientists, and between scientists and the public."[1] Former AAAS president Dr. Jane Lubchenco wrote, "[Scientists] must engage more vigorously with society…But we cannot do so from lofty perches above society; we must be more integrated."[2] These comments echo prior comments by former AAAS CEO Dr. Alan Leshner, who wrote[3] that "[Scientists] need to engage the public in a more open and honest, bi-directional dialogue about science and technology…addressing not only the inherent benefits, but also the limits, perils, and pitfalls." Decades of polling indicate that the U.S. public is largely supportive of and enthusiastic about science, and hold scientists in high regard as innovators and problem solvers. Still, scientists and the U.S. public may hold strongly divergent perspectives on a wide range of issues- from energy policy, to conservation, to vaccines, to biology education. These differences are not simply a reflection of science and technology knowledge or education, but also reflect differences in worldviews, values and identity.

Though science has never been an apolitical enterprise, or one in which broader social, cultural, or economic contexts have played no role, scientists and scientific institutions increasingly recognize the need to participate in robust and constructive conversations about the role of science and technology in society. This awareness comes at a time when some scientific topics have become polarized along political, cultural or religious lines. Some scientists may understandably feel wary or ill-equipped for a larger presence in the public sphere. Others may be concerned about public engagement activities as a drain on time, energy and resources that might be better spent in research or formal teaching. These challenges can be daunting for scientists uncertain about if, where and how to involve themselves in civic dialogue. Still, engagement with diverse publics, including by scientists themselves, is critical for ensuring that new advances and discoveries in science and technology are thoroughly discussed and understood from a range of perspectives, and to ensure that scientific progress serves all of humanity.

This booklet is a product of a joint effort by two programs within AAAS- the Center for Public Engagement with Science and Technology, and the Dialogue on Science, Ethics, and Religion (DoSER) program. Both programs seek to fulfill AAAS' mission to "advance science, engineering and innovation for the benefit of all people." The booklet author and communication scholar Dr. Nisbet has drawn on a robust multidisciplinary literature to outline (a) the social context for dialogue about science and technology, (b) why an engagement approach that is centered on dialogue is particularly fruitful and important, and (c) effective strategies for public science engagement. We hope that this booklet (along with other AAAS communication and engagement resources available at www.aaas.org) will be a useful resource for scientists seeking to become more effective ambassadors for their disciplines and for science as a whole.

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1 http://thepolitic.org/an-interview-with-rush-holt-ceo-of-the-american-association-for-the-advancement-of-science/
2 Lubchenco, J. (2017). Environmental science in a post-truth world, Frontiers in Ecology, Vol 15 (1): 3.
3 Leshner, A. (2003). Public engagement with science. Science, Vol 299 (5609): 977.

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Introduction

Scientists in the U.S. today enjoy almost unrivaled communication capital. They are respected and admired by the great majority of Americans, their work is considered essential to society, and their expertise is perceived as authoritative and impartial. Motivated by the intellectual excitement they derive from their work, most scientists are committed to sharing scientific insights with the public. They want to empower others to engage with deeper questions about life, nature, and the universe, encouraging the same feelings of awe, wonder, curiosity, and beauty that they experience as part of their daily lives. Most scientists also feel a strong obligation to tell the public about the benefits of their research, including how knowledge in their fields can be translated into applications that save lives, boost the economy, and address complex problems.[1]

Yet on some issues, members of the public may discount or reject the expert input of scientists. This often occurs when scientific knowledge or innovations raise difficult social and political questions, and/or when they challenge deeply held values, beliefs, or worldviews. Moreover, for many scientists, the reasons they value science or find a subject so interesting may not be shared by those with whom they are most interested in engaging. These individuals may remember science in school as difficult, obtuse, and disconnected from real world concerns. They may perceive science as the domain of an elite few. By way of popular culture and news media portrayals, they may also hold stereotypes of scientists as brilliant and passionate, but also potentially strange, eccentric, socially awkward, and hostile (or at least indifferent) to cultural mores and values, including faith.[2] Scientists may therefore face uncertainty about how to deploy their communication capital wisely and effectively. In some cases, because of faulty assumptions or intuitions, communication efforts by scientists on high-profile issues have had limited reach or have inadvertently deepened public reservations. Scientists may also underestimate or overlook opportunities to facilitate conversations and to forge connections across their communities.[3]

Scientists are likely to be most successful at facilitating dialogue about science when they recognize themselves as members of the communities with whom they seek to engage. By one 2012 survey estimate, 44 percent of Americans say they have personally met a scientist, and 20 percent say they have a friend who is a scientist.[4] Scientists will almost always have something in common with the publics they are engaging with, such as living in the same neighborhood, town or city, sending their children to the same school, knowing the same network of friends, attending the same church, following the same sports teams, or participating in similar hobbies and cultural activities. Awareness of these human connections is critical to effective science engagement.

This booklet provides an overview of relevant research, strategies, and examples that scientists can draw on for participating in fruitful dialogue about science and society, bringing fellow scientists and people of diverse backgrounds together to spend time talking to each other, contributing to mutual appreciation and understanding of science and technology, and building new relationships. Fostering constructive public conversations about science and society can strengthen democratic processes, improve science literacy, improve decision-making, promote trust and credibility in scientific findings, provide opportunities to explore scientific issues from diverse perspectives, and encourage broad collaboration for identifying and solving problems. Scientists who engage in public dialogue can gain new insights about their research, learn about public concerns and questions about their work, improve their communication and listening skills, and develop professional contacts and social connections that benefit their careers and enrich their lives.[5]

Communication approaches that focus solely on imparting scientific information can be counterproductive.

Section I of the booklet, "The Social Context for Dialogue," reviews research on the nature of science and society debates, and how people form judgments and make decisions about complex science-related issues. Contrary to conventional wisdom, studies show that science literacy has only a loose connection to public attitudes. As a consequence, communication approaches that focus solely on imparting scientific information can be counter-productive. Instead, beliefs about contentious science issues mirror who we are socially and politically, and therefore efforts to broker more thoughtful dialogue must be sensitive to the strong role that identity plays. Section II, "Dialogue-Based Communication," reviews several approaches to dialogue that scientists can use to facilitate thoughtful conversations with a broad range of individuals. These share a focus on communication that is defined by an iterative back-and-forth process among multiple parties and stakeholders, in which non-scientists are active participants in determining what is discussed and sharing their own knowledge and perspectives on complex problems and issues. Modes of dialogue may need to be adjusted depending on the needs, background, and preferences of the individuals or groups involved. Section III, "Effective Strategies for Science Engagement," reviews evidence-based communication research that can inform approaches for public dialogue on science topics. In particular, scientists can build trust by partnering with opinion-leaders who are respected by a particular group or community, consciously emphasizing specific language or frames of reference, and by acknowledging uncertainties or limits to scientific knowledge. On a more personal level, scientists can connect around shared values and identities, by conveying sincerity and personal warmth, and by discussing their passion, curiosity, and dedication to discovering new knowledge and solving problems.

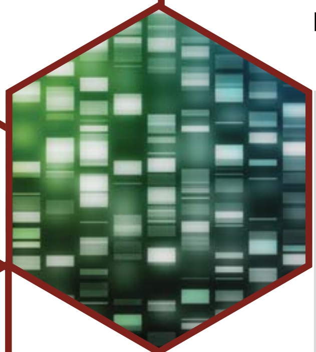
Section I: The Social Context for Dialogue

Since the 1970s, polls indicate that the great majority of Americans have consistently held scientists in high regard, voicing confidence in their leadership and believing that the societal benefits of their work outweigh any harms. In contrast, during the same period, public confidence in almost every other major institution has plummeted. Americans express similarly strong support for government funding of scientific research, recognizing the value of scientific activity to society. For decades, according to surveys commissioned by the U.S. National Science Board, about 80 percent of Americans have agreed that "even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the federal government."[6] Most technological innovations and areas of scientific inquiry take place beyond the public eye, rarely rising to gain wider attention by way of news coverage or a political decision.[7] Many that do gain notice are viewed by the public optimistically and as contributing to societal progress. For example, even during an era of tight government budgets and political distrust, approximately two-thirds of Americans have a favorable view of NASA, ranking it among the most admired and trusted government agencies. A similar proportion believe that the International Space Station has been a good investment and a majority believe that human astronauts are essential to the future of the space program.[8]

However, as some science-related issues gain political attention and news coverage, they become contentious, generating disagreement. In these cases, a view held by many scientists has been that a lack of public knowledge (or "deficit") is at the root of conflict over issues such as evolution, vaccination, stem cell research, or genetically modified foods. In this paradigm, the main goal of communication and outreach efforts should be to educate Americans about the scientific and technical details of a matter in dispute, correcting the perceived "deficit" through a process of information transmission.[9] Once deficits in knowledge are addressed, and the public is brought up to speed on the relevant science involved, the expectation is that they will be more likely to judge scientific issues as scientists do, adopting policy preferences and behaviors that are in line with their expert advice. Facts are assumed to speak for themselves and to be interpreted by all decision-makers, stakeholders, and members of the public in similar ways. If non-scientists reject these facts, then the failure is assumed to be a failure in transmission and is blamed on scientists' inability to make their work simple enough for non-experts to understand, or on journalists, advocates, "irrational" public beliefs, the public education system, or a combination of these factors.[10]

A deficit model approach to science communication is ill-suited to engaging people, especially on contentious issues. First, science is subject to constant refinement in which evaluation of competing hypotheses, debate, and scrutiny are important parts of the process. Scientific "facts" and bodies of evidence are often complex, provisional and interpretable in multiple ways even among credible experts.[11] For example, even though scientists with expertise in the field overwhelmingly agree that climate change is occurring, is human caused, and is a major threat, there is a greater degree of uncertainty about its relationship to various extreme weather events.[12] Experts also disagree over the relative efficacy of renewable energy sources like solar and wind to substantially reduce greenhouse gas emissions, and whether the benefits of nuclear energy outweigh the costs and risks.[13] An emphasis on facts rather than process does not reflect the realities of science. A need to recognize uncertainties, a normal and healthy characteristic of the scientific enterprise, is easily exploited by interest groups whose goal is to cast doubt on certain scientific conclusions in an effort to block policy action, or to promote one set of technological options over others.[14] Second, news reports and academic organizations have highlighted legitimate problems with replication in some fields of scientific research, as well as instances of scientific wrongdoing. The promises of scientific findings and their applications have at times been exaggerated or hyped. These trends, which can contribute to public distrust and cynicism, require more than just a focus on the translation of scientific evidence to address.[15] Third, even though debates such as those over genetically-modified (GM) foods or climate change focus on supposedly competing claims over scientific evidence, such claims often function as proxies for larger moral and ideological differences, such as the appropriate role of government in society, the implications of technological progress and economic growth, humankind's relationship with nature, and the balancing of personal autonomy versus societal well-being. For example, decisions regarding whose values and worldviews should determine whether government funding should be provided for embryo research, what priority climate change should take as a policy problem, whether parents should be required to vaccinate their children, or the scope and content of public school science curricula are questions that involve not only scientific considerations, but also social, political, and economic factors.[16]

Fourth, research suggests that those who perceive that they have the most at stake in a science-related decision are likely to evaluate expert advice based on a set of criteria that have more to do with trusting the source of information than trusting the evidence. In other words, the perceived credibility of the 'messenger' matters. These stakeholders unsurprisingly can feel alienated if experts have not consulted them and conveyed that their input is valued. Perceptions of science and scientists will also vary based on the institutional affiliation of the experts involved, the track record of government representatives or agencies in holding relevant parties accountable for past mistakes, and other issues that might overlap with the decision at hand (See also Box 1).[17]



Box 1. Genetically Modified Food and the Local Food Movement

Among those Americans who are most opposed to genetically modified (GM) food, values-based judgments and a set of historically overlapping issues account for their skepticism of scientific advice and their support for labeling. These attitudes cluster together with preferences for their food to be organic, vegetarian, natural, locally produced, not processed, and without artificial colors or flavors.[18] The origins of the movement date back to the 1980s and a series of food safety controversies.[19-20] Influential activists, food writers, and documentary filmmakers have sought to make connections between industrial food production, agricultural policy, and problems such as obesity, income inequality, food-borne illness, and the decline of community life.[21] Many states and cities across the country have rebuilt their economies and identities around locally owned, mostly organic farms, restaurants, and artisanal foods, efforts which are complemented by the popularity of well-known national organic brands. In 2014, U.S. consumption of organic fruits, vegetables, dairy, breads, meat, and other foods generated an estimated $35 billion in sales, more than triple the amount from a decade ago.[22] Even though the broader public remains largely unaware of GM food and the issue of labeling, the growth in the organics industry and local food economies has created a formidable alliance of farmers, entrepreneurs, and activists supporting food system reforms that include the labeling or ban of GM food. Frustrated by federal rules that do not allow the consideration of issues such as economic impacts or local control as part of the regulatory process, these interests have turned to state politics to pass state-level laws requiring the labeling of GM products. For those in this alliance, corporate-controlled, "unnaturally" produced GM food is perceived as a direct threat to their livelihood and preferred way of life, a concern that they believe has been ignored by federal regulators and many scientists.[23] Merely providing more scientific information on the relative safety or benefits of GM food, no matter how effectively communicated, is unlikely to resolve these concerns since they are rooted in issues of local autonomy and community identity.

