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

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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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Training in Narrative Persuasion for Ethical, Effective Science Communication

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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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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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