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Communicating Science for Policy

Conference organized and convened by the ISGP
in partnership with Sigma Xi, The Scientific Research Society
August 10–11, 2015

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Institute on Science for Global Policy (ISGP)

Communicating Science for Policy

Conference organized and convened in
Durham, North Carolina, by the ISGP
in partnership with Sigma Xi, The Scientific Research Society
August 10–11, 2015

An ongoing series of dialogues and critical debates
examining the role of science and technology
in advancing effective domestic and international policy decisions

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Introduction

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Preface

The contents of this book were taken from material presented at a conference organized and convened by the Institute on Science for Global Policy (ISGP) on August 10–11, 2015, in coordination with Sigma Xi, The Scientific Research Society. This specific ISGP conference, *Communicating Science for Policy,* focused on (i) debating different approaches to linking scientifically credible information to the formulation and implementation of sound, effective public and private sector policies and (ii) exposing college and high school students from a variety of academic institutions to the challenges facing scientists seeking to effectively communicate scientific options to policy makers and the public. This conference also provided an opportunity to have representatives from a wide range of academic institutions participate in the type of conference offered through the ISGP Academic Partnerships (IAP). Some of these academic institutions also sent representatives from Sigma Xi chapters. The IAP program reflects a common commitment to significantly improve the communication of credible scientific and technological (S&T) understanding to students, policy makers and to the public *writ large.*

Science communication for policy makers has been identified by governments, international organizations, and the private sector as a key element in developing effective societal policies critical to economic prosperity and national security. Decisions within societies concerning how to appropriately incorporate transformational science into public and private sector policies rely on citizens and policy makers having a clear understanding of the credible options developed by scientific communities throughout the world. ISGP conferences offer rarely encountered environments in which critical debates can occur among internationally distinguished scientists, influential policy makers, societal stakeholders, students, and the public.

Based on extensive interviews conducted by the ISGP staff with subject-matter experts, and in consultation with Sigma Xi staff and members, the ISGP invited three highly distinguished individuals with expertise in scientific communication to prepare three-page, policy position papers (designed for the nonspecialist). On the first day of the conference, the author of each paper answered questions and commented in a moderated, 90-minute was debate involving academics, representatives from the private sector and non-governmental public advocacy organizations, and students. Each author was provided with 5-minute at the outset of each debate to summarize their views.

One the second day of the conference, groups of about 12 participants (debaters and audience) caucused with a moderator to identify areas of consensus and actionable next steps relevant to science communication *writ large*. The results from all the caucuses were presented to a plenary session involving all participants for discussion.

The three policy position papers, together with the not-for-attribution summaries of the debates of each paper (as prepared by the ISGP staff from a recording of the debates), and the areas of consensus and actionable next steps (as developed by all conference participants) are presented in this book.

Concluding remarks

ISGP conferences are designed to provide environments that facilitate publicly accessible debates of the credible S&T options available to successfully address many of the most significant challenges facing 21st century societies. The debates test the views of subject-matter experts through critical questions and comments from citizens and nonspecialists committed to finding effective, real-world solutions. Obviously, ISGP conferences build on the authoritative reports and expertise expressed by many domestic and international organizations already actively devoted to this task. As a not-for-profit organization, the ISGP has no opinions nor does it lobby for any issue except rational thinking. Members of the ISGP staff do not express any independent views on these topics. Rather, the ISGP and its IAP program focus on fostering environments that can significantly improve the communication of ideas and recommendations, many of which are in reports developed by other organizations and institutes, to the policy communities responsible for serving their constituents in the public.

While ISGP conferences begin with concise descriptions of scientifically credible options provided by those experienced in the S&T subject, they rely heavily on the willingness of nonspecialists and citizens to critically question these S&T concepts and proposals. Overall, ISGP conferences seek to provide a new type of venue in which S&T expertise not only informs the citizen, but also in which realistic policy options can be identified for serious consideration by governments and societal leaders. Most importantly, ISGP conferences are designed to help ensure that S&T understanding is integrated into those real-world policy decisions needed to foster safer and more prosperous 21st century societies.

Conference Conclusions

Area of Consensus 1

While the fundamental responsibility of publicly funded organizations to report the results of scientific research to the appropriate subject-matter experts is well established, their responsibility to communicate such information in a meaningful manner to nonexperts (i.e., the public or policy makers) remains to be effectively met. The communication of scientific information to nonexperts needs to be timely and in an accessible format, using nontechnical language and having relevance to the audience's respective lifestyles and policy decisions. Those tasked with such communication (researchers and/or surrogates) must have the communication skills required to ensure both the accuracy and relevancy of the information conveyed.

Actionable Next Steps

- Establish programs, as well as identify the resources needed to support them, to train scientists and communication surrogates to effectively communicate relevant scientific research information to the public and policy officials. Academic institutions need to incentivize scientific researchers to participate in such programs, perhaps through recognition in promotion, salary, and tenure decisions.
- Encourage public and private sector institutions to identify methods for closing existing gaps in the public communication of science by contributing to publicly accessible databases, in which diverse research outcomes are presented in accessible formats and language (e.g., The Golden Goose Award, Journal of Irreproducible Results).
- Request that academic institutions, professional societies, and advocacy groups create and/or enhance support programs for continuing education, mentorship, and public workshops designed to both train individuals in science communicators as well as communicate current research result to all stakeholders.
- Expand the requirement that publicly funded scientific researchers prepare material to effectively communicate the significance of their results to nonexperts. The impact of this material needs to be seriously considered in the evaluation process used to determine successful applications.

Area of Consensus 2

The validity and credibility of storytelling in science communication depends directly on whether the methods used reflect an accurate, transparent, and ethical interpretation of the scientific data on which it is based. The storyteller needs to clearly reveal his or her role as (i) a professional scientist conveying her or his understanding of scientific information, (ii) a concerned citizen expressing his or her understanding of scientific information, (iii) an individual proffering a specific interpretation of scientific information, or (iv) combination of all three. Such distinctions need also to separate individual views and opinions as well as the support for specific policy positions.

Actionable Next Steps

- Foster the development and inclusion of the theory and practice of storytelling in educational curricula for science communication across school levels (e.g., high school, undergraduate). Such curricula need to emphasize accuracy and ethical fidelity in the communication practices used with all audiences.
- Encourage collaborations among all stakeholders (i.e., researchers, scientific societies, policy makers, and social scientists) to develop and disseminate guidelines for the effective, ethical, and timely communication of scientific information. Collaborations need to promote the exchange of views on science communication for all stakeholders through networking at academic and public events.

Area of Consensus 3

The commitment to improve public literacy concerning science *writ large* needs to include an increased effort throughout society to (i) train individuals in how to effective communicate scientific information and (ii) teach individuals how to more rationally evaluate the validity and relevance of the scientific information conveyed. While educational curricula can address the early-stage interests of students, broader programs are needed to provide citizens opportunities to hone their skills at accurately evaluating scientific information derived from evidence-based sources as well as its relevancy to their own lifestyle decisions.

- Reevaluate current education curricula and standards with respect to emphasizing critical thinking, especially for students at early stages of education (e.g., K–12). Enhanced critical thinking capabilities can prepare students to engage more effectively with societal issues related to science.

- Increase exposure to evidence-based communication in early-stage education (i.e., K–12) including discussions of science and technology with respect to evidence-based information and critical evaluations of its validity.
- Expand the training for teachers of these curricula to encompass specific communication methods, such as reporting on research projects, storytelling, social media venues, pictorial and art illustrations, and performing arts.
- Integrate the emphasis on improved scientific literacy with other core curricula topics (e.g., literature, creative writing, history, economics.) to covey to students the broad impact of science and technology throughout society. These early learning experiences also prepare citizens to give priority to obtaining an accurate and timely understanding of scientific information.

ISGP conference program

Monday, August 10th

8:00 – 9:00	**Registration**
9:00 – 9:15	***Welcoming Remarks*** **Dr. George Atkinson**, Institute on Science for Global Policy (ISGP), Founder and Executive Director, and Past President of Sigma Xi

Presentations and Debates

9:15 – 10:45	"To **Increase Science's Public Value We Must Improve Communication"** Dr. Arthur Lupia, Hal R. Varian Collegiate Professor, University of Michigan, Ann Arbor, Michigan
10:45 – 11:00	*Break*
11:00 – 12:30	**"Training in Narrative Persuasion for Ethical Effective Science Communication"** Ms. Liz Neeley, Executive Director, the Story Collider, New York, New York
12:30 – 13:30	*Lunch*
13:30 – 15:00	**"Improving Effective Science Communication"** Dr. William Hallman, Professor and Chair, Department of Human Ecology, Rutgers, The State University of New Jersey, New Brunswick, New Jersey
15:00 – 15:15	Small-group caucus instructions

Caucuses

15:30 – 19:00	Small-group caucus sessions
17:30	Dinner *(in breakout room)*
19:00 – 20:00	ISGP Workshop Reception

Tuesday, August 11th

9:00 – 11:30	**Plenary Caucus Session**
11:30 – 11:45	**Closing Remarks** **Dr. George Atkinson**, Institute on Science for Global Policy (ISGP), Founder and Executive Director, and Past President of Sigma Xi
11:45	Adjournment

To Increase Science's Public Value, We Must Improve Communication**

Arthur Lupia, Ph.D.
Hal R Varian Collegiate Professor, University of Michigan,
Ann Arbor, Michigan, U.S.

Summary

In the last hundred years, scientific research has transformed quality of life for people around the world. Science has great potential to do much more, but its public value depends on how well scientific information is communicated. While evolving communicative technologies have changed many communicative behaviors and expectations, several scientific communities have been slow to adapt to these changes. As a result, there are instances where scientific findings that could improve quality of life are drowned out by more sensational claims that are inconsistent with the best available evidence. This paper explains the challenges facing science communicators in the Internet era and offers a framework for improving science communication. The goal is to make scientific information more relevant, memorable, actionable, and valuable for more people.

Current realities

In the last century, scientific research has revolutionized medicine, transformed industry, altered food production, and changed how — and with whom — we communicate. In every corner of the populated world, science has fundamentally altered quality of life. It does this by applying the best available logic and evidence to a range of important questions. Science offers objective and rigorous evaluations of how our actions can, and cannot, affect our environments.

Today, however, science stands at a crossroads. At the same time that more people in more parts of the world are learning and using scientific methods, there are questions about science's public value. In the United States and elsewhere, elected officials and other societal interests are asking important questions about whether, and to what extent, governments should continue to support scientific research. These questions manifest in many ways — from complaints about how colleges and universities are funded to questions about the role that legislatures should play in directing government agencies' scientific agendas.

I do not expect these questions to dissipate in volume or frequency any time soon. The reason is that the global marketplace for the type of information that science produces has undergone radical and comprehensive changes in the last two decades. To make this change easier to see, consider the fact that for nearly a millennium, colleges and universities had a near-monopoly on the production and distribution of certain kinds of information — including information that many people would classify as science. In the "pre-Internet" era, people who wanted information about scientists' research had to approach the scientist directly. "Science communicators" were relatively few in number and many were in a near-monopolistic position in the market as information providers on the topics of their expertise. Their main "competition" was the content of local libraries or access to other experts in a person's geographic area. For most scientists, there were few or no geographically proximate scientific competitors. Absent competition, scientists had little incentive to communicate ideas to people who did not share the scientist's training. Scientists had little or no reason to rethink communicative norms and strategies that render so much research inaccessible to audiences that would put it to good use.