Fifth, despite the assumed importance of science literacy to public perceptions, studies indicate only a weak link between an individual's scientific knowledge and their attitudes about politically controversial issues like vaccination, evolution, genetically modified foods, or embryonic stem cell research. Other factors such as socio-economic status, race, political identity, and religious beliefs tend to be much stronger predictors of how Americans view these issues and others.[24]

Contrary to conventional wisdom, on many issues, it is often the most scientifically literate and best-educated Americans who are the most prone to biased processing of scientific evidence, and to discounting information which contradicts their pre-existing views. Researchers have not reached a consensus on explaining this paradox, but studies suggest that strong partisans with higher science literacy and education levels tend to be more adept at recognizing and seeking out congenial arguments, are more attuned to what others like them think on a given topic, are more likely to react to these cues in ideologically consistent

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ways, and tend to be more personally skilled at offering arguments to support and reinforce their preexisting positions.[25]

For example, liberals and conservatives who score low on science literacy tend to hold equivalent levels of support for federal funding of scientific research. But as science literacy increases, conservatives grow more opposed to funding while liberals grow more supportive, a shift that is in line with their differing beliefs about the role of government in society.[26] Other studies find that better-educated conservatives who score higher on measures of basic science literacy are more likely to doubt the human causes of climate change. Their beliefs about climate science conform to their sense of what others like them believe and that actions to address climate change would mean more government regulation, which conservatives tend to oppose.[27] Better-educated and more scientifically literate liberals engage in similarly biased processing of expert advice when forming opinions about natural gas fracking, genetically modified food, and nuclear energy. In this case, their opinions reflect what others like them believe and their skepticism toward technologies associated with big corporations and industry.[28]

The polarizing effects of knowledge have also been observed in relation to religious identity and beliefs about evolution. In this case, greater science literacy predicts doubts about evolution among the most religious but acceptance of evolution among the more secular. Rather than measuring scientific knowledge, studies show that questions about evolution tend to measure a commitment to a specific religious tradition or outlook. Many in the public are aware of the scientifically correct answer to questions about evolution, but if not otherwise prompted, they are inclined to answer in terms of their religious views (See Fig. 1.1–1.4 on page 10).[29]

In a 2012 survey, when half of respondents were asked by the U.S. National Science Board to answer true or false, "Human beings, as we know them today, developed from earlier species of animals," 48 percent of those questioned answered "true." But among the other half of the survey sample, those who were asked "*According to the theory of evolution*, human beings, as we know them today, developed from earlier species of animals," 72 percent answered "true." A similar difference in response occurs when a true or false question about the big bang is prefaced with "*According to astronomers*, the universe began with a big explosion."[30] Because they are socially contested issues, asking people whether they believe in evolution or human-caused climate change is equivalent to asking people to affirm the social group with which they identify. As a result, people's responses to these questions do not reflect what people know factually about the issue, but instead reflect their core political, social, and religious identities. Furthermore, the better-educated and more scientifically literate are more adept at recognizing the connection between an issue and their group identity.[31] Over the past two decades, as political leaders, activists, and journalists have increasingly framed policy debates in terms of a right-left divide in politics, it has become easier for better-educated and more knowledgeable Americans to bundle their opinions across issues in a politically consistent manner, no matter how complex an issue might be.

In the debate over federal funding for embryonic stem cell research, diverging messages from elected officials combined with a heavy focus by the news media on these differences led to increasing polarization in how Americans viewed the issue. In 2001, as President George W. Bush debated a possible ban on federal funding for research, leaders of his party were split on the issue. Some supported funding while others sided with some religious groups in opposing funding. Following President Bush's decision to restrict funding, given conflicting

Figure 1.1

"Human beings, as we know them today, developed from earlier species of animals. (True/False)"

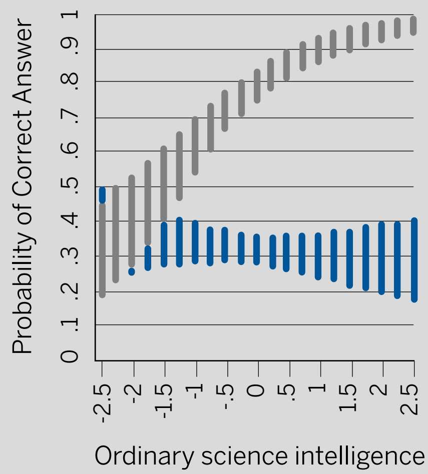


Figure 1.2

"**According to the theory of evolution**, human beings, as we know them today, developed from earlier species of animals." (True/False)

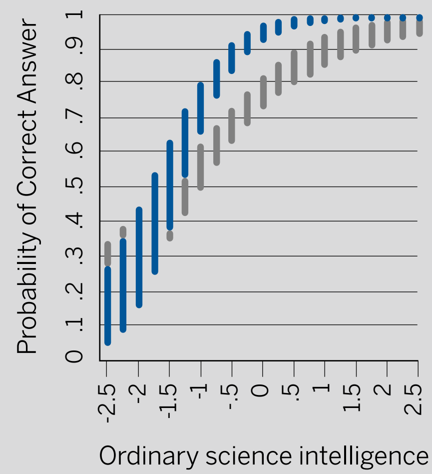


Figure 1.3

The universe began with a huge explosion. (True/False)

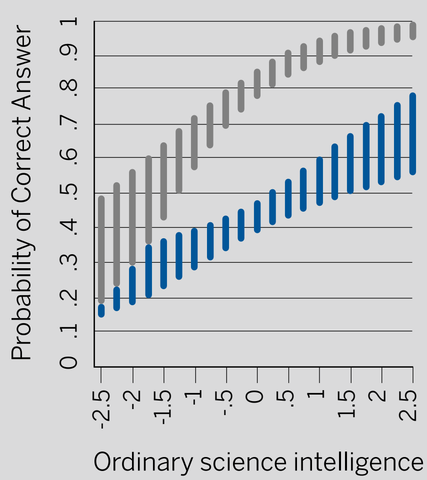
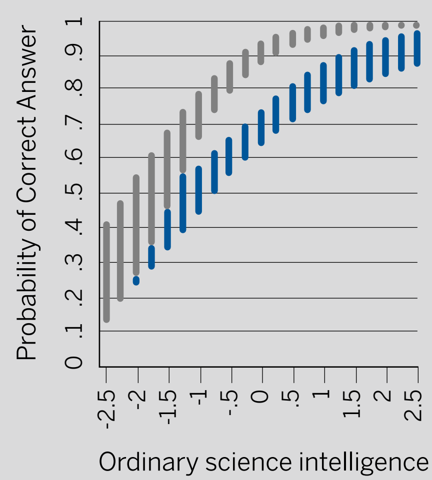


Figure 1.4

According to astronomers, the universe began with a huge explosion. (True/False)



Below Avg. Religiosity   Above Avg. Religiosity

Kahan, DM (2017). 'Ordinary science intelligence': a science-comprehension measure for study of risk and science communication, with notes on evolution and climate change. Journal of Risk Research Vol. 20 , Iss. 8.

cues among party leaders, survey studies showed that political identity had no statistically significant impact on public support for government funding. Instead, after controlling for a number of variables, religious identification and beliefs were the strongest influences on public judgments.[32]

However, in the months leading up to the 2004 presidential election, partisan differences were made readily apparent for the public by way of campaign messaging and news coverage. Polls showed that Americans became increasingly aware of the diverging positions on funding between President Bush and his Democratic challenger John Kerry, even as their knowledge of the relevant scientific, ethical, and policy considerations remained relatively low. Following the 2004 election, survey studies showed that religious identity remained a major influence on support for government funding, but in contrast to earlier years, political identity had also emerged as a substantial predictor of attitudes, with these differences being greatest among partisans holding at least a four-year college degree. Interestingly, by 2010, following President Barack Obama's decision to expand federal funding for embryonic stem cell research, polls showed that partisan differences had decreased (see Figure 2 on page 12).[33]

To summarize, during the early 2000s as elected officials and candidates from the two major political parties diverged on the issue, the best-educated and most scientifically literate among partisans aligned their beliefs to be consistent with these messages. By 2010, as political controversy on the issue subsided, the gap in how the best-educated partisans viewed the issue began to narrow.[34] Such closure suggests more understanding is needed of how controversies over science policy issues emerge and are eventually resolved. Scholars remain uncertain about the precise factors that bring a controversy like the one over embryonic stem cell research to a resolution. In many cases, closure occurs through a loss of interest by the major stakeholders involved. By the time President Obama decided to expand funding, political leaders and groups had already moved on to contest other issues such as health care reform that were deemed more politically advantageous. Absent diverging cues from their political leaders, members of the public were willing to trust in the perceived consensus of scientists and biomedical researchers on this topic. Public support for funding increased, as did the perceived moral acceptability of research. A related factor may be the discovery in 2007 of induced pluripotent (iPS) stem cells which did not require the destruction of human embryos during production, providing an ethically agreeable alternative.[35]

As complex policy choices related to gene editing and other biomedical advances are debated over the next decade, the years of polarization that occurred in public attitudes about embryonic stem cell research suggest what can happen if emerging scientific developments such as gene editing raise overarching political or ethical questions that cannot be addressed by science alone. By encouraging thoughtful dialogue to explore these concerns, scientists may be able to mitigate polarization around political, religious, or social differences. Noting broad-based public concern about the use of gene editing for human enhancement, a 2017 report from the U.S. National Academies of Sciences recommended that scientists and policymakers should facilitate ongoing input from the public regarding the benefits and risks of human gene editing and that more research was needed on how to effectively facilitate such a process. Similarly, University of California-Berkeley biochemist Jennifer Doudna, a pioneer in the field, has warned that broader discussion of the technology's social and ethical implications remains far behind the breakneck pace of its applications. Noting the risk of a public backlash, she has called for a robust global conversation about the technology, urging that

