Insights and Practical Considerations *for Communicating Basic Science*

SciPEP
Science Public Engagement Partnership

THE KAVLI FOUNDATION

U.S. Department of ENERGY | Office of Science

DOI 10.17605/OSF.IO/4KGQF

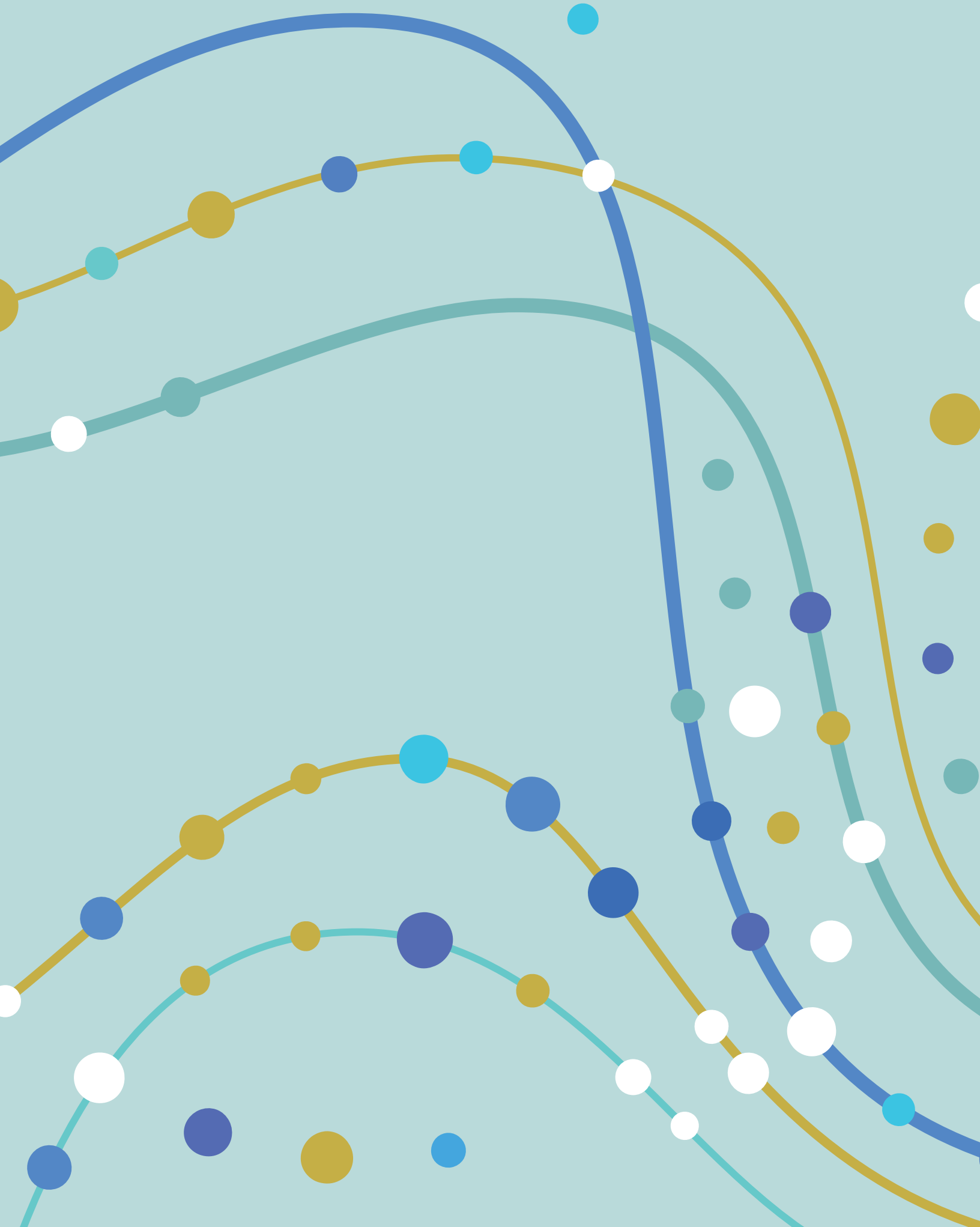
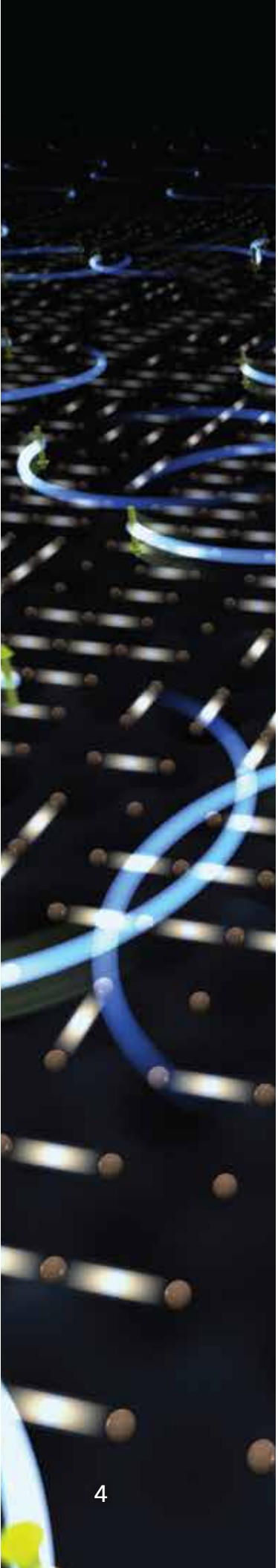