Today's scientific communities retain many professional norms developed from science's more monopolistic era. These norms include substantial professional incentives for publishing in journals and making presentations at conferences that tend to be inaccessible to all but a small number of scholars who are trained to speak exactly as they do. Incentives for conveying critical knowledge to broader audiences are far fewer in number and less connected to important career incentives. As a result, few institutions offer training in communicating scientific information to broader audiences, and few scientists have sufficient knowledge to do so.

For the scientific community to remain influential, its individuals and institutions must adapt to changes in the global information marketplace. Changing communication technologies have led many members of the public to have fast-evolving expectations about who is a trusted source of information. Increases in political and social polarization influence these expectations. There are a growing number of instances where people seek refuge in denial of scientific findings or advantages by exaggerating what scientific research actually shows. For these reasons, communicating science in politicized environments requires different skills and knowledge than communicating in other settings. Effective communication requires knowledge of (a) the scientific content to be conveyed, (b) the types of information that draw attention, and (c) the ways in which people process that information.

Scientific opportunities and challenges

My research and that of a growing interdisciplinary cadre of scholars using scientific training to examine science communication reveals that many scholars' intuitions about what audiences learn from scientific presentations are inconsistent with the best available evidence. Audiences tend to pay less attention to such presentations, remember less about them, and are less likely to act upon what little they remember than many scientists anticipate. These studies reveal a substantial gulf between the information science communicators believe themselves to be conveying and the manner in which audiences receive the content. To maximize impact, science communicators must become more skilled at finding the intersection between the knowledge they create and the types of information audiences' desire.

My proposal for improving science communication is built from three fundamental premises.

1. *Science has significant unrealized value-producing potential.* For many societies, preparedness, competitiveness, and the health of important social institutions depend on a continued commitment to the rigorous evaluation of critical hypotheses.
2. *Scientists face increased competition in the public sphere.* The same communication technologies that provide new opportunities to convey scientific research also offer new venues for others to circulate their views about scientific topics. In cases like climate science and vaccines, advocates present themselves as "experts" despite limited exposure to data or scientific training. Given the new ease with which people can publicize their own "facts," it is not surprising that policymakers, the public, and prospective funders may ask why they should pay scientists to study a wide range of natural and social phenomena when the "answers" are already on the Internet. These questions are not going away.
3. *Science has been slow to adapt to these changes.* As a whole, researchers have been trained to speak to relatively small groups of people who share their training. Researchers have lacked the incentives and infrastructure to motivate them to communicate their work for broader societal benefit. To realize more of science's potential public value and to adapt to an increasingly crowded and confusing communications landscape, we need a more constructive approach.

Making a more powerful case for the public value of scientific research not only requires recognizing and adapting to the challenges of a competitive communication environment but also taking internal actions to improve science's actual and perceived credibility. These actions are critical to counter individual scholars who, in attempts to gain the attention of the public and policymakers, cut corners in their research or sensationalize their findings. Science cannot substitute style for substance. The public value of science depends on providing incentives for scholars to communicate important ideas effectively while always adhering to the practices of transparency and rigor that are the scientific method's hallmarks.

Given that science can be a public good that is expensive to produce, we should expect those who are asked to pay for it to ask questions about the return on their investments. Our answers to these questions depend on recognizing and responding effectively to the increasingly competitive communicative environments in which we work. We need to find ways to communicate what we know in ways that interested members of the public and policymakers can understand. In closing, this is not a call for science communicators to "dumb down" their explanations, it is a call for science communicators to "smarten up" about evidence-based effective ways to convey scientific information to improve the well-being of citizens worldwide.

Policy issues

Few scientists are trained to communicate the value of what they do to researchers outside of their subfields or disciplines. Most scientists have even less experience communicating with potential nonacademic beneficiaries of scientific research. We can build stronger arguments for the public value of scientific research if we develop a "deep bench" of individuals and infrastructure that can produce content that effectively represents science's great value.

- For this reason, we need to develop greater knowledge of how to more effectively serve important publics. Scientific funding agencies and universities can incentivize such expertise by asking grant seekers to name specific stakeholders and to document specific learning outcomes, decision improvements, or production efficiencies that the research creates. These evaluations become part of public records and can be used by subsequent grant-seekers to serve public stakeholders more effectively.
- Universities and other agencies can also follow the United Kingdom's lead in developing metrics to evaluate the public impact of research activity in its universities. Impact is defined as "an effect on, change, or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life beyond academia." Funding agencies use these metrics as a basis for funding decisions and scholars have greater incentives to communicate broadly.

- More organizations can follow the lead of the American Association for the Advancement of Science and the National Academy of Science by developing programs for science graduate and undergraduate students to engage more effectively. The AAAS' new Leshner Institute, for example, will convene "15 scientist-leaders from disciplines at the nexus of important science-society issues … for a week of intensive public engagement and science communication training and public engagement plan development. The scientist-leaders will return to their institutions with … increased capacity for public engagement leadership."

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***** A policy position paper prepared for presentation at the workshop on Communicating Science for Public Policy, convened by the Institute on Science for Global Policy (ISGP), August 10–11 at the Sheraton Imperial Hotel in Durham, North Carolina, United States.***

Debate Summary

The following summary is based on the transcriptions of a recording made during the debate of the policy position paper prepared by Dr. Arthur Lupia (see above). Dr. Lupia initiated the debate with a 5-minute summary of his views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute debate period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Dr. Lupia. Although this summary has been written without attribution, the conference itself was open to the public and media and as such, did not restrict participants from attributing remarks to specific individuals. The views comprising this summary do not necessarily represent the views of Dr. Lupia, as evidenced by his policy position paper, or those of the ISGP, which does not lobby on any issue except

rational thinking. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate conclusions

- The effective communication of the often-complicated ideas in scientific research to the public requires recognition of the diversity of technical backgrounds and appreciation of an audience's core concerns and cultural values. While maintaining transparency and scientific rigor, communicators of scientific information to public audiences (e.g., research scientists) need to consider using strategic marketing methods (e.g., analogies, metaphors, personal examples, and stories).
- While recognizing that academic institutions have historically given a higher priority to the communication of scientific advances among peer scientists, it is increasingly important that increased priority also be given to communicating the significance of science to the public. Scientifically rigorous, yet compelling, public outreach demonstrating the relevance of research to the concerns of all stakeholders is both a public good and an opportunity to positively influence policy and funding priorities among public and private sector officials. Incentives for promoting public outreach within institutions of higher learning are available through the performance metrics used in decisions on tenure, awards, teaching assignments, and promotions.
- Societally polarizing topics (e.g., climate change, health impacts of vaccinations, food labeling) present special communication challenges since it appears that more credible information does not influence opinions based primarily on individual values. While recognizing the limitations of science to address such polarization with more data, science communicators can improve their effectiveness by seeking to understand the underlying values of their audience and listening carefully to the countering views, all in an effort to find common ground for understanding.

Current realities

For scientists to fulfill their responsibilities to improve the general quality of life, information needs to be conveyed in ways that is compelling and instills confidence. This requires scientists to first determine the type of information the public needs to make decisions based on credible scientific understanding. Despite skepticism concerning the need for scientists to change their approaches to public communication, research has found that scientists' natural instincts generally are inaccurate concerning what the public wants to know and how best to meet these interests. As a result, audiences do not normally pay enough attention to the messaging to remember the information, or remember something other than the intended messages.

Although scientists prefer to separate reason and emotion, neuroscience research has shown the two are linked. Emotional investment is a key first step in learning because it drives the brain to encode information. When communicators connect with listeners' aspirations and emotions, a key biological process is set in motion that enhances listeners' engagement with the information. To make this connection, communicators need to discover what prospective learners want to learn. If this initial step is omitted, communicators risk losing their audience to more compelling messages. Such lessons are found in commercial marketing and high-end political campaigns, both of which are adept at capturing public attention and building trust for their brands. These campaigns having identified the audience's concerns, emotions, and aspirations carefully craft messages built on this information. While many scientists are reluctant to imitate marketing and/or political campaigns, young people who grew up in the technological age are at ease using these techniques. The American Association for the Advancement of Science (AAAS), the National Aeronautics and Space Administration (NASA), and the 150-year-old Cooperative Extension Service are organizations that have recently used such methods in constructing compelling and effective science communications.

These types of communication strategies permit scientists to establish credibility with the public by both demonstrating their expertise and creating a bond with listeners through showing they have common interests. For example, in the 2011 Richard Alley documentary on climate change, "Earth: The Operators Manual," the opening minutes are used to establish common ground with listeners by talking about himself (interests, lifestyle, values) before explaining the science.

A separate study by LaCour-Green (Science, December, 2014), however, shows how such communication methods can have a negative effect on public trust in science. This study examined influences on people's opinions about same-sex marriage, and reported that one type of influence (e.g., being surveyed by interviewers who disclosed they were gay) was dramatically effective at changing opinions. Although the study received much media attention, it was abruptly retracted five months later after data irregularities were uncovered. When science communication is designed to pique public interest there is increased the risk that subsequent (less-interesting) retractions are overlooked, leading to public misinformation and damaged trust.

Another factor contributing to public distrust is the inevitability of scientific uncertainty. Small, specific "local" claims can be made with certainty, but "universal truths" are rare in a discipline that stresses examining all the evidence. When scientific uncertainty is poorly communicated, it confuses the public and sometimes leads to the general perception that scientists "do not know anything."

Although there are nascent signs of institutional support for effective public science communication (e.g., the requirement that scientists hired at the North Carolina Museum of Natural Sciences be proficient at public outreach), it was widely agreed that support and incentives (tenure and promotion requirements) for public outreach are minimal at the majority of academic institutions. With few exceptions, university culture remains focused on formal communication among scientists (i.e., in journals) and is often suspicious and dismissive of proficiencies in public communication that are not peer reviewed.

Concerns repeatedly were raised about the difficulty of communicating credible information to skeptical audiences who already have made up their minds about polarized topics such as climate change and/or childhood vaccinations. Since these topics are routinely divisive because of conflicts in cultural views at the intersection of logic, ethics, and morality, they are considered to be beyond the ability of science to address. Science may be effective at clarifying causes, effects, and consequences, but is challenged when addressing specific policy options since these are decisions that must consider value judgments (e.g., the value placed on the needs of future generations versus current generations, or the priorities of less-affluent countries versus affluent countries).

Scientific opportunities and challenges

Effectively communicating complicated ideas to the public with differing levels of scientific backgrounds and knowledge presents many challenges. To succeed, communicators need to understand the core concerns and values of their audiences. Although sometimes incorrectly termed "dumbing down" the material presented, it is more realistic to develop smarter material designed to reflect the primary interests of specific audiences. Scientists need to more fully embrace the importance of effective communication provided by the effective uses of analogies, metaphors, examples, and stories that accurately convey scientific knowledge.

Popular media personalities (e.g., Dr. Mehmet Oz) appear to fulfill the public need for quick, convenient, and easily understood science information. While acknowledging that there is a popular appeal for shows like Dr. Oz, there also is a segment of the public that wants more rigorous science reporting on which to base important decisions. Scientists need to help create vehicles for such reliable scientific information by ensuring the messaging is interesting, easily understandable, and timely while maintaining scientific credibility set by accepted standards of evidence.