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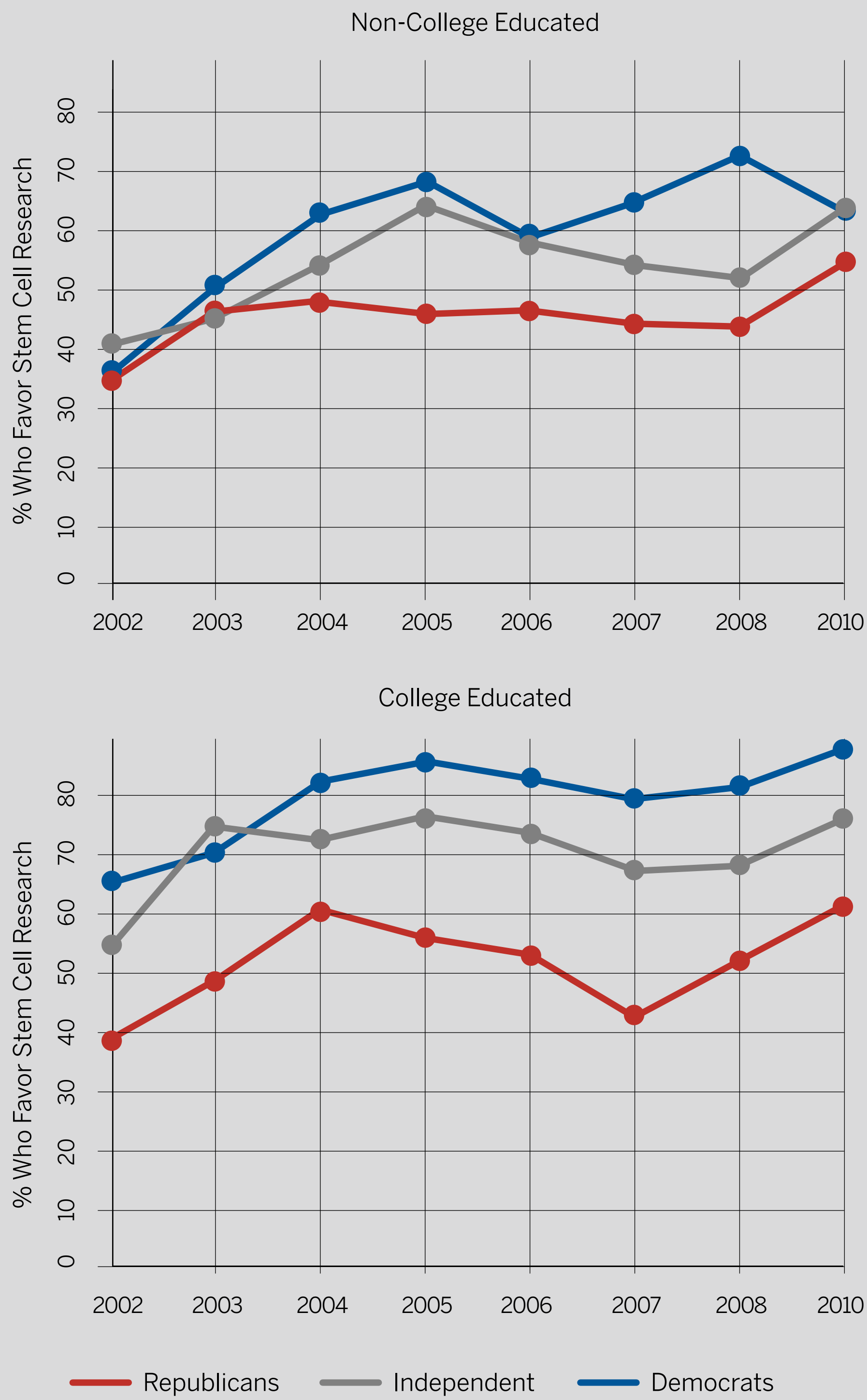
Figure 2

Polarization in Attitudes about Embryonic Stem Cell Research 2002-2010



Nisbet, Matthew, and Ezra M. Markowitz. "Understanding public opinion in debates over biomedical research: looking beyond political partisanship to focus on beliefs about science and society." PloS one 9, no. 2 (2014): e88473; VCU Life Sciences surveys, 2002-2010.

all scientists regardless of disciplinary expertise must be prepared to engage in dialogue about the far-reaching consequences of gene editing, applying the principle of “discussion without dictation” on how gene editing might be used.[36]

Scientists cannot take the trust of their audience for granted

Political polarization is not limited to longstanding debates over climate change or biomedical research, but in recent years has extended to even traditionally non-partisan issues such as infectious disease. Within a few weeks of the October 2014 outbreak of the Ebola virus in West Africa, polls showed that Americans had split in their views of the risks of Ebola. Republicans were significantly more likely to say they were worried about Ebola than Democrats. They also reported substantially less confidence in the ability of the federal government to handle the situation. Coinciding with the U.S. midterm elections, cable news and talk radio programs tended to frame the U.S. government’s response to Ebola in strongly political and partisan terms, making it easier for those Americans who may have already distrusted the Obama administration and/or who opposed that administration’s immigration policy to discount reassurances from government health officials that there was little need to worry.[37]

The role of cable news in polarizing opinions over Ebola is emblematic of long-term changes in the news media system that have accelerated in recent years. Efforts by scientists, public health officials, or other experts to clearly and thoughtfully explain the complexities and uncertainties of an issue like Ebola are in stark contrast to some of the discourse mobilized by highly visible pundits and the opinion-driven coverage that can dominate news media. Sensationalization of disease outbreaks and their consequences provoke emotional responses from audiences and may increase viewership, but reduces the ability to have a productive societal discussion about how to handle epidemics and other pressing concerns.[38]

In a polarized political culture and news media context, the proficiency with which highly educated and scientifically literate Americans will at times argue against scientific evidence that counters their existing views explains why it is so challenging to broker agreements on socially contested science issues. Media can amplify the ways that certain scientific topics become associated with individual identity related to ideology or political party. In turn, misleading arguments in the media can make it easy for an individual to reject scientific consensus or evidence because these counter-arguments may provide an alternative perspective that affirms their existing viewpoint.

There is no obvious solution to this dilemma. The tendency for people (regardless of their political leanings) to rely to some degree on group identity to make sense of contentious issues does not mean that scientists should avoid emphasizing scientific evidence, or the conclusions from research. However, it does mean that scientists cannot take the trust of their audience for granted. To effectively engage with a broad spectrum of publics about science, scientists should consider adopting specific practices that may help to defuse the biased processing of information, opening up a space for thoughtful dialogue.

Science, Inequality, and Social Identity

Since the 1970s, scientists have been fairly insulated from the forces disrupting the global economy, enjoying consistently strong employment prospects that place them among the top tier of society’s income earners. The success of the science and engineering sector has not come without profound societal implications. Scientific advances have generated career opportunities and wealth for those at the top of the knowledge economy, just as those same innovations have eliminated millions of jobs among those at the bottom, transforming entire industries and geographic regions, generating public resentment among those who have been left behind, and seeding political polarization.[39] In order to facilitate conversations with a broad spectrum of Americans, scientists involved in public dialogue must be sensitive to differences in socio-economic status, race, gender, and other forms of social identity, including their linkages to public reservations about technology or distrust of scientific advice.

Studies indicate, that enduring disparities related to income, education, and race play an important role in how individuals view the relationship between science and society. When asked generally about the societal impact of scientific advances and technological innovations, those members of the U.S. public who express the strongest optimism tend to be white, hold a college degree or higher, and rank among the top quartile in terms of income. Due to their socio-economic status, these individuals can justifiably expect that their careers will benefit from an innovation-based economy, and that they will be able to afford new technologies and medical treatments. In contrast, individuals who express the strongest reservations about science and technology tend to hold a high school degree or less, earn less than $50,000 annually, and are more likely to be non-white. These individuals may be justifiably concerned about how they will compete in an innovation-based economy, afford access to new technologies or medical advances, and how such advances may reinforce patterns of discrimination and other social disparities.[40]

The potential for public anxiety based on socio-economic disparities can be clearly illustrated in the case of driverless cars and by extension applications related to artificial intelligence (AI). These innovations are promoted as a boost for the economy, as contributing to public safety and environmental protection, and as enhancing consumer convenience- though some analysts suggest that these outcomes are not certain.[41] If these technologies develop as their advocates claim, they are likely to eliminate the jobs of millions of truck and taxi drivers, retail workers, and professionals. In a 2017 survey, when asked to consider a future in which robots and computers can do many human jobs, more than twice as many Americans (72 percent) expressed worry than enthusiasm (33 percent) and a similar proportion expected that economic inequality would become much worse as a result of such advances. Concerns about the negative impact of workplace innovations were strongest among those lacking a four-year college degree.[42] In a similar vein, Americans also express strong reservations about the impact on social inequality of biomedical innovations related to human enhancement. Strong majorities say they are "very" or "somewhat" worried about gene editing, brain chips and synthetic blood, and that these technologies would become available before they were fully understood. Much of their anxiety relates to anticipated disparities: more than 70 percent fear these innovations would exacerbate the divide between "haves" and "have-nots" because they would only be available to the wealthy.[43]

Science communication efforts that focus on informally educating the public by way of TV documentaries, popular science books and magazines, and science museums tend to engage the best-educated and highest earning Americans who on average are the heaviest consumers of these resources. These demographics tends to be already enthusiastic, knowledgeable, and optimistic about technological innovations (see Box 2). If scientists, science advocates and policymakers are to constructively engage with individuals who hold rational

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Box 2. Science News, Museums, and Knowledge Disparities

Between 2004 and 2007, as hundreds of nanotechnology-related products and applications were introduced into the U.S. marketplace, knowledge of nanotechnology increased substantially among the best educated, but declined among the least educated. These disparities in knowledge occurred even as news coverage of nanotech increased and science museums, science centers, and universities invested considerable resources in informal education and outreach activities.[44] This "knowledge gap" effect has been tracked by researchers across issues for several decades. As an emerging scientific issue like nanotech, gene editing, or artificial intelligence gains news attention and is the subject of outreach at museums and other venues, those individuals who hold higher socio-economic status tend to acquire knowledge at a faster rate than their lower status counterparts, so that the difference in knowledge between these segments tends to increase rather than decrease.[45]

There are several reasons for these disparities. First, individuals from higher socio-economic backgrounds tend to follow science-related information in the news more closely. A 2017 Pew Research Center survey found, for example, that less than 1 in 5 Americans are active science news consumers, seeking out and consuming science news at least a few times a week. This group tends to be on average better educated, higher wage earners, and predominantly white. In turn, attention to science news along with socio-economic status are the strongest predictors of whether an individual engages in other informal science education activities, such as attending a museum, taking up a science-related hobby, or participating in a citizen science project.[46] Second, through cognitive skills and knowledge acquired in formal schooling, better-educated individuals also tend to comprehend, remember, and retrieve complex information encountered in the news more efficiently and can rely on their equally well-educated friends and family members to discuss and follow up on concepts they do not understand. Third, as higher wage earners, they also possess the financial means and time to access high quality, subscription-based sources of news coverage and to pay for admission at often costly science museums and centers. Moreover, because of their greater spending power, advertising-dependent news media outlets select stories and admission-dependent museums develop exhibits that also tend to cater to the interests of higher earning Americans.[47] In 2012, 40 percent of Americans in the top quartile of wage earners said they had visited a natural history museum or a science center during the past year compared to less than 20 percent among those in the bottom quartile.[48] The knowledge gap effect has even been observed relative to TV media outreach strategies such as Discovery Channel and National Geographic Channel programs that are intended to engage broader audiences who otherwise may never consume science-related information.[49]

and legitimate concerns about technological innovations as potential drivers of inequality, they will need to turn to novel approaches for reaching segments of the public from lower socio-economic backgrounds. Examples discussed later in this booklet include working with trusted opinion-leaders to create opportunities for dialogue in 'non-scientific' contexts- including church, at work, and community events that encompass diverse spectrums of the U.S. public.

Most Americans (whether religious or otherwise) are broadly supportive of the scientific enterprise and value the role of science and technology to society.