TABLE OF CONTENTS



At first, it was a simple enough observation.

It was 2019. We'd attended an incredible science communication summit. But we and some colleagues realized we weren't seeing much guidance specific to sharing basic research with non-scientist audiences. In contrast, we knew of extensive resources for sharing applied work like climate science or vaccines.

We marvel at basic science—from the atomic makeup of materials to galaxy formation. It is the focus of investment for our institutions: The Kavli Foundation and the United States Department of Energy (DOE) Office of Science.

Our organizations formed the Science Public Engagement Partnership, or SciPEP, in 2020. This collaboration set out to explore what we knew and didn't know about basic science communication and engagement.[1,2] Our thinking was that we'd commission scholars to gather the best available evidence on basic science communication, and then transform that knowledge into resources for basic scientists, communication professionals, and leaders of communications training programs.

Except the literature search on basic science communication came up practically empty.

Just a few of the thousands of journal articles scoured covered basic science communication, and those were isolated papers rather than studies that built on one another.[3,4] In short, our ambitions to curate robust evidence were no longer realistic. The information didn't exist.

So, we pivoted. SciPEP hosted deep, rich discussions with colleagues in science communication.[5,6,7] We tapped social scientists to better understand the mindset, goals, and needs of different publics, including scientists.[8,9,10] And we pondered what questions we ought to ask that could lead to improvements in basic science communication.

This publication is the culmination of those efforts. It is a synthesis of five years of discovery (pun intended)—key takeaways, themes, tips, and even more questions. It is a resource for others (yes, you, dear reader) to build upon and adapt for your needs.

And it is laser-focused on insights unique to the communication of basic science. While there exist shared considerations with the communication of applied sciences and technology, this resource won't cover those. To give a few examples:

- Many institutions don't adequately incentivize and fund science communication work.
- There's a lack of evaluation—we must go beyond attendance counts and satisfaction surveys to learn exactly what our communications achieve and the extent to which their effects last.
- We must continue to face uncomfortable truths about racism in science and distrust of big institutions because both affect communications practice.

This resource, and indeed SciPEP, would not have been possible without the visionary leadership of Rick Borchelt, who retired from the role of director of communications and public affairs at the DOE Office of Science in September 2023. Rick dedicated his career to communicating the value of science and ensuring that communication practice is grounded in evidence. We're grateful to the fearless leaders who championed SciPEP from the start: Dr. Cynthia Friend, president of The Kavli Foundation, and Dr. Harriet Kung, acting director of the DOE Office of Science. We cannot imagine having had more capable SciPEP teammates than Kavli's Science and Society program specialist, Lauren Budenholzer, and administrative specialist Melina Fuentes. And we acknowledge and appreciate the countless contributions of our colleagues on this journey: Allison Eckhardt, Stacey Bailey, Natalie Soldan, Katie McKissick, and Elaine Bui.

We can hardly believe all we've gained from our SciPEP collaboration. The insights and energy will live on in this resource for the dynamic science communication community. SciPEP will end with more questions than answers and that's OK. We as a community need more research, more conversation, and better sharing of each other's findings. Consider this our call for you to access this knowledge and carry forward what SciPEP started. We've built the rocket, cultivated the launch team, and hit the ignition switch. It's up to you to steer the vessel, explore this vast space, and come back to share what you discover.