Science communicators need to focus on identifying field studies that generate the generally understandable data needed to inform local, personal decisions (e.g., studying the health of a stream affected by a nearby coalmine that owners want to expand or whether vaccinations can be expected to ensure a statistically clear, safe health outcome). Because these studies have direct relevance for policy formulation, the accurate, timely communication of results from such studies serves the public interest quickly in the short term. These reports also build the public confidence with respect to the relevance of other reports on more highly technical projects having long-term impact. Before one type of science communication can be prioritized over another, performance measures need to be developed that accurately assess the impact of science communications on audiences.

Convincing universities and colleges to support and encourage improved public science communication through the metrics used in promotion and tenure decisions remain difficult. The greatest leverage in this quest is competition among institutions of higher learning for limited funding. An institution's "existential crisis" about financial survival creates an opportunity for skilled communicators to highlight the public relevancy of the research results obtained at a given institution, data that can attract public attention and potentially, more funding. Under these circumstances, communication skills assume value in tenure and hiring decisions. The development of effective performance metrics is critical to this process. When it is possible to demonstrate the impact of effective public communications, adjustments can be made in hiring, promotion, and engagement programs. While funding challenges create the impetus for universities and colleges to embrace improved public outreach, performance metrics are the tools needed to formally incorporate that outreach into an individual university's goals.

Focusing on student education can be another way to leverage university support for science communication. At teaching colleges, faculties need to effectively communicate science to students who are not necessarily majoring in a science or engineering field. Improvements in science communication to students can be encouraged by focusing tenure and promotion decisions on these classroom skills.

Crafting scientifically sound messages designed to engage science skeptics, especially around highly polarized topics such as climate change, remain an important challenge to be addressed. Two strategies cited as effective require scientists to learn more about their audiences:

(i) based on identifying sincere areas of common ground that may connect polarized groups, scientists need to focus on communication methods that strengthen these particular perspectives (e.g., the shift in opinions on same-sex marriage occurred after marriage advocates reframed their message from "rights and benefits" to "love and commitment," an interest held in common by gay and straight populations)

(ii) after determining specific issues driving the conflict, communicators need to deliver the information using methods that acknowledge these different values (e.g., the economic issues associated with differing views of climate change require that the credible scientific data be described in terms of their economic significance).

A challenge overarching all these questions is the communication of uncertainty found in essentially all in scientific research results. Public confidence in decisions is needed while acknowledging reasonable levels of risks associated with uncertainty. Postponing decisions based on infinite caution remains a decision made.

Policy issues

Evidence-based conclusions, procedural transparency, and a commitment to the scientific method must characterize science communication, especially to the public. It is important that the data themselves are not the focus of message being communicated, but the relevancy of the scientific information to individual lifestyles choices. The public is increasingly unlikely to defer to scientists based on their perceived expertise and authority. To attract public support and funding, communication must demonstrate how science is relevant to public and individual decisions. Scientists need to start small and focus on achieving victories in local communities rather than striving to reach the entire country.

At the most fundamental level, no money is needed to craft effective science communication. A scientist simply needs to be willing to share her or his knowledge with an interested person. The goal of accurately determining the interests of a specific audience, especially with respect to correcting misinformation and/or addressing pressing societal problems, however, requires focused funding. Of special interest are programs focused on communicators learning about the concerns, values, needs, and beliefs of audiences. Based on such understanding, communicators can tailor their messages to address misunderstandings and improve societal decisions aimed at improving the quality of life. While emphasis can be given to the importance of public communication in publicly funded research, such attention does not ensure that the best scientific research is supported. The significance of these "abstract advances" obtained by researchers may not appeal immediately to the public, these results are critical to the often transformational research results that have had profoundly impacted societies worldwide.

Universities and colleges need to be encouraged to train and reward faculty to develop effective communication skills. A variety of incentives are critical to this process (e.g., awards for public engagement and outreach, priorities in tenure and promotion decisions). Such changes in the tenure and promotion process need to be initiated from the upper levels of administration by redefining the value proposition in these ways as in the public interest.

Beyond academia, journals and foundations need to encourage public communication by encouraging scientists to clearly explain the replicability, reliability, and validity of the research results. These institutions and organizations can continue to broaden their support for public outreach by rewarding junior scientists for effectiveness in public engagement (e.g., a program in the United Kingdom is a successful model of this approach in which junior scholars become eligible for an award if they have published peer reviewed research which has been cited by a newspaper, a government or NGO report). The Cooperative Extension Service was mentioned as a long-running model of effective science communication that could be emulated and expanded. These approaches encourage science communication in the next generation of scientists by capturing the interest of young people and helping them understand how science works in the real world.

While all scientists need to receive training in public communication, it is acknowledges that not all scientists can be expected to be effective at public communication as a primary duty. Creating career science communicator positions to serve as liaisons between scientists and the public is an important activity to encourage. This approach can be expanded to include the formation of teams of communicators at universities/colleges and government agencies concerned with scientific issues. The four-week communication course for undergraduates at the University of Michigan, started by a team of graduate students, culminates in an "American Idol"-style event for student presentations and "Nerd Night Ann Arbor."

Training in Narrative Persuasion for Ethical, Effective Science Communication**

Liz Neeley, M.A.
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Summary

From inspiration to entertainment, education to persuasion, a wide range of goals motivates individual science communicators; goals that they often fail to explicitly acknowledge or critically examine. Unfortunately, the intuitions, assumptions, and social norms of those trained in the sciences are often ineffective and sometimes disastrously counterproductive in achieving these goals. In the realm of health and science policy, such missed connections might cost huge sums of money or even bear life-or-death consequences. Given such high stakes, scientists must strive to understand and continually improve their ability to accurately represent their knowledge about the world. This task may include educational components, but the critical role of science communication in a democratic system is not to teach facts, but rather to empower citizens and elected officials to make informed decisions. Training scientists in narrative persuasion and storytelling is the most effective way to help scientists navigate the uncertain ethical and emotional terrain of decision-making.

Current realities

In the United States, climate, vaccines, food, and other polarized, politicized issues tend to dominate discussions of science communication. While these topics certainly are the subject of bitter controversy, they are inappropriately generalized as evidence of a widespread rejection of empiricism and scientific enterprise. Amidst overheated rhetoric about a war on science, recent survey work has found that researchers rank "defending science" as their top priority for engaging in science communication, followed closely by "education." This defensive posture is consistent with scientists' perceptions of the public as uninformed and uninterested in learning, driven by self-interest and sensationalism, and prone to irrationally misjudge risks.

Natural scientists are trained to control variables and to strive for objectivity. Years of graduate and post-doctoral training select for people who enjoy — or at least tolerate — dense presentations of complex information; people who trust and often prefer numerical data, and the precision of technical jargon. They are shaped in other, less obvious ways as well. Research groups and entire disciplines coalesce around philosophical perspectives on what can be known (i.e., ontology) and how we obtain valid knowledge (i.e., epistemology). As young scientists progress, they are absorbing not only the technical knowledge taught in formal coursework, but also the philosophical perspectives, professional norms, and tacit understandings of success in their fields. These so-called "hidden curricula" reinforce existing power structures and shape assumptions about knowledge, authority, and decision-making. Unfortunately for researchers, these expectations are poorly aligned with the reality of working for public and policy audiences.

This uncomfortable reality is perhaps best illustrated in the arena of risk management. In fields as disparate as disaster response, energy development, and biomedicine, researchers who seek to inform public debate and decision-making must understand that their science communication challenge is a social one. Risk, fully defined, combines the probability of an event with the total cost of its consequences. The first element can be calculated, while the second is a value judgment that can vary wildly from person to person. This means risk is also subject to social amplification or attenuation, as peoples' perspectives influence each other to magnify, alter, or reduce perceived impacts. Whole fields of psychology and economics are dedicated to understanding what shapes our value judgments, yet science communicators frequently fail to understand that a feeling is almost never conquered with a fact.

To be clear, there are many instances where audiences are hungry for more information and want an educational experience. Enthusiasm and good teaching are incredibly powerful tools, but controversial subjects trigger a shift from the realm of education into one of persuasion, which has entirely different dynamics. The assumption that opposition and anger will dissipate once an audience has all the facts is called the "deficit model of science communication," and it is a recipe for disaster. For a rare few, it might work. For most, it will likely have no effect. At worst, flooding audiences with more information can backfire, hardening resistance and closing minds, or even boomerang, creating fear or opposition where none existed before.

Scientists encountering these dynamics often recoil, lamenting the lack of public trust in science. Although they see themselves as objective providers of valuable knowledge, scientists are not dispassionate observers; they are active participants in social debate, beholden to history and context. Credibility is not bestowed upon academics by their peers, rather, it is earned, based on the perception of valid knowledge and common interest. These two themes — legitimacy and community — are central to the future success of science communication for public policy, and teaching scientists narrative persuasion is the key to building both.

Scientific opportunities and challenges

Narrative persuasion is the use of stories to influence peoples' mental models, beliefs, and behaviors in the real world. The concept raises two immediate challenges: first, whether persuasion itself is an ethical pursuit, and second, whether stories are a valid form of persuasion. 1) Persuasion can be best defined as convincing an audience to make a decision of his or her own free will. Both coercion and manipulation strip audiences of their agency, either directly, through threat or force, or indirectly, by deception or obfuscation. An honest examination of scientific history reveals the tragic legacy of both. Moving forward requires an honest accounting, as well as an explicit commitment to avoiding such harm in the future. One research question is how to shape persuasive messaging so it does not produce anxiety, guilt, or stigma. 2) Stories, both real and fictional, tend to be more interesting, more persuasive, and more memorable than evidence-based communication. In fact, people rarely allow evidence to contradict satisfying stories; the evidence is altered to fit instead. Stories work by drawing people into an exploration of characters' intentions and actions over time. They help reduce ambiguity by prompting audiences to draw inferences, make predictions, and empathize with the emotions and experiences of the story's characters. Empathy has both cognitive and affective components, and it is the emotional appeal of stories that makes them so powerful. Many scientists fear that emotional appeals are inherently irrational and can only cloud judgment. Yet research shows that some emotional states enhance, and are perhaps required for, rational decision-making. In short, the best available science suggests that scientists must embrace the essential role of stories in human communication.

Once we confirm *whether* we should be teaching storytelling for science communication, we can turn attention to the question of *how* to teach narrative persuasion. It will require a diverse set of interdisciplinary undertakings: from psychology to pedagogy and performance. With respect to the efficacy of narrative persuasion, research questions abound, and can be generalized to a) exploring underlying neurological mechanisms, b) measuring strength in overcoming psychological resistance, and c) understanding persistence of effects over time. As a teaching question, we must establish best practices for translating knowledge into practical skills, perhaps drawing inspiration from work on teaching scientists design-thinking, improvisational theater, and visual communication skills. As a performed skill, individuals will need time to find their authentic voices, to develop sensitivity to storytelling skills such as language and timing, emotional pacing, and the ability to adjust to nonverbal cues of audience engagement.