Scientists should be sensitive to how racial and gender disparities relate to public reservations and trust and to attitudes about specific science, technology, and environmental issues. Many black, Latino, indigenous peoples and other people of color encounter systemic discrimination from an early age. School systems across the U.S. are racially segregated and often poorly resourced, limiting access by minority students to quality science education and the opportunities that accrue to those pursuing careers in science and engineering. Similarly, even informal science engagement in the form of science festivals, science centers and museums are impacted by structural inequalities, including opportunities to attend and participate in them, and perceptions of who these institutions and activities are meant to serve.[50-51] Reservations and concerns about science among underrepresented minority communities are also rooted in history, as science has been used to justify racist social policies and unethical medical experiments.[52]

Because of discrimination in housing and community development in the U.S., blacks and Latinos are substantially more likely to live near industrial sites that pose environmental health risks and to live in areas and housing that are among the most vulnerable to climate change impacts. Perhaps not coincidentally, surveys show that Latinos and blacks tend to be more concerned about climate change and other environmental threats than their white counterparts. For scientists, leaders of these communities are therefore important potential partners in efforts to engage with decision-makers about environmental problems.[53] In California, the Hewlett Foundation has funded opportunities for dialogue and relationship-building between environmental scientists, public health officials, and opinion-leaders from among the state's black and Latino communities. These opinion-leaders in turn have helped businesses in their communities and their state legislative officials understand the serious environmental risks faced by people of color in California, leading to changes in policy and business practices.[54]

Race and socio-economic status also combine to influence parental attitudes about childhood vaccination and vaccination rates across communities. In addition to careful consideration of the communication approaches used by health care providers and public health officials, scientists and science communicators should be aware of financial and other barriers that impact vaccination rates, particularly among children from low-income black and Latino households. These may include unaffordable co-payments for vaccination-related doctor's visits, limited opportunities for home visits by health care providers, vaccination services at day care facilities, schools, pharmacies and government offices, and vaccinations as part of other government benefits provided to low-income women and children.[55]

Specific to gender, women obtain more than half of U.S. undergraduate degrees in biology, chemistry, and mathematics, but fewer than 1 in 5 degrees in computer science, engineering, and physics. In fields where women are under-represented, overly-masculine cultures, perceptions of success as reflecting innate ability rather than opportunities, and early childhood experiences that favor boys over girls may account for the disparities.[56] Culturally-derived concepts of gender are also embedded in many computing algorithms which in turn can reinforce conceptions about who does science, and who science is for. For example, because AI applications such as online text translation or web search tools are based on patterns in human language, they can replicate cultural biases such as associating the words "female" and "woman" with household work, the arts, and service professions, and "male" and "man" with math, science, and programming or

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engineering professions.[57] Dialogue-based initiatives should therefore be sensitive to the possibility of gender-based differences in perceptions and trust.

Science, Religion, and Faith Institutions

Most Americans (whether religious or otherwise) are broadly supportive of the scientific enterprise and value the role of science and technology to society. When Evangelical Christians, for example, are asked about how they view the relationship between science and their faith, only 30 percent say science and religion are in conflict. Instead, a combined 70 percent see the two as either in collaboration or as independent from each other.[58] Moreover, most scientists and people of faith hold a shared commitment to service, compassion, and perseverance, values that enable collaboration on problems related to health, education, poverty, human rights, and environmental stewardship.[59]

However, apart from socio-economic and racial differences, those Americans who express the strongest optimism about the impact of science and technology on society tend to be less religious in their background. Those who hold the strongest reservations are more likely to identify as born-again or Evangelical Christian, attend church regularly, and say that religion plays a more important role in their life.[60] Americans with a greater depth of religious faith tend to express the strongest reservations when asked about debates over advances in the biomedical sciences and the teaching of evolution. A 2016 survey study, for example, indicates that Americans who say religion plays a strong role in their daily lives and who attend church and pray regularly, are more likely to oppose the use of gene editing to reduce the risk of disease among infants, the use of brain chips to enhance cognitive ability, and the use of synthetic blood to improve physical ability. When asked why they oppose these potential applications, most said they viewed them as crossing a moral boundary, and as meddling with nature.[61]

A second recent survey study indicates that among Americans who report religion playing a strong role in their daily lives, only 40 percent believe that the scientific community is capable of developing human gene editing applications in a responsible way. Seventy percent believe that scientists should consult the public before pursuing gene editing applications. Interestingly, a strong preference for consultation is also shared among those Americans who score highest in knowledge about gene editing, and who report stronger levels of news attention to the topic. In all, these trends indicate a broad public demand for dialogue and discussion about the future of gene editing.[62]

Specific to the teaching of evolution in public schools, a systematic review of U.S. polls conducted between 1999 and 2005 (a period of several high-profile legal challenges to creationism and Intelligent Design in public schools) indicated that more than two-thirds of Americans supported teaching creationism along with or instead of evolution, compared to less than a third who supported teaching evolution only.[63] For those Americans who continue to oppose the teaching of evolution, they may do so because it directly contradicts their literal interpretation of scripture. But for many who fully accept evolution, the teaching of evolution in public schools is also a complex political and legal question about which they may be ambivalent or unsure. They may be uncertain about why an overwhelming majority of scientists agree that evolutionary theory is the only appropriate explanation of life's origins to offer in a science course, and what role elected officials, parents, courts, scientific experts, teachers, or some combination of these groups should play in curriculum decisions.[64]

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Scientists and their organizations need to foster and participate in forms of dialogue about science and society across a variety of social settings.

Even for individuals who perceive no direct conflict with sacred texts, evolutionary science elicits more philosophical questions about our place in the universe, and can challenge deeply held concepts such as free will or beliefs about how the mind works. Survey research conducted in the UK and Canada show that in both countries, half of religious or spiritual people thought human consciousness could not be explained by evolutionary processes. But similar doubts were also expressed by 1 in 3 Canadian atheists, and nearly 1 in 5 U.K. atheists.[65]

Debates over biomedical research and the teaching of evolution tend to distract from the opportunities that scientists and religious Americans have to forge relationships built on common values and goals. Importantly, religion is more than just a belief system that shapes how people understand science or prioritize a problem like climate change. Churches are communication centers where information can be shared and conversations can take place about science and technology-related issues. Church leaders rely on strong interpersonal bonds and norms of stewardship to encourage their members to participate in civic-related activities. These networks are further strengthened by the moral framing of issues by church leaders, the conversations that church-goers have with others, and information provided directly when at church. [66]

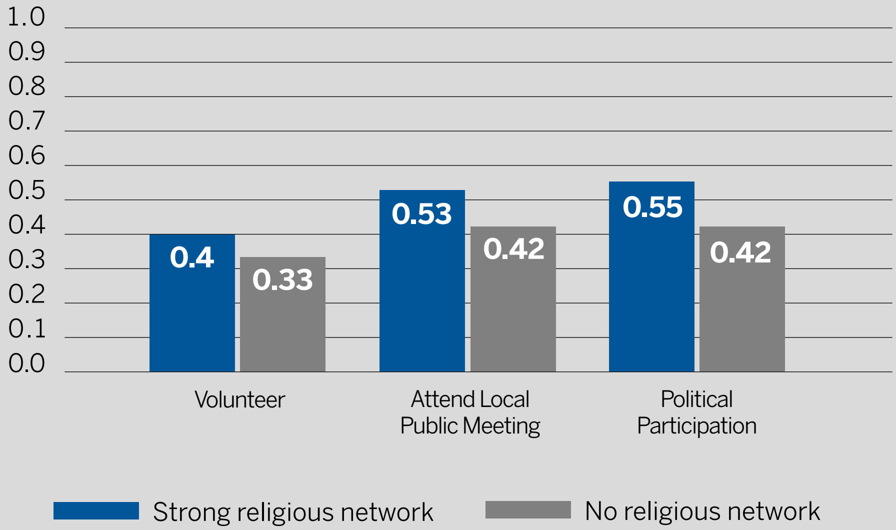
Churches and other faith institutions can therefore serve as powerful networks of civic recruitment. In such contexts, people receive requests to become involved in their communities to address problems like climate change or to voice their opinions to elected officials on topics like evolution or biomedical research. Studies show that the more requests a person receives in a social setting like a church, the higher the level of their civic and political participation.[67] Churches also indirectly provide “hard” and “soft” resources that individuals need to become involved in their communities. Examples of hard resources include a space to meet and access to computers and photocopiers. As examples of soft resources, the time that church-goers invest in building relationships with each other and in shared communal action translates into higher rates of civic participation outside of the church (see Figure 3).[68]

Recognizing the role that churches play as forums for dialogue and as catalysts for civic participation, several initiatives have invested in facilitating opportunities for church-based dialogue about science and society-related topics. For example, as part of the multi-year “Scientists in Congregations” initiative, thirty-five Christian congregations across twenty-five U.S. states (as well as congregations in Canada and France) have worked with local scientists to develop lecture series and events that cover the intersections of theology and science in relation to genetics, neuroscience, evolution, and other topics. The lectures were recorded and archived online, along with instructional materials and resources that can be adopted by other congregations.[69] The American Association for the Advancement of Science (AAAS) has partnered with several historically black church denominations, pairing local churches with local scientists to facilitate conversations across congregations about obesity, nutrition, mental health, and drug abuse prevention, among other topics, and to encourage youth to consider scientific careers in related fields. The Black Church Health Connection Project included the development of guidebooks, training videos and materials, and a searchable database of local scientist volunteers with whom church leaders could connect.[70] In similarly designed initiatives, the U.S. Centers for Disease Control and Prevention have partnered with black and Latino congregations to educate and provide services to their communities related to childhood vaccination, cancer screening, AIDS prevention, and diabetes treatment.[71]

Figure 3

Churches as Engines of Civic Engagement

Predicted probabilities of participation by religious network strength.



Source: Lewis, Valerie A., Carol Ann MacGregor, and Robert D. Putnam. "Religion, networks, and neighborliness: The impact of religious social networks on civic engagement." Social Science Research 42, no. 2 (2013): 331-346.

Apart from public health topics, church-based dialogue may be especially important for engaging U.S. Latinos about science-related issues such as gene editing, climate change, or evolution. Latinos account for 18 percent of the U.S. population, and are the second largest ethnic group behind whites.[72] A majority of Latinos (55 percent) identify as Catholic, but a growing proportion also identify as Evangelical (16 percent). Among Latino Catholics, 40 percent say they attend church weekly, and among Latino Evangelicals 71 percent say the same.[73]

Section II: Dialogue-Based Communication

Given the complexity of the relationships between science and society, and the role that social identity plays in how Americans find, use, and interpret information, traditional efforts at one-way science communication that focus primarily on filling in gaps in public knowledge are not likely to be effective. Instead, scientists and their organizations need to foster and participate in forms of dialogue about science and society across a variety of social settings. Dialogue-based approaches to communication take different forms, but each approach shares in common a few key principles.

First, communication is defined as an iterative back and forth process between various members of the public, stakeholders, experts, and decision-makers. Such approaches assume that there is no single "correct" way to talk about and understand science-related issues. Second, rather than being top-down and controlled by scientists and their partners, stakeholders and members of the public are invited to be active participants in defining what is discussed, and sharing their own knowledge and perspectives on complex problems and issues.

If scientists are to facilitate conversations about science and technology among more diverse audiences, they must also work to build relationships with trusted opinion-leaders from these groups.

Third, despite the ubiquity of using a term like "the public" when discussing science communication (including in this booklet), in reality there is no single "public" with which to communicate or engage. The general public is made up of multiple diverse and cross-cutting "publics." These include but are not limited to residents of local communities, church leaders and congregations, racial or ethnic groups, types of consumers, political identity groups like liberals or conservatives, professionals like public health workers, teachers, farmers, industry sectors, businesses, non-profits, and school groups. Each "public" may require a different mode of communication or engagement strategy, with engagement activities tailored to their needs, backgrounds, and preferences.[74] Scientists are therefore encouraged to consider the demographic background of the groups they seek to engage including characteristics related to age, race, language and cultural affiliation.

Facilitating Informal Conversations

When considering opportunities for dialogue, scientists may overlook the vital role played by informal, everyday conversations at work, church, community events, or similar contexts. Studies show that opportunities to informally discuss complex science and society issues, including potentially contentious topics such as genetically modified foods, the teaching of evolution, or gene editing, can promote more attentive processing of the information that people might subsequently 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, in expressing an opinion, or when participating in a formal dialogue event.[75]

If scientists are to facilitate conversations about science and technology among more diverse audiences, they must also work to build relationships with trusted opinion-leaders from these groups. Surveys show that scientists, science communicators, and science educators tend to be disproportionately white, male, liberal, and non-religious.[76] Like most Americans, scientists tend to live, work, and socialize within social circles that mirror their background, social identity, and religious beliefs. Such scientists are therefore likely to have fewer friends and acquaintances who are from lower socio-economic backgrounds, are black or Latino, have a conservative ideological outlook, or are churchgoers, particularly Evangelical or born-again Christians. Like-minded social circles can limit the ability of scientists to reach and communicate with people who do not share their background. Scientists therefore need to recognize ways that they can connect with others by emphasizing shared interests and values. They also need to collaborate with trusted individuals who can build bridges to groups that are difficult for scientists to reach and who can lead discussions of complex science topics in ways that are personally relevant.[77]

In facilitating productive dialogue about science topics that intersect with faith and religion, all scientists have a role to play. Regardless of their personal beliefs, when engaging in conversations with faith communities, scientists can connect around common values and interests on topics such as health, education, sustainability, and food security. Every scientist is also likely to find something in common with people and groups who live and work in their local community. As fellow residents, scientists can build connections by way of their identification with local pastimes, sport teams, entertainment choices, favorite businesses, economic trends, school districts, cultural traditions, natural resources, and climate/weather events. Moreover, though some areas of scientific inquiry such as evolution, human sexuality, or biomedical research may generate disagreements, many other areas of science do not. Even in the face of such disagreements, dialogue-based efforts can help break down stereotypes between scientists and people of faith, cultivating mutual respect and personal relationships.

Table 1. Religious Beliefs and Behaviors Among U.S./U.K. Biologists and Physicists

	U.S. %	U.K. %
Identifies with some religious affiliation	39	37
Claims to be at least a slightly religious person	30	27
I know God exists, no doubts	10	9
Reports praying once a day or more	11	9
Reports attending religious services weekly	11	8
Number of respondents	**1,779**	**1,531**
Response rate %	**57**	**50**

Note: Survey conducted during 2011/2012. Respondents include biologists and physicists affiliated with universities and research institutes. See Ecklund, Elaine Howard, David R. Johnson, Christopher P. Scheitle, Kirstin RW Matthews, and Steven W. Lewis. "Religion among scientists in international context: A new study of scientists in eight regions." Socius 2 (2016): 2378023116664353.

Scientists who are themselves already a part of faith communities may be particularly well-positioned to serve as trusted dialogue brokers. By one 2011/2012 survey estimate, approximately 11 percent of U.S. biologists and physicists say they attend church services at least weekly and a similar proportion say they hold no doubts about the existence of God. More than one-third claim a religious affiliation.[78] Through their shared beliefs and community membership, these "boundary pioneers" are likely to be effective at facilitating conversations between their fellow scientists and those members of the public who share their faith. In doing so, boundary pioneers can draw on their own experience to share insights on the relationship between science and their personal faith. For these scientists and their peers involved in post-secondary education, another successful strategy for promoting dialogue can be to use available teaching modules and resources to model thoughtful ways to think about science and faith for students in their classrooms (see also Box 7).[79]

An example of such a "boundary pioneer" is Dr. Francis Collins, currently director of the National Institutes of Health and past director of the Human Genome Project. In 2006, Collins published *The Language of God: A Scientist Presents Evidence of Belief*, a best-selling book in which he describes how as a scientist he came to believe in God. Collins introduces to readers the concept of "Biologos," a framework he uses to reconcile his Evangelical Christian faith with his scientific understanding of evolution, astronomy, biology, psychology, and other fields. Combining bios (Greek for "life") and logos" ("the word"), Collins' framework is grounded in the premise that God is the source of all life, creating the universe 14 billion years ago, but that once life began no further interventions from God were needed. For Collins, humans are not an exception to this process, sharing a common ancestor with apes, but as he emphasizes as part of his Biologos framework, there are unique aspects of human life that defy evolutionary explanation, revealing our spiritual nature.[80]

Following the publication of his book, Collins received thousands of emails asking him questions about science and scripture. In response, Collins founded the

Biologos Foundation, an organization and website (www.biologos.org) aimed at facilitating conversations about science and religion among Evangelical Christians and others. By way of explainer articles, blog posts, videos, and events, the organization focuses on common questions asked by the public or that are present in popular culture, relating each back to the Biologos framework. Examples include "Are science and Christianity at war?", "Can science and scripture be reconciled?", "Are gaps in scientific knowledge evidence for God?", and "How should we interpret the Genesis flood account?"[81]

Many religious leaders and clergy are also interested in facilitating constructive conversations among their congregations and faith communities about scientific topics. Unfortuately, clergy have historically not been likely to have formal training in how to lead thoughtful dialogue about the social implications of science. To address this gap, the AAAS Dialogue on Science, Ethics, and Religion (DoSER) program has partnered with Christian seminaries and theological schools to include more science in their core curricula as part of an ongoing "Science for Seminaries" project. Each partner seminary, in consultation with AAAS, integrates science articles, books, films, guest lectures, laboratory and research site visits, and other content into core course offerings such as biblical studies, church history, and theology. These resources are developed in collaboration with local scientists, to build and strengthen relationships with local science institutions. Short educational videos and affiliated study guides have been produced with seminaries in mind, but are freely available to the public through the AAAS website. The videos cover topics such as evolution, neuroscience, astronomy, and the nature of scientific inquiry (See also Box 3).[82] Through this project, the participating institutions are provided access to a wide range of scientific resources and perspectives, yet have the freedom to engage with the scientific topics that are most relevant to their needs and interests.

Some community opinion-leaders do not hold formal positions of authority. Instead, their influence is derived from 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. Such opinion-leaders help draw the attention of others to a particular issue. Perhaps most importantly, they also signal how others like them might think, respond, or act.[84] Consider the example of Wisconsin Green Muslims, a grassroots initiative led by opinion-leaders among the state's Muslim community. The organization sponsors a "Faith & Solar" initiative that provides information, demonstrations, and encouragement on how to install residential solar units, connecting the action to faith-based messages about cost savings, thriftiness, and environmental stewardship. The organization also promotes a "Green Ramadan" campaign that encourages Muslims to adopt a new environmentally conscious action or behavior each day of the observed holiday.[85] In a similar initiative, Interfaith Power & Light is a multidenominational partnership that encourages its member congregations to "be faithful stewards of Creation by responding to global warming through the promotion of energy conservation, energy efficiency, and renewable energy," and ensuring the voice of faith communities are heard in the environmental policy realm.[86]

For scientists seeking a systematic way to identify and work with opinion leaders across groups, survey measures informed by several studies have been developed to reliably and validly identify individuals who hold opinion-leader traits. Shortened versions of these measures 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

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Box 3. The Clergy Letter Project: Local Opinion-Leader Engagement

The Clergy Letter Project is a high-profile example of local scientists and clergy members collaborating together on behalf of efforts to constructively facilitate conversations about evolutionary science with school board members, their communities, and congregations. In 2004, concerned by the passage of anti-evolution policies by a local school board, University of Wisconsin-Oshkosh biologist Michael Zimmerman (now at Evergreen State College) reached out to a colleague's husband, Rev. John McFadden, who was pastor of a local Protestant church. Zimmerman encouraged McFadden to pen an open letter on why science and religion can co-exist. Within a few weeks, the letter was co-signed by more than 200 of the state's protestant clergy, and delivered to members of the school board. "We the undersigned, Christian clergy from many different traditions, believe that the timeless truths of the Bible and the discoveries of modern science may comfortably coexist," the letter stated. "We believe that the theory of evolution is a foundational scientific truth, one that has stood up to rigorous scrutiny and upon which much of human knowledge and achievement rests." Combined with similar statements from local parents and other community leaders, the school board eventually reversed their decision. Zimmerman then extended this collaboration to the national level. Within a year, he had recruited more than 10,000 signatories to the original letter and had helped author versions of the letter for Jewish and Buddhist clergy to adopt. At www.clergyletterproject.org, Zimmerman also created an online database listing scientists by state and zip code willing to talk to local congregations. In a related project called "Evolution Sunday" (the Sunday closest to February 12, Charles Darwin's birthday), clergy at hundreds of churches across the country devote their sermon to discussing evolution.[83] Although the Clergy Letter Project is more an example of grassroots coalition building than dialogue brokering, several of the principles involved apply to most dialogue-based communication efforts. These include identifying influential opinion-leaders and working with them as partners to craft narratives that resonate with tough-to-reach audiences, thereby unlocking mutual understanding and collaboration on behalf of shared goals.

opinion-leader-like traits. More informally, as part of their dialogue-based activities, professional lives, and community interactions scientists can observe and identify those individuals who appear to be key influencers and go-betweens.[87]

In designing initiatives that connect scientists with community opinion-leaders, one 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 science-related topics, gain knowledge and skills in explaining science-related information to others, and improve their ability to assess the validity of others' claims and conclusions. Scientists and engineers involved in the program build relationships with opinion-leaders living in the Pittsburgh-area who can serve as community go-betweens in disseminating 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."[88]

In combination with face-to-face dialogue, cultivating opinion-leaders using social media platforms can under certain conditions serve as a complementary means of encouraging conversations about science and society. Research suggests that involving people in online conversations and sharing of information with others may actually lead individuals to identify as a valuable communicator on a complex science and society topic, imparting a sense of efficacy and possession of the skills needed to take part in various other forms of civic engagement.[89] Research indicates that these platforms should complement but not replace face-to-face connections. People still tend to prefer recommendations they receive face-to-face over those they receive online. Face-to-face interactions also tend to form stronger, closer ties with others. In the absence of a strong foundation in face-to-face dialogue, initiatives that rely predomoninantly on social media may be more likely to generate misunderstanding, encourage like-minded rather than cross-cutting interactions, foster polarization, and cultivate incivility.[90]

Social media platforms can be used as a tool for enhancing face-to-face dialogue, helping to elevate attention to issues and providing information on how people can participate in public discussions, such as attending a community meeting or similar event. But as a direct source of information about science, social media may have a limited impact. Twice as many social media users say they mostly distrust rather than trust the science posts they encounter online. This sentiment is in line with a growing skepticism of social media generally, and is confounded by the tendency for social media to facilitate the spread of misinformation.[91] More research to assess strategies for fostering constructive dialogue on social media is needed. Such research should incorporate generational differences news media consumption, with younger generations more likely to use social media than older ones (see also Box 4).