Policy issues

From universities to scientific societies to top levels of the executive branch, academic leaders are discussing modernizing graduate education. Although newly minted Ph.D.s far exceed tenure track job openings, more than half of graduate school deans report dissatisfaction with their university's ability to provide preparation for nonacademic careers. Narrative is not merely a "science outreach activity." It exposes students to critical concepts and helps them produce better presentations, proposals, and publications wherever their careers might lead. Introducing science communication, especially storytelling, into existing STEM graduate education will require addressing faculty support, financial resources, time to degree completion, and more. Yet the idea reflects demands of, and upon, the emerging science workforce. The legitimacy of science as a social enterprise hinges on the ability not just to create knowledge, but to share it. Learning narrative persuasion challenges scientists to build a more sophisticated understanding of themselves, their research, their audiences, and the role of science communication in civil society and policy. Key actions include:

- **Incentivize science communication.** To escape a perpetual cycle of reform without change, intentions and rhetoric must be paired with real-world consequences. Scientific societies, universities, and research groups can foster excellence by creating competitive grant programs to support skill development. Faculty can revisit tenure and promotion criteria. Federal funding agencies can look to key policies, such as broader impacts criteria and requirements for trainee career development, as well as considering ethical communication in the context of required research ethics training for students.
- **Support an interdisciplinary community of practice.** To galvanize knowledge sharing, learning, and organizational change, interested parties need mechanisms for 1) finding each other, 2) building and accessing shared repositories of information; and 3) engaging in discussion. The value of such exchanges scales with the size of the network, which requires both technology infrastructure and human resources. Institutions and individuals should leverage digital communication and collaboration platforms, such as Trellis, hosted by the American Association for the Advancement of Science (AAAS), as well as funding community manager roles and periodic in-person conferences.

- **Develop best practices for narrative persuasion.** Education reform is time- and resource-intensive, and requires appropriate design and evaluation. Those developing workshops and courses should work with academics specializing in communication and curriculum design to develop consensus around the core knowledge, skills, and attitudes training is intended to impart, and how to evaluate 1) how well students are learning, and 2) how effectively instructors are teaching.

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** ***A policy position paper prepared for presentation at the workshop on Communicating Science for Public Policy, convened by the Institute on Science for Global Policy (ISGP), August 10–11 at the Sheraton Imperial Hotel in Durham, North Carolina, United States.***

Debate Summary

The following summary is based on the transcriptions of a recording made during the debate of the policy position paper prepared by Ms. Elizabeth Neeley (see above). Ms. Neeley initiated the debate with a 5-minute summary of her views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Ms. Neeley. Although this summary has been written without attribution, the conference itself was open to the public and media and as such, did not restrict participants from attributing remarks to specific individuals. The views comprising this summary do not necessarily represent the views of Ms. Neeley, as evidenced by her policy position paper, or those of the ISGP, which does not lobby on any issue except rational thinking. Rather, it is, and should be read as, an overview of the

areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate conclusions

- While narrative persuasion is an effective strategy to capture and keep the public's attention, the practice poses potential dangers in science communication, including the possibility of manipulating, fabricating, or overstating data to create a better story. Scientists need to utilize narrative persuasion carefully, ensuring that the scientific processes are followed, facts checked, and evidence cited, and with an understanding of the background/values of the audience.
- Scientists are often reluctant to utilize storytelling skills in communicating research because it violates deeply ingrained scientific training and could have a negative impact on their credibility and careers, especially when storytelling conveys a degree of uncertainty not appropriate for one's research. Academic institutions need to encourage scientists to engage in the effective and accurate communication of science, including the use of storytelling, by recognizing its importance in tenure and promotion decisions.
- Given (i) the increasing public importance of effective science communication, (ii) the lack of training for scientists in the ethical use of narrative persuasion, and (iii) the lack of standardized best practices for science communication, academic institutions would be well served to offer options for formal training in science communication, beginning as early as high school, but definitely by graduate school.

Current realities

Good science communication is essential to the general wellbeing of the public and society *writ large*. It was generally agreed that the current state of science communication needs to be improved and that the public is placed at risk by poor science communication. For example, despite the widely available public information about HIV AIDS, many individuals still express misinformation. When a topic is emotionally charged (e.g., HIV AIDS, climate change), a communication strategy that focuses primarily on giving people more facts has been shown to strengthen opposition to the scientific message.

Although it was generally agreed that storytelling can be an effective mode of public science communication, sharp disagreement emerged concerning the role of narrative persuasion within the rigorous discipline of science, specifically in training scientists to become storytellers about their own work. Concerns were raised about the danger for scientists of crossing the fine line between persuasion and manipulation, especially with respect to their responsibility to accurately report data versus advocacy. The need to tell a compelling story might lead to small details being changed for narrative purposes. Narrative persuasion, is difficult to use without sacrificing some degree of accuracy and thus, scientific credibility.

While storytelling might not always be the right tool to use, scientists must recognize the power of other compelling forms of communication that are competing for people's attention every day. People are inundated with information and quickly reach decisions based on who they trust even though they often receive a remarkably small amount of data. To have scientists' message heard in this information-rich environment, they need to learn to effectively use storytelling to accurately communicate science, make ethical arguments, and connect with the audience.

There is evidence that stories help improve people's understanding and recall, and are overall more convincing. Storytelling lowers barriers and promotes the consideration of other perspectives. In a National Science Foundation project on graduate school science communication training, storytelling was identified as one of five core competencies needed for effective communication of science.

The term "persuasion" troubled some debaters, who argued that a scientist's job is to present data, not to persuade people to adopt a particular position concerning the interpretation of data. Being considered a policy advocate could have irreversible repercussions for a scientist's credibility and career. It was suggested that those risks are one reason storytelling is not a more robust field within the scientific community. Academic institutions resist including science outreach in tenure decisions and scientists who deemphasize research to focus on the communication of scientific information are normally considered to be "jumping ship." Because science culture values unbiased, unemotional reporting, there is deep resistance among scientists to utilizing storytelling in science communication. Some science cultures are slowly changing, to permit scientists to provide objectivity while exposing the more human aspects associated with communicating complex information to nonspecialtists.

Substantial discussion centered on the importance of traditional scientific rigor and discipline in science storytelling. Scientists don't speak with a single voice, but rely on peer viewpoints expressed through extensive conversations. When scientific information is released to the public, it generally represents the unified voice of a discipline that has come to some consensus. Additionally, once scientists determine the validity of their research with respect to the scientific method, their narratives typically are aimed at persuading others that they can be trusted as authorities on the subject. A credible science story, it was suggested, needs to be able to defend its point of view in the presence of challenges and other points of view. A shortcoming of many current science narratives is that they are just a new way to relay an old message: "We are the scientists and we have the answers."

Although peer review is an essential part of scientific rigor, insightful peer review is not restricted to scientific journals. Science blogs were cited as one example in the changing field of science communication. Traditional publishing was identified as only one route for scientists to make an intellectual contribution. To support scientific rigor in storytelling, scientists who have undergone communication training are forming social networks and sharing their successes and solutions with others in their field.

While it is important to show the public that information is scientifically sound, communication that focuses mainly on scientific rigor probably won't resonate with mainstream audiences. Effective science communication first addresses the values of the audience; for example, policy makers who are not interested in learning about the impact of global warming on sea urchins may care about the impact on shrimp, which affects the economy. Research on stereotype formation suggests that "warmth" is a key component in helping people trust strangers, and it was proposed that warmth is generated by the connection people feel to a personal story. Consequently, science communication needs to start with warmth and then introduce rigor and evidence, not the other way around.

Given that most scientists aren't versed in storytelling skills, and given the need for educators to teach student-scientists to be good communicators, it would be helpful to provide storytelling frameworks or templates for use by scientists in constructing their narratives. Finding the right style depends on the audience and the intention of the communicator (e.g., to educate, inform, persuade). Storytelling elements include characters, conflicts, surprise, and overturning conventional wisdom. Depending on the goals of the communicator, the template may vary (e.g., it could resemble a Hollywood screenplay, a college lecture, good literature, or marketing communications). New tools and techniques exist to help scientists with storytelling, such as COMPASS' "message box" (http://compassblogs.org/), an approach that helps scientists organize their communication by diagraming the problem, its significance, possible solutions, and the costs and consequences of those solutions.

Effectively communicating science to policymakers goes one step beyond having a well-crafted story that speaks to the values of its audience. Although there are anecdotes about people whispering in a policymaker's ear at a wedding and influencing policy as a result, it is more effective for scientists to understand the critical points in policymakers' decision-making process (e.g., not right before the final vote), and determine how the right scientist can be at the right place having the right conversation with the right people.

Scientific opportunities and challenges

Given the focus on objectivity and certainty in science culture, one of the biggest challenges lies in empowering scientists to tell stories that often begin and end with curiosity, doubt, and confusion, without causing scientists to worry they are undermining both their credibility and careers. Scientists must get better at self-reflection and the metacognition of "what do I know and how do I know it?" These challenges can be viewed as opportunities to gather, incorporate, and expand upon data about trust and decision-making. The role of emotions in decision-making is an emerging field; scientists need to learn more about how emotions influence decisions, but also to consider whether science narratives with emotional content can do more harm than good by creating shame and fear.

Incorporating science communication training into formal schooling poses implementation challenges, including determining when instruction should begin and what it should include. While some proposed beginning training in high school (or earlier), others pointed to graduate school as a likely place to start, as graduate students often already have their own research findings.

Although a few college-level science programs expose students to narratives and varied perspectives through required courses in literature, philosophy, religion, and politics, these programs typically do not emphasize the *creation* of such narratives. A scientific community that can develop best practices is needed. Although a number of science communication training programs have arisen in recent years, two overarching questions remain: (i) do the skills that are taught make a difference in the real world? and (ii) what are the most effective strategies for teaching science communication?

Given the challenges posed by science culture and the lack of incentives for scientists to become storytellers, it might be more effective to teach science to the storytellers instead. Although there was general enthusiasm for the idea, it was noted that preliminary research suggests scientists are better regarded by audiences; people surveyed at fairs and events who heard presentations by scientists were more engaged and retained more compared to those who heard presentations by science interpreters. While there are lessons to be learned from studying venerable science communication role models such as Carl Sagan and Bill Nye, information flow has changed dramatically in the past 20 years. Rather than anointing a few highly regarded communicators, the challenge now is to have as many well-trained communicators as possible, representing a variety of personalities.

Concern was raised about the danger to the public of narratives with incomplete or misleading information. It was argued, however, that incomplete information is not the biggest public challenge, as it is rare than anyone has complete information about a subject. The bigger challenge is teaching good decision-making skills about who to trust. A public that can identify credible science information will be better able to cope with flawed messages.

Policy issues

While storytelling skills need to be a core competency for science communicators, acquiring these skills requires scientists to develop new styles of thinking. There is a need to create and distribute best practices for narrative persuasion that preserve scientific rigor while preventing abuses.

While it's likely that some precision will be sacrificed when speaking to a nonscientific audience, accuracy must never be sacrificed. Stories must show evidence, and fact checking must be incorporated into every step of story development. Science communicators must hold themselves to the highest standards of veracity and never exaggerate or change details for dramatic effect.

Scientists need to develop a clear way to communicate uncertainty. Stories must never overreach or overstate the certainty of scientific results, but at the same time, they need to be constructed to be useful to "a mother standing in a grocery store trying to make the best decision for her kids" (i.e., to readers seeking concrete guidance about personal choices). Public health campaigns provide some of the best examples of effective stories that strike this balance, and should be consulted for guidance.

Another key area for policy development is formally teaching and supporting the use of narrative science communication skills. As new programs are developed and implemented, they must be based in the rigorous process of scientific review and discernment.

Interdisciplinary collaborations between scientists and nonscientist communicators (e.g., teachers) can lead to "true collaborations," where both parties are exchanging knowledge and working together. Although scientists often completed their research before partnering with a professional communicator, it was proposed that the arts and humanities be equal partners with science from the outset of educational programs. This potentially would inform the nonscientist about the rigors of science, and the scientist about the subtleties of communication.