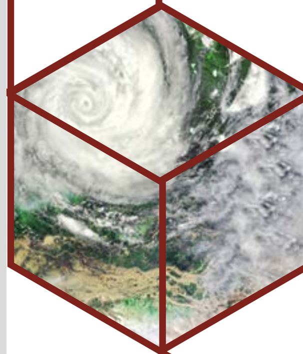
Facilitating Formal Dialogue

In combination with informal conversations about science and technology involving a diversity of opinion-leaders, scientists and their organizations can also sponsor and participate in forums and similar structured events for dialogue. Science cafes are a common type of public dialogue event. These casual forums held in coffee shops, bookstores, pubs, libraries, restaurants, and other community venues feature informal conversations between scientists and the public about current science topics. A typical science cafe is usually about 90 minutes long and involves one or more expert speakers and a moderator. Usually speakers give short presentations without visual aids, a strategy aimed at building a stronger connection with those in attendance. Science cafes, however, are likely to be limited in their reach, engaging members of the public already strongly enthusiastic about and interested in science, or who have close ties to the scientists involved and their institutions. Nevertheless, science cafes can be important opportunities for scientists to develop their communication and listening skills, especially if they have prior training.[94] For example, as part of the University of Michigan's "Learn to Relate" program, graduate students and early career scientists participate in a series of communication workshops before putting their newly acquired knowledge and skills into practice at science cafes held at local pubs and coffee shops.[95]

Science festivals are a popular and growing form of engagement now held across several dozen U.S. cities and states. Festivals bring together temporary exhibits,

Box 4. Local TV News, Metereologists and Conversations about Climate Change

As ubiquitous as social media use might be, local TV news remains an important platform by which to engage Americans in conversations about complex issues related to science and technology. For example, specific to climate change, studies have identified television news metereologists as especially important community influencers. Local TV broadcasts remain the top news source for a majority of Americans and those from lower socio-economic backgrounds (though this audience is skewed towards older Americans).[92] Most Americans say they watch the local news primarily for the weathercast. Given their training, visibility, reach, and trusted status, weathercasters as opinion-leaders hold the unique ability to describe how local weather conditions, such as heat waves, drought, or heavy precipitation, may be related to climate change. Among viewers, such descriptions are likely to prompt further discussion about weather and climate change, facilitating learning and motivation for more information on the topic. Drawing connections between local weather and climatic change is important. Research shows that when people understand that they have personally experienced the effects of climate change, they are more likely to be concerned about the issue and to support a variety of policy actions. To date, more than 250 local weathercasters in the United States representing 185 stations and 105 media markets have been recruited to include regular "Climate Matters" segments as part of their broadcasts, using easily adopted visuals that are localized to specific audiences. A longitudinal study evaluating a pilot program at a local TV station in Columbia, South Carolina, found that after one year of regular Climate Matters segments, viewers of the station's broadcast had developed a more science-based understanding of climate change than viewers of other local news stations.[93]



museum-type activities, short experiments, scientists, art organizations, students and members of the public, often attracting several thousand attendees. For example, the Wisconsin Science Festival is held each year in the state's capital in Madison, home to the state's flagship university. Festival activities also extend to cities and towns across the state. Events include hands-on interactive activities, special exhibits, lectures, films, food vendors, and opportunities for socializing and networking.[96] To prepare scientists to effectively engage with attendees at science festivals, the "Sharing Science" initiative organized by the National Informal STEM Education Network offers day-long trainings on "Sharing Science through Conversation," that focuses on avoiding jargon and facilitating conversations with attendees and "Sharing Science through Hands-On Activities," which focuses on effective interaction and relationship building around festival demonstrations.[97] As part of its annual meeting (held in a different U.S. city each year), the AAAS hosts a free Family Science Days to promote science and technology activities, education, careers and advocacy. Activities include Meet-A-Scientist forums and a range of presentations and activities. Despite the appeal and advantages of such events for participants (in terms of visibility, access, and organization), the adults who attend festivals (often with their children) tend to be strongly knowledgeable and enthusiastic about science. According to a 2012 evaluation of several major festivals, 40 percent of attendees held a Masters or doctoral degree, and half worked or studied in a science and technology related field.[98]

Other public dialogue-focused initiatives integrate contributions from scientists with those from experts specializing in the humanities, philosophy, ethics, the

> Among the most important types of organized dialogue initiatives are smaller, more intimate events that bring together scientists with other societal leaders to facilitate the sharing of perspectives.

creative arts, and journalism. Experts from the humanities and philosophy draw on literature, religious traditions, and diverse ethical frameworks to help the public consider a range of impacts and what is of value about scientific advances and technological innovations. They can also help both scientists and other publics consider how a problem like climate change may relate to their strongly held values and sense of identity. Artists, media producers, and other creative professionals have the potential to be inspiring storytellers about complex problems, communicating about issues such as climate change or biotechnology in imaginative, compelling, and novel ways. Their work can motivate different forms of learning, sponsor critical reflection and deliberation, generate empathy for others, and produce inspiring and thought provoking visions of the future.[99]

In one example that harnessed multi-disciplinary perspectives, faculty at the University of Alberta in Canada hosted workshops about the social implications of human genetic engineering among visual artists, scientists, bioethicists, social scientists, and journalists. Inspired by their conversations together, the artists were commissioned to produce visual works reflecting on the themes discussed, while the other participants were asked to write short essays. The project culminated in the artistic exhibit "Perceptions of Promise," which toured Canada and the U.S. In each country, public forums were held at museum venues, generating local news coverage of the themes expressed. The essays and artistic works were published as part of a book sold at affiliated art museums, and distributed internationally.[100] Also at the University of Alberta, a similar exhibit-based initiative titled "Immune Nations" brought together medical researchers and visual artists in an effort to promote constructive dialogue about childhood vaccination, combining art with research evidence in an effort to build public support for universal vaccination.[101] However, the same issues noted above regarding science festivals remain: art museums and books of essays may not reach publics beyond those who are already interested in science, or who are already likely to visit museums.

Among the most important types of organized dialogue initiatives are smaller, more intimate events that bring together scientists with other societal leaders to facilitate the sharing of perspectives, the forging of relationships, and the identification of common goals and values. In one example, the AAAS DoSER program organized six workshops in 2014-2015 that convened scientists and religious leaders to discuss topics of mutual concern and possible tension such as the teaching of evolution, climate change, and global health. The first three workshops held in different regions of the country focused on dialogue between scientists and Evangelical leaders. The next three involved scientists and leaders from a range of other Christian and Jewish religious traditions. To inform the discussion, focus groups were conducted in advance of the events, and the meetings were professionally facilitated. Global health and climate change were identified by many participants as topics upon which scientists and religious leaders could collaborate. Human origins, evolution, stem cell research, and human sexuality were identified as topics where agreement would be difficult, but issues about which scientists and religious leaders could understand and respect their differences. Participants also expressed that the meetings helped break down stereotypes about the "other" group, facilitating learning and relationship building.[102]

"Science in Synagogues" is a similar grassroots initiative designed to equip Jewish clergy, scientists, and laypeople with the knowledge and skills to engage in dialogue and learning about society's biggest questions, drawing on science and religion as sources of wisdom and inspiration. At synagogues and Jewish

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community centers, the program sponsors adult education courses, lectures, and events on topics exploring the intersections among Judaism, neuroscience, astronomy, evolutionary science, moral psychology, and other scientific fields. At many of these events, Jewish scientists discuss the connections between their scientific research and their faith. In more specialized forums, Science in Synagogues brings together clergy and scientists to engage in mutual learning and to design adult educational programs on topics such as "Are We Using Technology, or Is Technology Using Us?"[103]

Knowledge Co-Production Approaches

Other organized approaches to public dialogue actively involve the public in the co-production of expert knowledge and in the discussion of policy options. In perhaps the most widespread approach to knowledge co-production, citizen science projects enable members of the public to make scientific observations and collect data. Some even involve the public in the definition of research questions, the interpretation of data, and broader translation and policy efforts. Emerging information science technologies and software, including smartphones, easy-to-use graphical user interfaces and web-based data management systems have allowed citizen science initiatives to grow both in scope and quality.[104] In the "GalaxyZoo" project, for example, hundreds of thousands of citizen scientists have helped astronomers quickly and reliably classify thousands of images of galaxies. The contributions of citizen scientists to the identification of galaxies has enabled astronomers to more efficiently use valuable observatory time, leading to the publication of more than 50 scientific papers.[108] In a similar way, the "Chimp & See" project[105] allows participants to score video data collected from camera traps in wild habitats across central Africa. The goals for this project include assessing the density and distribution of animal species (particularly chimpanzees), as well as developing and testing hypotheses about the behavior and ecology of the animals recorded. Discussion boards allow citizen scientists to ask questions, post ideas, and discuss challenges of the research with the lead scientists.

Cultural beliefs and practices, including traditional ecological knowledge (TEK) in indigenous communities, or activities drawn from spiritual or religious perspectives, can sometimes directly inform scientific inquiry and practice. The U.S. Fish and Wildlife Service incorporates TEK perspectives into wildlife and forestry management.[106] The Ecological Society of America hosts a TEK section[107] which includes among its goals "to promote the understanding, dissemination and respectful use of traditional ecological knowledge in ecological research, application and education" and "to facilitate communication among people with diverse ways of knowing, both within ESA and between ESA and other communities." [108] In another example, the investigation of meditation as a form of mental and physical therapy has involved thoughtful collaboration between religious leaders and scientists (see Box 5 on page 28).

University-led Engagement

At many land grant universities, cooperative education in the form of agricultural extension and Sea Grant offices is a second widely used approach to knowledge co-production. The emphasis in these programs is on trust building and social learning, using existing university-affiliated infrastructures, networks, resources, and expertise to facilitate an iterative, two-way exchange of knowledge and perspectives. Expert advice and techniques on issues such as innovations in farming practices, energy conservation, and coastal resilience strategies are provided to relevant professionals and stakeholders. These groups in turn provide feedback to university representatives and experts on what is likely to work. This process involves not only consulting the public about specific concerns, needs,

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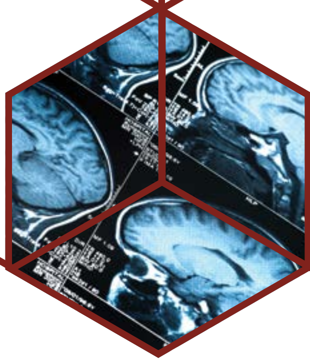

Box 5. Buddhism and the Scientific Study of Stress Reduction

Many citizen science approaches co-develop scientific knowledge by way of observations and inputs from a broad network of non-scientists. By contrast, in the health sciences, the growing field of Mindfulness-Based Stress Reduction is an example of scientific knowledge that has been generated by way of a dialogue between scientists and religious leaders. This decades-long collaboration has transformed meditation from a ritual rooted in Buddhist tradition into a scientifically-grounded health-promotion practice. An influential figure in the acceptance of mindfulness as a secular and scientific practice is molecular biologist Jon Kabat-Zinn. After being introduced to meditation by a Zen missionary as an undergraduate student, he ultimately helped transform the practice into a clinical intervention, enabling mental, physical, and behavioral outcomes to be evaluated and published in peer-reviewed literature.[109]

To gain legitimacy within the medical community, Kabat-Zinn understood that he needed to strip his approach of any overt religious connections, framing mindfulness as a mental skill acquired through meditation that involves "paying attention in a particular way; on purpose, in the present moment, and nonjudgmentally." By promoting mindfulness, meditation could help patients manage the suffering associated with illness, reasoned Kabat-Zinn, by enabling them to be more accepting of their experience, which in turn would lessen pain, anxiety, and depression. Though not necessarily a replacement for more traditional medical treatments, some meditation research suggests it has utility as a tool to help speed the recovery process and in preparing patients to navigate their experiences and future decisions.[110] Today, more than 600 studies are published annually on meditation and mindfulness suggesting that a collaborative approach was successful in encouraging the scientific community to investigate meditation as a form of medical treatment.[111]

and specialized knowledge, but also recruiting opinion-leaders and early adopters of best practices among these groups to influence their peers. In all, the networks maintained by university-based cooperative education programs offer tailor-made opportunities for scientists and their collaborators to engage in dialogue with a broad spectrum of publics.[112]

In knowledge co-production approaches developed by sustainability science researchers, public consultation starts early with the identification of relevant research questions and lines of inquiry that integrate the needs and questions of relevant stakeholders and policymakers. This type of early "upstream engagement" often takes time. Yet, if successful, as the research is eventually produced, at the final "downstream" stage it will be perceived as having greater value by policymakers and the public, and therefore be easier to communicate and translate. In a leading example, the George W. Mitchell Center for Sustainability Solutions at the University of Maine has developed elaborate upstream consultation methods in studying state-wide decisions related to river dam removal, invasive species, the development of tidal wave power and offshore wind projects, the management of lobster fisheries, and the safety of beaches. Mitchell Center projects involve physical scientists, engineers, economists, anthropologists, and communication scholars working together to understand the physical, social, and human dimensions of sustainability issues. This interdisciplinary process extends from the campus into communities, organizations, and state agencies, as Maine residents, professionals, and stakeholders are consulted early on in