Incentivizing science communication skills by considering them in tenure and promotion decisions is beginning to occur at educational institutions nationwide. Increasingly, faculty members are being asked, "What kind of public outreach (service) are you doing?" Such support, and additional incentives, need to be incorporated into academia tenure and promotion decisions to help scientists move beyond traditional forms of communication without sacrificing rigor.

Improving Effective Science Communication**

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Summary

The need has never been greater for more effective science communication specifically designed to help the public and policy makers comprehend important issues involving science and technology. Without a clear understanding of the science involved, it is impossible for citizens to engage in meaningful thought, debate, or actions regarding some of the most pressing, controversial, and consequential matters facing society. Yet, current efforts to communicate with the public about these questions are often hampered by Americans' general lack of knowledge about basic science and a system of science education that fails to prepare members of the public to become life-long learners and to engage with science topics after they graduate. A growing skepticism of those who fund, practice, and profit from the pursuit of science has also made it more difficult to communicate with the public, and has made it increasingly possible for those hostile to science to influence public opinion. The decline in the newspaper and magazine industry has significantly reduced the number of trained journalists who are effective science communicators, and part of this gap has been filled with pseudoscientific experts able to reach large audiences through influential websites, blogs, and other social media. What is needed is to train the next generation of scientists to become better science communicators and to create a culture where they are supported and rewarded for effectively communicating with the public.

Current realities

Society faces significant challenges to the environment, public health, and public welfare that have been brought to light by scientific inquiry and that require complex scientific information to appropriately assess and to manage. At the same time, the pace of scientific advances and the deployment of new technologies is accelerating, often overtaking the ability of the public, policy makers, and regulators to comprehend and fully evaluate the costs, benefits, and potential unintended consequences of these developments. As a result, individual and societal decisions must be made about a growing array of issues that require a thorough understanding of the science involved, the potential consequences of the problems, and the choices available to solve them. We must therefore rely on effective science communication to help elucidate what is known about these issues, what is not known, and the implications for people and the planet.

Yet, many Americans lack the foundation in basic science necessary to put new scientific information into context. For most, formal science education ends in high school, and according to figures compiled by the National Math + Science Initiative (www.nms.org), only about a third of American high school students are ready for college-level science when they graduate. Moreover, fewer than 29% of Americans over the age of 24 have earned a bachelor's degree or higher, and only about 10% hold a degree in a STEM discipline. Colleges and universities also do a poor job in preparing their graduates to understand and actively take part in debates about emerging science. Students are not trained to become "citizen scientists," or even educated consumers of scientific information available in the media. Instead, most are required to take introductory science classes that focus primarily on remembering detailed scientific facts. While perhaps appropriate for those who aspire to careers in science, it merely serves to frustrate, humiliate, and alienate many students whose primary interest in taking required science courses is to pass them. Too often, the experience leads them to conclude that science is "too hard to understand," leaving them unprepared and unmotivated to engage with scientific topics after they leave college, and without the skills they need to make decisions as informed citizens.

Scientific opportunities and challenges

There is a significant opportunity for effective science communication to promote greater public understanding of science as well as public participation in decisions regarding the development and funding of science, the implementation and regulation of new technologies, and the assessment, management, and resolution of significant problems that are informed by science. Yet, efforts to improve science communication in the United States face significant challenges.

Recent experience with environmental disasters resulting from the misuse or failure of technology, misplaced assurances regarding the safety and effectiveness of drugs, medical devices and procedures, and the reversal of decades-old advice concerning diet and nutrition have contributed to an undermining of the trust and credibility of science and scientists. This has led to deep skepticism regarding science, and a questioning of the motivations of institutions that fund science, those who practice science, and the companies that profit from scientific discoveries and the resulting technologies. This skepticism has provided opportunities for those who are hostile to science to cynically manipulate public skepticism to influence public opinion. The result is a call for schools to "teach the controversy" about evolution, climate change, and other topics where the science does not support their existing belief systems.

With the decline of the newspaper and magazine industries, there are fewer trained science journalists with the skills to be effective science communicators, the credibility necessary to be trusted by scientists to represent their work fairly and accurately, and with the ability to reach large audiences. This gap is being filled by an increasing number of amateurs and pseudoscientific experts with influential blogs, websites, and social media followers likely to share misinformation.

Younger scientists have become much more active in promoting science, especially using social media channels. However, the academic system has failed to respond to the need to facilitate and reward faculty and students for their science communication efforts. Tenure at research universities is still awarded based on peer-reviewed publications and grant awards and not on efforts to communicate with the public about the science or its potential implications. At best, these important efforts are still seen as subsidiary to one's real job as a scientist, and at worst, are actively discouraged as grandstanding, or as taking valuable time away from "real science."

Perhaps the greatest challenge is that few scientists have received any training in effective science communication. As a result, communications authored by scientists often begin at a level that is too advanced, mired in details, or irrelevant for the public to grasp. In part, this is because we have not taught scientists to meet the specific needs and learning styles of lay audiences. The dominant way that people take in new information is through stories, analogies, and metaphors. The problem is that it is often difficult to create these such that they resonate with the public, without also losing some of the precise details of the underlying science. Fearful that other scientists will criticize their efforts as "oversimplification" or perhaps "unscientific," what often emerges are communications that are designed to meet the approval of other scientists instead of well-crafted stories that connect with lay-audiences.

The opportunity for more effective science communication lies in that social scientists know a great deal about how to effectively communicate about science with nonscientific audiences. There is, in fact, a science of science communication that can and should be taught to the next generation of scientists that would enable them to better tell their own stories. It might also serve to focus their attention on the things about science that most matter to the public and to policy makers, thereby potentially improving the quality and relevance of the science itself.

Policy issues

To meet the challenges and take advantage of the opportunities to improve effective science communication we must:

- Support advances in science communication theory and applied practice, as well as the development and distribution of practical, empirically tested communications. Federal agencies and foundations involved in funding science research must take the lead.
- Train future scientists to be better science communicators. Universities and curricular accreditation bodies must include required courses on effectively communicating science to the public as a universal part of graduate training.
- Facilitate and reward effective efforts by scientists to communicate with the public. Universities, funding agencies, and organizations that hire scientists must recognize and provide tangible rewards for these efforts, including consideration during hiring, tenure, and promotion decisions. National Science Foundation (NSF), National Institutes of Health (NIH) and other funders of science already require statements of "broader impacts" as part of grant submissions. They must also require those who are awarded grants to create statements at the end of their projects describing the outcomes of their research, specifically targeted for public audiences.
- Establish academic centers of excellence focused on applied science communication to create a core group of experts, graduate students, and post-docs who can assist scientists in developing more effective science communications, teach undergraduate courses, and become a source of expertise for companies, governmental, and nongovernmental agencies. The academic centers could potentially be funded by a consortium of agencies (e.g., NSF, NIH, National Oceanic and Atmospheric Association, Food and Drug Administration, U.S. Department of Agriculture (USDA), Centers for Disease Control and Prevention (CDC), and the Environmental Protection Agency).
- Create international guidelines/standards for science-based risk management decisions, which include mandates for transparency, openness, and timeliness. Guidelines set by the FDA, CDC, USDA, as well as the United Nation Food and Agriculture Organization, European Food Safety Authority, Codex Alimentarius, and other international organizations dealing with food safety can serve as a model.

- Create and implement model curricula and materials to enhance "science media literacy" at the high school and college level. Science-oriented foundations (e.g., NSF) could take the lead in these efforts to encourage lifelong learning and engagement with science.
- Empower federal agencies to conduct research and to develop more effective messaging about important topics with potential impacts on public health and the environment. Congress needs to reexamine the consequences of the Paperwork Reduction Act of 1995, which serves as a substantial barrier to the timely collection of information from the public that could help guide effective communications.

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Debate Summary

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as evidenced by his policy position paper, or those of the ISGP, which does not lobby on any issue except rational thinking. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate

Debate conclusions

- Because science communication is a multifaceted and nuanced discipline based on an understanding of the audience's decision-making priorities and their world views, highly effective communication requires professional training and extensive engagement with the audience.
- Optimized science communication results from effectively connecting the results from research endeavors to their societal implications, particularly in regards to how research findings might influence decision making for policy makers and the average citizen.
- Elevating science literacy and improving the effectiveness of science communication requires a multipronged approach that includes enhancing (i) the quality of science education in high school and college, (ii) the professional commitment to increased training in the skills associated with science communication, and (iii) revamping governmental policies that have historically hampered the collection of information needed to promote timely policy decisions.

Current realities

Scientists must recognize that some audiences are unlikely to become fully engaged by a formal scientific narrative. Thus, those seeking to communicate scientific information need to avoid a one-size-fits-all, technical message by crafting a message designed to reflect the interests and background of a specific audience. Such efforts require scientists to broaden their communication skills. For example, are scientists seeking to describe scientific data related to a particular issue, or are there societal questions involving cultural, morals, and/or ethical issues.

Decision makers often must act on limited data and sometimes even inconclusive analyses. They also may have an incomplete understanding of the public's opinion on the matter. As an example, key aspects of public opinion on the genetically modified food (GMO) regulation are often poorly communicated to policy makers and the public. While nine out of 10 people respond in the affirmative to a question regarding adding GMO labeling to products, if they are asked instead what labels they want to see on products, a higher priority is placed on labeling for pesticides and hormones rather than GMOs. Furthermore, although the majority of people indicate that they do not know anything about GMO science and are unaware of the current level of GMO ingredients in the market, most express strong opinions about the advisability of having GMOs in the food supply (mostly negative). In this way, imprecise studies create false impressions about what the public thinks, and the result is that decision makers obtain an incorrect understanding about their constituents' concerns.

It was noted that the public is not necessarily ignorant of scientific issues. Rather, while people are exposed routinely to large amounts of information — both accurate and inaccurate — many tend to embrace that information that coincide with personal experiences. Thus, the public is not irrational in responding to scientific information, but rather make decisions based on what they think they know independent at times of the information provide externally. These types of decisions are the basis of their "mental models" (i.e., personal models that people construct to explain the way the world works). These models encompass not only physical and causal relationships, but also personal and societal motivations. Understanding the perceptions and actions of various groups requires an understanding of their mental models.

Compared with previous generations, today's public has many opportunities to be exposed to science. The Internet and social media have facilitated many new modes for people to find scientific information (correct and incorrect) and to connect to specific parts of the scientific community. It is critical to acknowledge that too often such sources provide misinformation. While the current generation may have much more access to "scientific information," such access alone is not a good metric for progress in science literacy. An assessment of critical thinking abilities was argued as a better metric for progress.

The ability to connect a scientific discovery with its impact on society and how it influences a citizen's decision making, is an essential aspect of science communication. Not every scientist needs to be an expert communicator, but collectively scientists must do a better job of explaining what research findings mean for personal lifestyle choices.

A fundamental question was raised as to whether communication challenges are unique to the scientific disciplines. Other topics (e.g., current Middle East conditions) often are just as complicated and poorly understood by stakeholders. It was argued, however, that the critical need for better communication in science-based topics is different than the need in complex geopolitical topics, in that scientific inquiry not only can identify problems, but better identify potential solutions and potential unintended consequences.