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the problem definition process through the implementation stage. This two-way interaction enhances expert understanding while building relationships of trust and networks of communication.[113]

Some approaches to knowledge co-production involve directly consulting the public on emerging areas of research and novel technologies. In these conferences, deliberative forums, and town meetings, recruited members of the public typically receive background materials in advance, provide input on the types of questions they would like addressed at the meeting, and then provide direct input on recommendations about what should be done in terms of research directions or policy. Each format, however, varies by how participants are asked for feedback, how much their feedback matters, and exactly when in the progression of a science-related issue consultation occurs. Such efforts conducted early on in the development of a technology can involve various groups in important exploratory conversations that identify and anticipate social, political, and ethical concerns. [114]

For example, in 2008, Johns Hopkins University organized public meetings and focus groups in several U.S. cities in order to consult the public on a proposed national biobank that would collect human tissue and genetic material to be used in medical research. Participants were asked about privacy protections and the possible misuse of personal information, donor consent agreements, and whether donors would be able to receive research results back from the study.[115] Importantly, forum participants were diverse (>40% non-white) and drawn from a broad spectrum of education levels (only ~55% had a bachelor's degree or higher). Among those who participated, most believed that the biobank should go forward, and more than half indicated they were likely to donate to the bank if asked. Similar deliberative-style approaches have also been used to consult the public on nanotechnology. More recently, at the University of Wisconsin-Madison, organizers used a consensus conference format to divide locally recruited senior citizens, college students, and other area residents into "expert groups" and "lay groups." The expert group researched one aspect of nanotechnology and presented it to the lay group whose objective was to ask clarifying questions, discuss among themselves, and reach a consensus recommendation on nanotech's benefits and risks. Following the event, apart from appreciating the opportunity to learn, participants also said they valued hearing what others had to say and having a voice on the topic.[116]

Other studies evaluating similar dialogue-based public consultations find that participants not only learn directly about the technical aspects of the science linked to the topic discussed, but perhaps more importantly, they also learn about the social, ethical, and economic implications of the issue. Participants also feel more confident and efficacious about their ability to participate in science decisions, perceive relevant institutions as more responsive to their concerns, and say that they are motivated to become active on the issue if provided a future opportunity to do so. Such dialogue-based forums, if carefully organized, can demonstrate scientists' openness to feedback and respect for public concerns. Such perceptions that predict eventual acceptance and satisfaction with a policy decision, even if the decision is contrary to an individual's original preference.[117]

Section III: Effective Strategies for Science Engagement

In combination with these approaches to facilitating public dialogue, over the past decade a growing body of research has tested specific types of communication strategies that can be used by scientists and science communicators to achieve a number of related goals. When incorporated into public dialogue approaches

> Distrust of expert advice is most likely to occur when an individual or group perceives science as being used to support actions that threaten their values, sense of identity, or strongly held beliefs.

and activities, the "science of science communication" can aid in communicating personal, religious, cultural, or political relevance; and in building and maintaining trust. These evidence-based strategies can be used by scientists and practitioners in their informal conversations with the public and non-scientists, but they can also be used as part of the design of formal public dialogue activities and forums, including how those forums are framed and the materials and presentations that are provided.

Research on effective science communication continues. In order to effectively apply such research to a specific public dialogue initiative, scientists and practitioners will need to collaborate with social scientists who can apply and test various approaches relative to the specific issue, audiences, and contexts. Such collaborations are necessary for building a broader infrastructure for public dialogue initiatives.

Maintaining Trust and Credibility

In facilitating or participating in conversations with the public, scientists are often sensitive to the balance between discussing scientific evidence and advocating for a specific decision or policy outcome. Some believe, for example, that urging the public to support specific actions to address climate change or advocating policies to encourage childhood vaccination may damage their credibility in the eyes of the public and also among their peers. Other scientists argue that on climate change, vaccination, and other issues, the stakes are too high not to encourage the public to consider concrete steps to address these challenges. Research in the social sciences paints a complicated picture of how the public arrives at judgments of trust and whether or not advocacy damages scientists' credibility.[118]

Distrust of expert advice is most likely to occur when an individual or group perceives science as being used to support actions that threaten their values, sense of identity, or strongly held beliefs. Conservatives, for example, are more likely to dismiss scientific evidence about climate change if they are also told the solutions to the problem involve regulating the economy.[119] Therefore, some scholars recommend that maintaining trust across audiences with differing political perspectives requires scientists to avoid endorsing a specific outcome. Instead, they advocate that scientists should work to ensure relevant science is used (or at least consulted) in considering a policy decision. Scientists should communicate when possible about scientific consensus supported by diverse lines of evidence, yet also explain when possible how scientific judgments were reached rather than responding to questions by asserting that a scientific matter is settled.[120] From this perspective, a scientist should convey 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."[121]

Others argue that the distinction between discussing science and advocating for a specific political outcome is a false binary comparison. Instead, they conceptualize communication efforts as falling along a continuum. At the 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. From this perspective, there is no single "correct" role for a scientist. However, scientists should be prepared that more advocacy-focused efforts at the high end of the continuum are likely to lead to a loss of credibility among some audiences. Given this knowledge, individual scientists should 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.[122] Ultimately, scientists must bear responsibility for clearly delineating which of their public statements reflect their best understanding of the scientific evidence, and which statements reflect their personal policy preferences or recommendations.

Researchers have begun to evaluate how engaging in forms of advocacy might influence the perceived credibility of scientists with different audiences. According to one study, climate scientists may have more leeway in conversations and public forums to endorse the need for general action, or even to advocate for specific limits on coal plants without losing credibility.[123] However, if the goal is to reduce biased reasoning relative to expert advice, other studies suggest that scientists and their organizations might be best served by providing the public and decision-makers with a diverse range of solutions and options rather than just a few. In the case of climate change for example, those options might range from investments in renewable energy to nuclear energy to geoengineering. Such a strategy allows scientists to "present information in a manner that affirms rather than threatens people's values."[124]

People tend to doubt or reject expert information that could lead to restrictions on social activities that they value, but studies find that if they are provided with information that upholds those values, they react more open-mindedly. For example, studies show 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 geoengineering, actions that to them symbolize human resourcefulness.[125]

Finally, regardless of the approach that a scientist takes relative to advocating for a specific decision or action, some scholars recommend that in conversations scientists should emphasize those motives for which the public rates scientists highly, such as a desire to educate the public, serve the public interest, and protect the environment. By doing so, scientists may be able to balance existing perceptions of expertise with greater perceptions of warmth, a key factor influencing feelings of trust.[126] Moreover, scholars also recommend that in seeking to engage with new and unfamiliar groups, scientists may benefit from not hiding but displaying their human side and personal beliefs. Connecting with diverse groups and gaining their attention and trust requires researchers to exhibit their passion for a topic, why they care, and their personal motivations.[127] Further, to promote trust, as reviewed in Section II, scientists can benefit from facilitating and organizing dialogue-focused events with trusted opinion-leaders who can relate the science under discussion more directly to the interests and cultural background of various audiences.

Consider how these principles were applied to a recent initiative designed to facilitate public dialogue and learning about geological history. In response to the rising popularity of Young Earth Creationist tours of the Grand Canyon, non-religious and religious scientists collaborated in publishing *The Grand Canyon Monument to an Ancient Earth: Can Noah's Flood Explain the Grand Canyon?*[128], a 240-page photo-driven book that explains the science behind the Grand Canyon's formation over millions of years, a history that the contributors present as fully compatible with Christian beliefs. Sold on Amazon and at stores near the Grand Canyon, the goal of the book and related outreach activities is to engage those Americans interested in the Grand Canyon who may have questions about how the history of the Grand Canyon relates to Christian teaching. Importantly, the book

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has been reviewed, discussed, and endorsed by a spectrum of Christian clergy and church leaders, providing these leaders with examples to discuss in explaining why the development of the Grand Canyon over millions of years is compatible with Christian faith.[129]

Framing Conversations

In combination with these strategies for maintaining trust and credibility, how scientists "frame" their informal conversations with different audiences and publics will influence which groups they are able to reach and how their communication efforts will be interpreted. "Frames" are thought organizers that structure presentations, conversations, public debate, and media portrayals. Frames help simplify complex science-related issues by lending greater weight to certain considerations and arguments over others.[130]

There is no such thing as unframed information, and many successful scientists and science communicators are already effective at framing their ideas (whether intentionally or intuitively) in conversations, through article and grant writing, class lectures and teaching, public presentations, social media use or other interactions. Framing should *not* be taken as synonymous with placing a false or misleading spin on an issue. 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. When scientists and science communicators apply research on framing to efforts at facilitating thoughtful conversations and public dialogue, they can aid others in making connections between their everyday lives, their specific values, and the world of science. Framing can also be used to focus conversation on common interests and values rather than points of disagreement.[131]

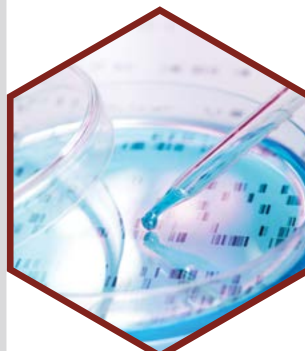
As a general principle, studies find that frames are likely to influence judgments of complex science-related debates when they are relevant — or "applicable" — to individuals' existing views about the world, such as their beliefs about the relationship between science and society, the government and the economy, or their moral duty to others.[132] For example, human gene editing might be framed as a powerful new technology that potentially crosses moral and ethical boundaries or as a scientific breakthrough that will reap major benefits to human health and the economy. Both frames accurately depict the nature of the issue, though place different emphasis on what is at stake and the possible courses of action. Depending on an individual's point of view and social outlook, many people are likely to be more open to one of these accounts over the other in reaching judgments about the social implications of gene editing. Framing can be particularly influential in shaping how individuals interpret and understand a new or unfamiliar issue (see also Box 6).

Over the past decade, research on framing has been used to help structure more thoughtful and engaging conversations with the public about several potentially contentious science-related issues. In one leading example, the National Academies of Science, Engineering and Medicine relied on framing research to structure *Science, Evolution, and Creationism*. Released in 2008, the report was intended for use by scientists, teachers, parents, and school board members who wanted to engage in more constructive conversations with individuals and groups who remain uncertain about evolution and its place in the public school curriculum. To guide their efforts, the Academies commissioned focus groups and, in collaboration with a large number of professional scientific societies, a national survey to gauge the public's understanding of the processes, nature, and limits of science. They also specifically wanted to test the effectiveness of various frames

Box 6. Framing and Public Opinion about Stem Cell Research

In 2001, as President George W. Bush considered placing limits on federal funding for embryonic stem cell research, elected officials and advocates sought to selectively frame for Americans why embryonic stem cell research mattered and what was at stake for society. To convey their reservations about research, opponents of funding argued that it was morally wrong to destroy embryos, since they constitute human life. They conveyed this meaning by relying on metaphors and catchphrases such as "scientists playing God," allusions to books such as Frankenstein, Brave New World, and 1984 and by making moral appeals to the sanctity and purity of human life. In contrast, to convey their optimism about stem cell research, those advocating for expanded funding emphasized the moral duty to move forward with research that could benefit many Americans. They did so by referencing metaphors such as scientists "racing to find a cure," arguing that it was "pro-life to be pro-research," and emphasizing the many types of diseases and health problems that could be treated with stem cell-derived therapies, thereby highlighting the moral duty to help suffering patients.[133]

Two selectively worded national survey questions asked in 2001 (before most Americans were familiar with the debate over stem cell research) suggest how framing can differentially activate one interpretation of an issue over another, shifting public opinion in opposing directions. The first national survey, sponsored by a group advocating for federal funding, mentioned as the source of stem cells extra embryos "donated to research" and then includes as background information a list of eight high-profile diseases or injuries for which stem cell research might provide "cures." Not surprisingly, public support for funding was measured at 65 percent. The second survey, sponsored by a group opposed to federal funding, told respondents, "Congress is considering whether to provide funding for experiments using stem cells from human embryos. The live embryos *would be destroyed* in their first week of development to obtain these cells." The respondents were then asked, "*Do you support or favor using your federal tax dollars for such experiments?*". Given this information, 70 percent of respondents voiced their opposition to funding.[134]



of reference in persuading people that alternatives to evolution were inappropriate for science class.