Scientific challenges and opportunities

The most difficult science communication challenges involve controversial issues, particularly issues in which there is considerable uncertainty in the related scientific data. Scientists generally are reluctant to say "I don't know," and can be poor communicators when they don't know the specific answer. But uncertainty is crucial information to relay to lay audiences. Communicators must impart an understanding of how uncertainty plays into scientific research and how conclusions reach a certain level of confidence. Effective science communication requires explaining "here is what we know, here is what we don't know, this is why what we don't know is important, these are the conclusions that have been reached based on the available evidence, this is what you can do while waiting for better information, and this is what is being done to get better information." Scientists need to be able to communicate what is and isn't known in a way that enhances understanding of and confidence in the scientific process. In that way, the nature of progression in scientific inquiry, rather than a collection of data, can be better understood.

Just as not all science is the same, it was argued that not all communication is the same. This is especially true in terms of urgency. Some scientific information must be gathered and acted upon quickly. A difficulty in communicating science is in determining how to advance the topics that are in the best interest of the public and give the public the resources they need to make better decisions for themselves and for the collective society.

Another ongoing challenge in science communication is assessing the audience's mental model for understanding the world. Often an individual's knowledge on a subject is incomplete or incorrect. Consequently, the mental models created to guide actions can be imprecise or contradictory. Effective science communication needs to conform with what individuals accurately understand, corrects that which is incorrect, and fills in the gaps in mental models. However, this methodology is not just a matter of plugging an "education deficit" with data; multiple studies have suggested that is insufficient. Effective science communication instead works to understand how the audience thinks, and what they think they know. Effective communicators utilize the audience's experience and priorities to mold the narrative, and scientists and professional science communicators would be well served to develop these skill sets.

Although there are abundant assessments of the general public's attitudes regarding various scientific issues, in many cases the survey tools lack the methods required to obtain conclusive results. This deficiency is a serious challenge, as policy makers typically make decisions based on their knowledge of public opinions. Imprecise polling and surveys with poorly crafted questions hinder improved scientific literacy and impede the efforts to identify consensus on important decisions. Surveys must ask questions in neutral ways, or find ways to triangulate investigational approaches to derive answers.

Improved understanding of the information the public wants will lead to the development of better messages. The key to effective communication is to provide audiences with what they want to know, rather than what scientists think they need to know. For example, when community residents were concerned about living next to power lines, an industry information campaign focused on explaining electricity and magnetic fields and the molecular progression of cancer, but failed to address the audience's critical question: "Is it safe to live next to power lines?"

Readily available misinformation is a challenge that is often exacerbated by the fact that much misinformation appears plausible. When a scientifically flawed argument appears plausible to the general public — who traditionally have been trained to be fact-receivers, not critical thinkers — they do not question it. The education system needs to teach students to skeptically and critically think about why a scientific argument might or might not be true.

For many Americans, formal science education ends at the high school level, and a significant challenge in science communication is the need to create and implement educational models that promote citizen scientists, or at least informed consumers of science. Although there are many practitioners of science communication (e.g., museums, nonprofit organizations, scientific societies, journalists), these disciplines are not necessarily working towards a shared goal with an accepted common set of standards.

The U.S. Paperwork Reduction Act of 1995 was cited as a significant barrier to communication because of the strict requirement that surveys of more than nine Americans must go through an approval process, which takes a minimum of six months. Therefore, the best answers to empirical questions may come much later than needed. Given the iterative nature of risk communication, the scenario often is even worse since years would be required to develop the most effective messages. As a result, risk communication messages are often ineffective or may have unintended consequences (e.g., consumers not consuming any fish to avoid mercury exposure, as opposed to limiting consumption to no more than a specific amount per week).

Instances of natural, manmade, and technical disasters where stakeholders inherently have a common ground could represent "golden opportunities" for effective science communication. However, the important lessons often are lost during such teachable moments. For example, because the process of returning to their homes after Hurricane Sandy had been so lengthy, many residents decided not to evacuate after receiving warnings of subsequent hurricanes.

Another barrier to science communication efforts is the fear that an overgeneralized, imprecise message could result in the listener making a poor decision, and then filing law suits against the scientist. There was concern that researchers' institutions would not support scientists if they generalized or speculated. It was countered, however, that it would be much worse if a scientist withheld information from decision makers and the public, as that would pose a greater risk to trust and credibility.

Policy issues

Two overarching, nonexclusive goals were proposed to improve science communication skills: (i) enhance communication training for scientists, and (ii) create and support a cohort of professionals to act as guides, advisors, and liaisons for communicating science among researchers, regulators, policy makers, and the general public.

Science education at the high school and college levels must prioritize the critical thinking skills needed to determine whether an argument is scientifically valid. There needs to be less emphasis on data and more on how science progresses through the scientific method of rational thinking and peer review. It was widely agreed that all students need to be able to engage with science for the rest of their lives, even though few students will become career scientists. This level of science literacy goes beyond critical thinking skills to also develop the students' confidence that their role is not only to be receivers of knowledge, but rather to be critical thinkers about knowledge. Debaters emphasized that students must learn the importance of skepticism, and how to take a scientific perspective in real-world settings. At the high school level in particular, curriculum needs to incorporate "in the field" experiences where students observe and participate in experimental design and data analysis.

At the college level, there must be classes for nonscience majors that focus on how the scientific method works and the importance of reproducibility and validity, in particular by linking scientific understanding with policy recommendations. Science literacy needs to be improved where it matters most: enabling citizens to make critically informed decisions. Furthermore, at the college level and perhaps even at the high school level, all students need to be introduced to the theory and practice of science communication.

Many science education reform models have been adopted nationwide, but evidence for best practices is distinctly lacking. For any proposed reforms, clear learning objectives and outcome measurements must be in place to evaluate and optimize science education programs. Despite much study, significant uncertainty remains regarding what constitutes best practices in education. A controversial recommendation was made that science education programs need to be designed to teach students to question authority as a means of seeking veracity.

Academic centers of excellence need to be established that focus on applied science communication. These centers, located across the country, would enrich study in the science of science communication and provide a place for professional science communicators to train and collaborate. Academic centers of excellence also could provide a resource for scientists who do not want to make communication part of their career.

Additionally, academic centers of excellence could develop a set of professional standards for science communication. A conduit would then be created between trained professional science and risk communicators, and science-orientated federal agencies. Highly trained analysts and communicators could be placed in critically important roles across the public and private sectors. The most effective approach is to have highly trained translators of science contribute to the decision-making processes of select people already embedded into a system.

Some debate participants strongly disagreed with the notion that improved science communication and literacy in the general public would improve science policy. It was argued that there has been no demonstration of a causal relationship between science literacy and policy making.

To provide timely communication in the event of natural or manmade disasters, the communication materials for emergency situations need to be composed in advance. For example, almost all the necessary components of a rapid communication response to a salmonella outbreak can be developed before they are needed. This advanced preparedness also will help prevent instances of insufficient communication between stakeholders.

The U.S. Congress needs to re-examine the U.S. Paperwork Reduction Act to detect and potentially change impediments to effective science and risk communication. Barriers to timely data collection (i.e. lengthy scrutiny of survey and interview instruments) must be eliminated.

Federal granting agencies (e.g., National Science Foundation) need to require funded scientists to compose a nontechnical summary statement at the conclusion of the research project to help convey the significance of research findings. Such a statement could enhance communication to decision makers by better explaining how taxpayer dollars are being spent and how the science can influence a particular debate. Furthermore, the requirement to write such a statement could provide incentives and opportunities for scientists to improve their science communication skills. While it was noted that some federal agencies (e.g., National Institutes of Health) already have such a policy, a possible shortcoming is that there is no feedback mechanism to tell the researchers whether their statements are effective communications. A further suggestion was made that research grantees might be required to follow-up on claims made in their pre-award justification statement (e.g., by indicating how their work influenced a particular policy debate). However, some participants questioned the effectiveness of a post-research summary, since it would not be tied to the evaluation criteria of the research grant.

Acknowledgment

Numerous individuals and organizations have made important contributions to the Institute on Science for Global Policy (ISGP) programs. Some of these contributions directly supported the efforts needed to organize the ISGP conference, *Communicating Science for Policy,* convened in partnership with Sigma Xi, The Scientific Research Society, August 10–11, 2015 in Durham, North Carolina. Other contributions aided the ISGP in preparing the material presented in this book, which includes the three invited policy position papers and the not-for-attribution summaries of the views presented in the discussions, critical debates, and caucuses that ensued.

The willingness of those in the scientific and policy communities to be interviewed in the preparation for the conference is appreciated, as are the efforts of the three subject-matter experts invited to present their views concerning science communication in their policy position papers. The willingness of these authors to engage all conference participants in the vigorous debates and caucuses that compose all ISGP conferences was especially noteworthy. The biographies of these three authors are provided here.

The success of every ISGP conference critically depends on the active engagement of all participants in the often-intense debates and caucuses. The exchange of strongly held views, innovative proposals, and critiques generated from questions and debates fosters an unusual, even unique, environment focused on clarifying understanding for the nonspecialist. Since these debates and caucuses address specific questions related to formulating and implementing effective public and private-sector policies, ISGP and Sigma Xi are greatly indebted to all those who participated in the conference.

The efforts made by Sigma Xi in partnership with the ISGP to organize and convene this conference were uniformly recognized as outstanding and are appreciated. The results of their efforts served the interests not only of the academic community, but of the communities engaged with Sigma Xi.

The members of the ISGP Board of Directors also deserve recognition for their time and efforts in helping to create a vital, increasingly relevant not-for-profit organization that is addressing many of the most important societal questions of our time. The ISGP remains a not-for-profit organization that does not lobby on

any issue except rational thinking. The brief biographical backgrounds for the ISGP Board members are presented here.

The energetic, highly professional work of the ISGP staff merits special acknowledgment and appreciation. The staff's outstanding interviewing, organizing, and writing skills remain essential to not only organizing the conference itself, but also to recording the often-diverse views and perspectives expressed in the critical debates, capturing the areas of consensus and actionable next steps from the caucuses, and persevering through the extensive editing process needed to assure the accuracy of the material published here. Biographical information on all the ISGP staff involved is presented here.

ISGP programs are financially supported by U.S. government agencies and departments and through gifts from private-sector entities and philanthropic individuals. Specifically, the IAP conference on *Communicating Science for Policy* benefited greatly from generous gifts provided by the MARS Corp., Monsanto Corp., and Edward and Jill Bessey.

It is important to note that the ISGP has benefitted from major financial support from Sigma Xi, The Scientific Research Society that has helped facilitate the organizing and convening of this conference on science communication as well as related ISGP conferences on (the Ursinus and Eckerd conferences with titles and times are listed below).

Dr. George H. Atkinson
Founder and Executive Director
Institute on Science for Global Policy
September 30, 2015

ISGP books from ISGP conferences listed below are available to the public and can be downloaded from the ISGP Web site: www.scienceforglobalpolicy.org. Hardcopies of these books are available by contacting info@scienceforglobalpolicy.org.

ISGP conferences on, or related to, Emerging and Persistent Infectious Diseases (EPID):

- *EPID: Focus on Antimicrobial Resistance,* convened March 19–22, 2013, in Houston, Texas, U.S., in partnership with the Baylor College of Medicine.
- *21st Century Borders/Synthetic Biology: Focus on Responsibility and Governance*, convened December 4–7, 2012, in Tucson, Arizona, U.S., in partnership with the University of Arizona.
- *EPID: Focus on Societal and Economic Context*, convened July 8–11, 2012, in Fairfax, Virginia, U.S., in partnership with George Mason University.
- *EPID: Focus on Mitigation*, convened October 23–26, 2011, in Edinburgh, Scotland, U.K., in partnership with the University of Edinburgh.
- *EPID: Focus on Prevention*, convened June 5–8, 2011, in San Diego, California, U.S.
- *EPID: Focus on Surveillance*, convened October 17–20, 2010, in Warrenton, Virginia, U.S.
- *EPID: Global Perspectives*, convened December 6–9, 2009, in Tucson, Arizona, U.S., in partnership with the University of Arizona.

ISGP conferences on Food Safety, Security, and Defense (FSSD):

- *FSSD: Food Security and Diet-linked Public Health Challenges*, to be convened September 20–23, 2015 in Fargo, North Dakota, in partnership with North Dakota State University.
- *FSSD: Focus on Food and the Environment*, convened October 5–8, 2014, in Ithaca, New York, in partnership with Cornell University.
- *FSSD: Focus on Food and Water,* convened October 14–18, 2013, in Lincoln, Nebraska, U.S., in partnership with the University of Nebraska–Lincoln.
- *FSSD: Focus on Innovations and Technologies,* convened April 14–17, 2013, in Verona, Italy.

- *FSSD: Global Perspectives,* convened October 24, 2012, in Arlington, Virginia, U.S., in partnership with George Mason University.

ISGP Academic Partnership (IAP) conferences

- *Communicating Science for Policy*, convened August 10–11, 2015, in Durham, North Carolina, in partnership with Sigma Xi, The Scientific Research Society.
- *Food Security: Production and Sustainability*, convened April 24–25, 2015, in St. Petersburg, Florida, in partnership with Sigma Xi, The Scientific Research Society, and Eckerd College.
- *FSSD: Safeguarding the American Food* Supply, convened April 10–11, 2015, in Collegeville, Pennsylvania, in partnership with Sigma Xi, The Scientific Research Society, and Ursinus College.
- *EPID: Focus on Pandemic Preparedness,* convened April 11–12, 2014, in Collegeville, Pennsylvania, U.S., in partnership with Ursinus College

ISGP conferences on Science and Governance (SG):

- *The Genomic Revolution,* convened September 6, 2013, in cooperation with the Parliamentary Office on Science and Technology of the British Parliament within the House of Lords. London, United Kingdom.

ISGP reports from ISGP conferences on Global Challenges are available to the public and can be downloaded from the ISGP Web site: www.scienceforglobalpolicy.org:

- *ICCAP: The Shore's Future: Living with Storms and Sea Level Rise,* November 20–21, 2015, in cooperation with several local partners, including the Barnegat Bay Partnership and the Barnegat Bay Foundation with financial support provided by the Jay and Linda Grunin Foundation.
- ICCAP: *Sea Level Rise: What's Our Next Move*, convened Oct. 2–3, 2015, in St. Petersburg, Florida, in cooperation with the St. Petersburg/Pinellas County Working Group and the Institute for Strategic Policy Solutions at St. Petersburg College.
- ISGP Climate Change Arctic Program (ICCAP): *Sustainability Challenges: Coping with Less Water and Energy,* convened June 5, 2015, in Whittier, California, in cooperation with the Whittier Working Group

- ICCAP: *Living with Less Water*, convened February 20–21, 2015, in Tucson Arizona, in cooperation with the Tucson Working Group.

Biographical information of Scientific Presenters

Arthur Lupia, Ph.D.

Dr. Lupia is the Hal R. Varian Collegiate Professor of Political Science at the University of Michigan. He currently serves as Chair of the National Academy of Science's Roundtable of the Application of Social and Behavioral Science Research, is an executive member of the Board of Directors of Climate Central, and is on the Advisory Board of the National Academies' Division of Behavioral and Social Science and Education. Dr. Lupia has held a range of scientific leadership positions including Principal Investigator of the American National Election Studies, and founder of TESS (Time-Sharing Experiments in the Social Sciences), which has helped hundreds of scientists from many disciplines run innovative experiments on opinion formation and change using nationally representative subject pools. Dr. Lupia's research examines how people make decisions when they lack information and how they manage complex information flows. His topics of expertise include information processing, persuasion, strategic communication, and civic competence. His newest book is "Uninformed: Why People Know So Little About Politics and What We Can Do About It" (Oxford University Press, forthcoming).

Elizabeth Neeley, M.A.

Ms. Neeley is Executive Director of The Story Collider, an organization dedicated to the idea that there is power in true, personal stories about science, told live. She is the former Assistant Director of Science Outreach for COMPASS, a nonprofit dedicated to helping scientists effectively engage in public discourse and decision-making about the environment. An experienced professor and workshop leader, Ms. Neeley's approach to science communication is strongly influenced by network science and her graduate research into the evolution of visual communication systems in tropical reef fishes. Ms. Neeley has co-authored the peer-reviewed journal articles "COMPASS: Navigating the Rules of Scientific Engagement," and "A critical evaluation of science outreach via social media: its role and impact on scientists," and contributed chapters to the books "The Complete Guide to Science Blogging" (Yale University Press, forthcoming), "Effective Risk Communication" (Routledge, 2014), and "Escape from the Ivory Tower" (Island Press, 2010). A member of The National Association of Science Writers and Public Communication in Science and Technology, she has more than 10,000 Twitter followers, including hundreds of scientists she has trained in the use of social media.

William K. Hallman, Ph.D.

Dr. Hallman is a professor and Chair of the Department of Human Ecology at Rutgers University, New Jersey, and the current Chair of the Risk Communication Advisory Committee of the U.S. Food and Drug Administration. A member of the Rutgers' graduate faculty of the Department of Nutritional Sciences, and of the Bloustein School of Planning and Public Policy, Dr. Hallman is the former Director of the Food Policy Institute at Rutgers. He also serves on the Executive Committee of Rutgers Against Hunger (RAH), and helped to found the New Brunswick Community Farmers Market. His research examines public perceptions of controversial issues concerning food, health, and the environment. Recent research projects have looked at consumer perceptions and behaviors concerning genetically modified foods, animal cloning, avian influenza, accidental and intentional food contamination incidents, and food recalls. His current research projects include studies of public perceptions and responses to food safety risks, the safety of fresh meat, poultry, game, and seafood products purchased on the Internet, the use of nanotechnology in food, and public understanding of health claims made for food products.

Conference debaters

Rick Borchelt
Director, Office of Communications and
Public Affairs, Office of Science,
Department of Energy

Marla Broadfoot
Freelance Science Writer and Editor
Wendell, North Carolina

Graham Bullock
Assistant Professor, Political Science and
Environmental Studies Departments,
Davidson College

Russ Campbell
Communications Officer,
Burroughs Wellcome Fund

Nancy Conrad
Founder and Chairman,
Conrad Foundation; education advocate

Norman Fraley
Principal Analytical Chemist;
Project Program Manager, NutrAfrica

Teresa Fryberger
Director, Board on Chemical Sciences and Technology,
National Academies of Sciences, Engineering, and Medicine

Eric Grunden
Chief School Officer and founder,
Research Triangle High School

Aaron Huertas
Science Communications Officer,
Union of Concerned Scientists

Judith Jones
Science teacher, Chapel Hill/Carrboro
Schools, retired; eMSS (e-Mentoring for Student Success)

Elana Kimbrell
Communication Program Officer,
American Association for the Advancement of Science

Amy Knisley
Professor, Environmental Law and Policy
Warren Wilson College

Bill Koch
Analytical Chemist, consultant;
Retired NIST and USP;
Member, Sigma Xi Board of Directors

Michael Madden
Research Biologist, University of North Carolina, Chapel Hill; UNC Sigma Xi

Brian Malow
Science Comedian; Curator of the Daily Planet at the N.C. Museum of Natural Sciences

Craig McClain
Marine Biologist, Science Communicator,
Deputy Director, Triangle Center for
Evolutionary Medicine, Duke University

David D. Moran
Hydrodynamics; Publisher of American Scientist magazine; Board of Directors, Sigma Xi

Abby Olena
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Duke Initiative for Science and Society

Theodora Pinou
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Science writer and editor, National Association of Science Writers; Science Communicators of North Carolina

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Research Assistant Professor,
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Wade Roush
Program Outreach Officer, Knight Science Journalism; Research Associate, Program in Science, Technology, and Society, Massachusetts Institute of Technology

Fenella Saunders
Managing Editor, American Scientist magazine, Sigma Xi

Laura A. Schoppe
President,
Fuentek, LLC

Amy Sheck
Teacher and Dean of Science, North
Carolina School of Science and Math

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Kyle Trenshaw
STEM Education Postdoctoral Research Associate, Brown University

Nancy Turner
Research Professor, Department of Nutrition and Food Science, Texas A&M University

Jamie Vernon
Director of Science Communications and Publications, and editor-in-chief of American Scientist magazine, Sigma Xi

Jory Weintraub
Science Communication Director, Duke Initiative for Science & Society; Senior Lecturing Fellow, Duke University

Robert Youker
Assistant Professor, Department of Biology, Western Carolina University

Paula Young
Professor of Mathematics; Director of the Center for Teaching Excellence and Innovation, Salem College

Biographical information of ISGP Board of Directors

Dr. George Atkinson, Chairman

Dr. Atkinson founded the Institute on Science for Global Policy (ISGP) and is an Emeritus Professor of Chemistry, Biochemistry, and Optical Science at the University of Arizona. He is former head of the Department of Chemistry at the University of Arizona, the founder of a laser sensor company serving the semiconductor industry, and Science and Technology Adviser (STAS) to U.S. Secretaries of State Colin Powell and Condoleezza Rice. He launched the ISGP in 2008 as a new type of international forum in which credible experts provide governmental and societal leaders with understanding of the science and technology that can be reasonably anticipated to help shape the increasingly global societies of the 21st century. Dr. Atkinson has received National Science Foundation and National Institutes of Health graduate fellowships, a National Academy of Sciences Post Doctoral Fellowship, a Senior Fulbright Award, the SERC Award (U.K.), the Senior Alexander von Humboldt Award (Germany), a Lady Davis Professorship (Israel), the first American Institute of Physics' Scientist Diplomat Award, a Titular Director of the International Union of Pure and Applied Chemistry, the Distinguished Service Award (Indiana University), an Honorary Doctorate (Eckerd College), the Distinguished Achievement Award (University of California, Irvine), and was selected by students as the Outstanding Teacher at the University of Arizona. He received his B.S. (high honors, Phi Beta Kappa) from Eckerd College and his Ph.D. in physical chemistry from Indiana University.

Dr. Ben Tuchi, Secretary/Treasurer

Dr. Tuchi is chairman of the board of directors of the Arizona Research Park Authority. He received his B.S. and M.S. degrees in Business Administration from the Pennsylvania State University and his PhD in Finance from St Louis University. His full-time teaching career began in 1961 at St. Francis College and continued until 1976 at West Virginia University. From 1976 through 1996 he served in cabinet levels at West Virginia University, The University of Arizona, The University of North Carolina at Chapel Hill, and finally as Sr. Vice Chancellor for Business and Finance of the University of Pittsburgh. During those assignments he was simultaneously a tenured professor of finance. He retired from the last executive post in 1996 and returned to a full-time teaching position as Professor of Finance at the University of

Pittsburgh, until his retirement in 1999. For the two years prior to his retirement he was the Director of Graduate Programs in Business in Central Europe, at Comenius University, making his home in Bratislava, The Slovak Republic.