The Academies' committee had expected that a convincing storyline for the public would be a traditional emphasis on past legal decisions and the doctrine of church-state separation. Yet the data revealed that audiences were not persuaded by this framing of the issue. Instead, somewhat surprisingly, the research pointed to the effectiveness of defining evolutionary science in terms of social progress, explaining its role as a building block for advances in medicine and agriculture. The research also underscored the effectiveness of reassuring the public that evolution and religious faith can be fully compatible. Taking careful note of this feedback, the National Academies decided to structure and then publicize the final version of the report around these main points of emphasis.

To reinforce these messages, the Academies' report opens with a compelling "detective story" narrative of the supporting evidence for evolution. Also, placed prominently in the first few pages is a call out box titled "Evolution in Medicine: Combating New Infectious Diseases," featuring an iconic picture of passengers on a plane wearing masks to protect against SARS, a viral respiratory disease.

On subsequent pages, other societal benefits are made prominent in call out boxes titled "Evolution in Agriculture: The Domestication of Wheat" and "Evolving Industry: Putting Natural Selection to Work." To engage religious audiences, at the end of the first chapter, following a definition of science, there is a prominent three-page special color section that features testimonials from religious scientists, religious leaders and official church position statements, all endorsing the view that religion and evolution are compatible. Both the report and the press release state that: "The evidence for evolution can be fully compatible with religious faith. Science and religion are different ways of understanding the world. Needlessly placing them in opposition reduces the potential of each to contribute to a better future." The booklet also was reviewed by a broad array of people from scientific and various religious communities prior to publication and it contains a series of Frequently Asked Questions that focus on issues that research indicated were of paramount importance to the booklet's intended readers.[135] (See also Box 7).

In other examples, several framing-related studies and initiatives have focused on shifting how Americans view the personal significance and relevance of climate change. Many of these studies suggest that climate scientists can benefit from joining with public health experts and community leaders to re-frame the issue in terms of public health risks, and the benefits to public health if societal actions are taken. Results indicate that a public health focus is especially persuasive to political conservatives and to African-Americans. Framing climate change in terms of public health stresses its potential to increase the incidence of infectious diseases, asthma, allergies, heat stroke, and other salient health problems, especially among the most vulnerable populations: ethnic minorities, communities of color, the elderly and children. A public health frame makes climate change personally relevant to new audiences by connecting the issue to problems that are already familiar and perceived as important. The frame similarly shifts the geographic location of impacts, replacing visuals of remote Arctic regions, animals, and peoples with local and more familiar people and places.[141]

Other research has examined the narratives, metaphors, imagery, and frames of reference that can be used by scientists and religious leaders to engage people of faith on climate change by way of informal conversations, public statements, popular articles, and sermons. Consistent with a public health focus, this research recommends presenting a commitment to climate change as representing a moral responsibility to God, to our children, neighbors, to the "least of us," and "all of creation." Climate change can be discussed as part of a story arc that encompasses a challenge, an action, and a resolution- a narrative style familiar from scripture.[142] Even when framed in such terms by the highest religious authorities, scientists and science communicators should recognize that this approach has limits, especially outside of a dialogue-focused framework. For example, an analysis[143] of responses by Catholics to Pope Francis' 2015 *Laudato si* encyclical on climate change found that those aware of the encyclical held more polarized views on climate change than those who were not. In response to the encyclical, liberal Catholics tended to assign the pontiff greater credibility, while more conservative Catholics assigned the pontiff less credibility.

Conclusion: Building a Culture of Dialogue

As scientists take up the challenge of sharing their knowledge and insights with the public, they must recognize that approaches to science communication that focus primarily on filling in gaps in technical knowledge (the "deficit" model) are unlikely to address questions and reservations of many Americans. Effective communication requires more than presenting a scientific lecture in more

Box 7. Classroom Conversations about Evolution and Religion

Insights from framing research are also being applied to the development of strategies that engage college students in more thoughtful conversations about evolution and religion. Studies indicate that students are more likely to choose a science career if they feel a sense of belonging as part of their course work and if they encounter role models who share their identity. Yet for many religious students, strong cultural cues suggest to them that science and religion are in conflict, and spread false stereotypes that religious students lack competence in science. As a consequence, religious students are less likely to experience a sense of belonging in their introductory biology courses, explaining in part why religious Americans are strongly underrepresented in life science-related careers.[136] Feelings of alienation also intersect with race. Given their higher rates of religiosity, the underrepresentation of minorities in the life sciences has been linked to their belief as students in the incompatibility between evolution and their faith.[137]

To address these barriers to broader student engagement, in a study conducted at Arizona State University, instructors led 95 students enrolled in an introductory biology course through a two-week module on evolution that incorporated discussion of the intersection of faith-based beliefs with scientific principles. In addition to chapters from their textbook on natural selection and speciation, students were also required to read the National Academy's Science, Evolution, and Creationism booklet. Drawing on themes from the booklet, the instructors emphasized the compatibility of religious belief and evolutionary science.[138]

To evaluate the module's impact, surveys were administered to the class before and after the module was completed. In contrast to the more than 50 percent of students at the start of the module who said they perceived religion and evolution as in conflict, only 26 percent said the same at the end, indicating that the module had reduced by half the number of students holding a "conflict" outlook. Interestingly, there were no observable changes in student scores on measures of religiosity. As this preliminary study suggests, carefully framed curricula integrated into college biology courses that shift the context for how students think and talk about evolution can change their outlook on the compatibility of science and religion without fundamentally challenging their religious faith.[139]

In a follow-up study examining how such a curricula could be more fully developed, the Arizona State researchers interviewed 23 evolution instructors working at Christian universities across the country. The experience of these instructors, many of whom had spent years teaching religious students about evolution, provided insights on possible best practices that could be further developed, evaluated, and implemented by college instructors more broadly. Common practices used by instructors at Christian institutions included 1) openly acknowledging that students in class might be struggling with how to reconcile evolution with religious beliefs; 2) providing students with role models of religious scientists who have reconciled evolution with their religious beliefs including emphasizing the instructor's own experience; 3) informing students about the spectrum of beliefs about evolution and religion that exist across denominations and traditions; and 4) discussing with students the perspective that science is only equipped to answer questions about the natural world, and does not necessarily have the tools to answer questions about the existence of God or how to lead a good life.[140]

Only with an emphasis on empathy, listening and learning can collaboration on shared values or common goals begin.

accessible language. Instead, scientists need to think carefully about forms of dialogue that maintain and strengthen trust and credibility while emphasizing shared goals, values, and interests. Shifting from "deficit" to "dialogue" requires scientists to understand the factors that influence public beliefs and decisions, and the different modes available to them for constructive interaction with various publics. Scientists should ask questions and reflect on how scientific information is relevant, or could be relevant, for diverse communities. An emphasis on empathy, listening and learning can foster collaboration on shared values or common goals.

As this booklet has reviewed, strategies are needed that encourage thoughtful conversations about science and society, including partnerships with trusted opinion-leaders who can help speak to the personal, religious, cultural, and social concerns of Americans. Though investments in a new dialogue-based culture can take different forms, success depends on recognizing a few basic principles:

- Dialogue involves an iterative back and forth process between various groups. Dialogue can take many forms, but a core principle is that non-experts are active participants in defining what is discussed, sharing their own knowledge, perspectives, and opinions on complex problems and issues.

- Public perceptions of contentious science-related issues often do not reflect what people know factually about the issue but instead mirror who they are politically, socially and culturally. Dialogue-based science communication must therefore be sensitive to the worldviews, values, backgrounds, and priorities of different groups.

- Scientists can foster trust, understanding, and participation by partnering with opinion-leaders who are respected by a particular group or community, consciously emphasizing specific language or frames of reference, and by acknowledging uncertainties or limits to scientific knowledge. On a more personal level they can connect around shared values and identities, by conveying personal warmth, and by discussing their passion, curiosity and dedication to discovering new knowledge and solving problems.

In some cases, as a first step towards improved relations, the goal of dialogue-based science communication may be to simply recognize and affirm shared values, beliefs, and goals. With this established, further dialogue can be structured in such a way as to encourage working together towards common goals on issues such as climate change or infectious disease. If common goals on an issue may not exist, investing in dialogue-based communication can at least help establish norms of civility.[144]

Dialogue-based science communication can also be used to encourage deliberation on emerging issues such as gene editing. The goal in this case is to create incentives and opportunities for publics and stakeholders to engage in informed discussion where the best available science is made relevant to decisions that ultimately involve a complexity of social, legal, and ethical implications. For those scientists who choose to openly advocate for a specific policy outcome, dialogue-based science communication may also be their most effective form of advocacy. By joining with opinion-leaders from the publics they are trying to engage with about an issue, scientists can better establish trust, make a complex topic more meaningful, motivate concern, deepen support for a particular outcome, and recruit people into action.

Putting dialogue-based principles and strategies into practice also requires a transformation in how scientists, scientific institutions, and universities view their roles, and the incentives and resources that encourage communication-related activities. Many scientists believe they lack skills in public communication, and are reluctant to share their insights and expertise outside of traditional scientific contexts. Moreover, almost all scientists lack skills and experience in facilitating genuine dialogue with non-scientific publics, despite evidence that it is only when people feel that they are being listened to that reservations can be overcome.[145]

Training initiatives like the AAAS Communicating Science Workshops, the AAAS Leshner Leadership Institute, the AAAS Science and Technology Policy Fellows program, the Alan Alda Center for Communicating Science workshops and a growing number of similar programs are designed to address such concerns, and to provide scientists with the skills they need to encourage more thoughtful public conversations about science and society. To be successful, scientists should consider partnerships with colleagues in the humanities, arts, and communication fields. These professionals can draw on literature, religious and cultural traditions, and broad ethical frameworks to enrich public discussion, and communicate about complex scientific issues in imaginative, compelling, and novel ways. Scientists will also benefit from collaborations with social scientists who can provide insights on the factors influencing public beliefs, attitudes, and knowledge; identify trusted opinion-leaders and sources of information; formulate and test specific narratives or frames of reference; and provide ongoing evaluation and feedback on the sucesss of dialogue-based communication.

Such partnerships and collaborations will require dedicated sources of funding. More attention is needed for how the "broader impacts" requirement by funding agencies such as the National Science Foundation can be applied to effective forms of dialogue-based science communication, with resources from research grants potentially pooled and coordinated at the university, college, or institute-level.[146] Funding may also be necessary from major foundations, philanthropists, and individual donors who recognize the importance of science communication in tackling social problems and to improving public discourse and decision-making.[147]

Investments of time, effort, and funding into a dialogue-based culture can improve understandings of scientific topics and also establish trust, build relationships, and support collective action on critical issues facing the world. With this booklet as a guide, scientists and their collaborators can engage with diverse publics to engage in fruitful and novel ways. This involvement can happen on a variety of levels, from simply reaching out as an individual within one's local community, to supporting large-scale institutional or even national efforts. Shifting from a "deficit" to a "dialogue" approach can help develop better ways to communicate about science as well as form common ground and trust that will allow scientists, collaborators, and diverse publics to work together for the betterment of both science and society.

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