Dr. Janet Bingham, Member

Dr. Bingham is former President and CEO of the George Mason University (GMU) Foundation and GMU's Vice President for Advancement. GMU is the largest university in Virginia. Previously, she was President and CEO of the Huntsman Cancer Foundation (HCF) in Salt Lake City, Utah. The foundation is a charitable organization that provides financial support to the Huntsman Cancer Institute, the only cancer specialty research center and hospital in the Intermountain West. Dr. Bingham also managed Huntsman Cancer Biotechnology Inc. In addition, she served as Executive Vice President and Chief Operating Officer with the Huntsman Foundation, the private charitable foundation established by Jon M. Huntsman Sr. to support education, cancer interests, programs for abused women and children, and programs for the homeless. Before joining the Huntsman philanthropic organizations, Dr. Bingham was the Vice President for External Relations and Advancement at the University of Arizona. Prior to her seven years in that capacity, she served as Assistant Vice President for Health Sciences at the University of Arizona Health Sciences Center. Dr. Bingham was recognized as one of the Ten Most Powerful Women in Arizona.

Dr. Henry Koffler, Member

Dr. Koffler is President Emeritus of the University of Arizona (UA). He served as President of the UA from 1982-1991. From 1982 he also held professorships in the Departments of Biochemistry, Molecular and Cellular Biology, and Microbiology and Immunology, positions from which he retired in 1997 as Professor Emeritus of Biochemistry. His personal research during these years concentrated on the physiology and molecular biology of microorganisms. He was Vice President for Academic Affairs, University of Minnesota, and Chancellor, University of Massachusetts/Amherst, before coming to the UA. He taught at Purdue University, where he was a Hovde Distinguished Professor, and the School of Medicine at Western Reserve University (now Case Western Reserve University). Dr. Koffler served as a founding Governor and founding Vice-Chairman of the American Academy of Microbiology, and as a member of the governing boards of Fermi National Accelerator Laboratory, the Argonne National Laboratory, and the Superconducting Super Collider Laboratory. He was also a board member of the Association of American Colleges and Universities, a member and Chairman of the Council of

Presidents and a member of the executive committee of the National Association of Land Grant Colleges and Universities. He was also Founder, President and board member of the Arizona Senior Academy, the driving force in the development of the Academy Village, an innovative living and learning community. Among the honors that Dr. Koffler has received are a Guggenheim Fellowship and the Eli Lilly Award in Bacteriology and Immunology.

Mr. Jim Kolbe, Member

For 22 years, Mr. Kolbe served in the United States House of Representatives, elected in Arizona for 11 consecutive terms, from 1985 to 2007. Mr. Kolbe is currently serving as a Senior Transatlantic Fellow at the German Marshall Fund of the United States, and as a Senior Adviser to McLarty Associates, a strategic consulting firm. He advises on trade matters as well as issues of effectiveness of U.S. assistance to foreign countries, on U.S.-European Union relationships, and on migration and its relationship to development. He is also Co-Chair of the Transatlantic Taskforce on Development with Gunilla Carlsson, the Swedish Minister for International Development Cooperation. He also is an adjunct Professor in the College of Business at the University of Arizona. While in Congress, he served for 20 years on the Appropriations Committee of the House of Representatives, was chairman of the Treasury, Post Office and Related Agencies subcommittee for four years, and for his final six years in Congress, he chaired the Foreign Operations, Export Financing and Related Agencies subcommittee. He graduated from Northwestern University with a B.A. degree in Political Science and then from Stanford University with an M.B.A. and a concentration in economics.

Dr. Charles Parmenter, Member

Dr. Parmenter is a Distinguished Professor Emeritus of Chemistry at Indiana University. He also served as Professor and Assistant and Associate Professor at Indiana University in a career there that spanned nearly half a century (1964-2010). He earned his bachelor's degree from the University of Pennsylvania and served as a Lieutenant in the U.S. Air Force from 1955-57. He worked at DuPont after serving in the military and received his Ph.D. from the University of Rochester and was a Postdoctoral Fellow at Harvard University. He has been elected a Member of the National Academy of Sciences and the American Academy of Arts and Sciences, and a Fellow of the American Physical Society and the American Association for the Advancement of Science. He was a Guggenheim Fellow, a Fulbright Senior Scholar, and received the Senior Alexander von Humboldt Award in 1984. He has received the Earle K. Plyler Prize, was a Spiers Medalist and Lecturer at the Faraday

Society, and served as Chair of the Division of Physical Chemistry of the American Chemical Society, Co-Chair of the First Gordon Conference on Molecular Energy Transfer, Co-organizer of the Telluride Workshop on Large Amplitude Motion and Molecular Dynamics, and Councilor of Division of Chemical Physics, American Physical Society.

Mr. Thomas Pickering, Member

Mr. Pickering is Vice Chairman of Hills & Co, international consultants, and Strategic Adviser to NGP Energy Capital Management. He co-chaired a State-Department-sponsored panel investigating the September 2012 attack on the U.S. diplomatic mission in Benghazi. He served as U.S. ambassador to the United Nations in New York, the Russian Federation, India, Israel, El Salvador, Nigeria, and the Hashemite Kingdom of Jordan. Mr. Pickering also served on assignments in Zanzibar and Dar es Salaam, Tanzania. He was U.S. Under Secretary of State for Political Affairs, president of the Eurasia Foundation, Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs, and Boeing Senior Vice President for International Relations. He also co-chaired an international task force on Afghanistan, organized by the Century Foundation. He received the Distinguished Presidential Award in 1983 and again in 1986 and was awarded the Department of State's highest award, the Distinguished Service Award in 1996. He holds the personal rank of Career Ambassador, the highest in the U.S. Foreign Service. He graduated from Bowdoin College and received a master's degree from the Fletcher School of Law and Diplomacy at Tufts University.

Dr. Eugene Sander, Member

Dr. Sander served as the 20th president of the University of Arizona (UA), stepping down in 2012. He formerly was vice provost and dean of the UA's College of Agriculture and Life Sciences, overseeing 11 academic departments and two schools, with research stations and offices throughout Arizona. He also served as UA Executive Vice President and Provost, Vice President for University Outreach and Director of the Agricultural Experiment Station and Acting Director of Cooperative Extension Service. Prior to his move to Arizona, Dr. Sander served as the Deputy Chancellor for biotechnology development, Director of the Institute of Biosciences and Technology, and head of the Department of Biochemistry and Biophysics for the Texas A&M University system. He was Chairman of the Department of Biochemistry at West Virginia University Medical Center and Associate Chairman of the Department of Biochemistry and Molecular Biology at the College of Medicine, University of Florida. As an officer in the United States Air Force, he was the assistant chief of the biospecialties section at the Aerospace Medical Research Laboratory. He graduated with a bachelor's degree from the University of Minnesota, received his master's degree and Ph.D. from Cornell University and completed postdoctoral study at Brandeis University. As a biochemist, Dr. Sander worked in the field of mechanisms by which enzymes catalyze reactions.

Mr. Richard Armitage, Special Adviser

Mr. L. Armitage is the President at Armitage International, where he assists companies in developing strategic business opportunities. He served as Deputy Secretary of State from March 2001 to February 2005. Mr. Armitage, with the personal rank of Ambassador, directed U.S. assistance to the new independent states (NIS) of the former Soviet Union. He filled key diplomatic positions as Presidential Special Negotiator for the Philippines Military Bases Agreement and Special Mediator for Water in the Middle East. President Bush sent him as a Special Emissary to Jordan's King Hussein during the 1991 Gulf War. Mr. Armitage also was Deputy Assistant Secretary of Defense for East Asia and Pacific Affairs in the Office of the Secretary of Defense. He graduated from the U.S. Naval Academy. He has received numerous U.S. military decorations as well as decorations from the governments of Thailand, Republic of Korea, Bahrain, and Pakistan. Most recently, he was appointed an Honorary Companion of The New Zealand Order of Merit. He serves on the Board of Directors of ConocoPhillips, ManTech International Corporation, and Transcu Ltd., is a member of The American Academy of Diplomacy as well as a member of the Board of Trustees of the Center for Strategic and International Studies.

Biographical Information of ISGP staff

George Atkinson, Ph.D.

Dr. Atkinson is the ISGP Founder and Executive Director and an Emeritus Professor of Chemistry, Biochemistry and Optical Science at the University of Arizona. His professional career includes academic teaching, research, administration, roles as a corporate founder and executive, and public service at the federal level. He is former Science and Technology Advisor (STAS) to U.S. Secretaries of State Colin Powell and Condoleeza Rice. In 2014, Dr. Atkinson was named president of Sigma Xi, The Scientific Research Society.

Jennifer Boice, M.B.A

Ms. Boice is the ISGP Program Coordinator. She worked for 25 years in the newspaper industry at the Tucson Citizen, and was the Editor of the Tucson Citizen when it was closed in 2009. Ms. Boice received her M.B.A. from the University of Arizona and graduated from Pomona College in California with a degree in economics.

Sweta Chakraborty, Ph.D.

Dr. Chakraborty is the ISGP Associate Director. She received her doctorate in Risk Management from King's College London and has more than 20 published articles, has contributed to three books, and is author of the forthcoming book "Pharmaceutical Safety: A Study in Public and Private Regulation." She is currently an adjunct assistant professor at Columbia University and a program associate at Oxford University's Centre for Socio-Legal Studies.

Barbara Del Castello, B.A.

Ms. Del Castello is an ISGP Senior Fellow. She is a graduate of Eckerd College, St. Petersburg, Florida, with a degree in Biology and a minor in Anthropology. Before she began her work with ISGP, her focus was on Alzheimer's disease research in transgenic C. elegans.

Christina Medvescek, B.A.

Ms. Medvescek is the ISGP Program Administrator. She is an internationally published journalist and editor specializing in health, human development and conflict resolution. She also serves as an EEO mediator for the U.S. Postal Service, and as a volunteer mediator, facilitator and instructor at the Center for Community Dialogue, Tucson, AZ.

Aubrey Paris, B.A.

Ms. Paris is an ISGP Senior Fellow. She graduated with degrees in Chemistry and Biology from Ursinus College, Collegeville, Pennsylvania, in May 2015, and will begin pursuing her Ph.D. in Inorganic Chemistry shortly thereafter. Ms. Paris' research interest is electro- and photocatalytic reduction of carbon dioxide as an alternative energy and environmental remediation strategy.

Cleo Warner, B.A.

Ms. Warner is an ISGP Fellow. She is a graduate from Eckerd College, St. Petersburg, Florida, with a degree in Literature and Environmental Studies. Throughout her studies and various internships and jobs, she has focused on science communication with particular interest in food systems.

Ramiro Soto, B.S.

Mr. Ramiro Soto is a Fellow with the ISGP. He graduated in May 2015 from the University of Arizona College of Science with a degree in General Applied Mathematics and a minor in Hebrew Studies. He plans to enter a doctoral program to further his studies in mathematics

Andrea Vazquez

Ms. Vazquez is a Fellow with the ISGP. She currently is a student at Arizona State University pursuing her bachelor's degree in social work. She also serves as a college prep assistant at a Tucson, Arizona, high school. Her goal as a social worker is to advocate for people who are vulnerable and oppressed, especially youth.