Keegan Sawyer, Ph.D.
Project Director, Science of Science Communication
DEPARTMENT OF ENERGY OFFICE OF SCIENCE

Brooke Smith, M.S.
Director, Science and Society
THE KAVLI FOUNDATION

Cite as:

SciPEP. (2024). Insights and Practical Considerations for Communicating Basic Science. Report for the Department of Energy Office of Science and The Kavli Foundation as part of the Science Public Engagement Partnership.
DOI: 10.17605/OSF.IO/4KGQF

Managing Editor

Carmen Drahl, Ph.D.
Freelance Science Journalist

Contributing Writers

Mónica Feliú Mójer, Ph.D.
Director of Public Engagement with Science, Ciencia Puerto Rico; Director of Inclusive Science Communication and Engagement, Science Communication Lab

Bruce V. Lewenstein, Ph.D.
Professor of Science Communication, Cornell University

Michelle Warren, M.A.
Program Manager, Resources Legacy Fund
Former Civic Science Fellow for Advancing Diversity, Equity, and Inclusion in Public Engagement, SciCounts

Sara K. Yeo, Ph.D.
Associate Professor, Department of Communication, The University of Utah; Director and PI, STEM Ambassador Program

Consulting Experts

Cary Funk, Ph.D.
Former Director of Science and Society Research, Pew Research Center

Jeanne Garbarino, Ph.D.
Executive Director, RockEDU Science Outreach at The Rockefeller University

Todd P. Newman, Ph.D.
Assistant Professor, Department of Life Sciences Communication, University of Wisconsin-Madison

Copy Editors

Michael Church, Ph.D. (Federal Contractor)
Karyn Houston, M.A.
Sandra Allen McLean, MSIS
Office of Communications and Public Affairs, Department of Energy Office of Science

Layout and Design

Katie McKissick

SciPEP Team

Rick Borchelt
Special Assistant to the Director (Retired), Department of Energy Office of Science

Brooke Smith, M.S.
Director, Science and Society, The Kavli Foundation

Keegan Sawyer, Ph.D.
Project Director, Science of Science Communication (Federal Contractor), Office of Communications and Public Affairs, Department of Energy Office of Science

Allison Eckhardt, M.S.
Acting Director, Office of Communications and Public Affairs, Department of Energy Office of Science

Natalie Soldan
Internal Communications Manager (Federal Contractor), Office of Communications and Public Affairs, Department of Energy Office of Science

Lauren Budenholzer, Ph.D.
Science and Society Specialist, The Kavli Foundation

Melina Fuentes
Science and Society Administrative Specialist, The Kavli Foundation

Katie McKissick
Digital Engagement Manager, The Kavli Foundation

Elaine Bui
Meetings and Events Manager, The Kavli Foundation

SciPEP 2021 Conference

Steering Committee

Erika Shugart, Ph.D. (Chair)
Executive Director and CEO, National Science Teaching Association

Ani Aprahamian, Ph.D.
Frank M. Freimann Professor of Physics, University of Notre Dame

Sarah R. Davies, Ph.D.
Professor of Technosciences, Materiality, and Digital Cultures, University of Vienna

Suzanne Ffolkes, M.A.
Assistant Dean for Strategic Affairs and Public Engagement, Florida Atlantic University Christine E. Lynn College of Nursing

Tiffany Lohwater
Chief Communications Officer and Assistant Dean for Communications, College of Computing, Data Science, and Society, University of California, Berkeley

Spiros Michalakis, Ph.D.
Mathematical Physicist and Manager of Outreach for the Institute for Quantum Information and Matter, Caltech

Alysson Muotri, Ph.D.
Professor, Departments of Pediatrics and Cellular & Molecular Medicine, University of California, San Diego School of Medicine

Brian Nord, Ph.D.
Scientist, U.S. Department of Energy's Fermi National Accelerator Laboratory; Director, Deep Skies Lab

Rebecca Thompson, Ph.D.
Chief Science and Education Officer, Saint Louis Science Center

Matthew S. VanDyke, Ph.D.
Associate Professor and Faculty Lead of the Alabama Science Communication Initiative, Department of Advertising & Public Relations, The University of Alabama

Sara K. Yeo, Ph.D.
Associate Professor, Department of Communication, The University of Utah; Director and PI, STEM Ambassador Program

Chair, Abstract Review

Gail Porter, M.A.
Director of Public Affairs (Retired), National Institute of Standards and Technology

Find presentation slides for the material in this resource:

DOI: 10.17605/OSF.IO/2CGSM

Cover image: Two states of a cuprate high-temperature superconductor simultaneously: Each circle represents the two electrons of a Cooper pair, which exist at relatively low energy and can carry current with no resistance. In this image, the superconducting Cooper-pair state is superimposed on a dashed pattern that indicates the static positions of electrons caught in a quantum "traffic jam" at higher energy - when the material acts as a Mott-insulator incapable of carrying current. (Credit: Brookhaven National Laboratory)

Introduction to this resource

Why was this resource created?

Basic science, also known as fundamental, curiosity-driven, and discovery science, is seldom the focus of the science communication universe.[1,2] The Science Public Engagement Partnership (SciPEP) between The Kavli Foundation and the U.S. Department of Energy Office of Science has unearthed new insights about communicating basic science. This resource showcases the most salient insights from our SciPEP conferences, commissioned research, and conversations.

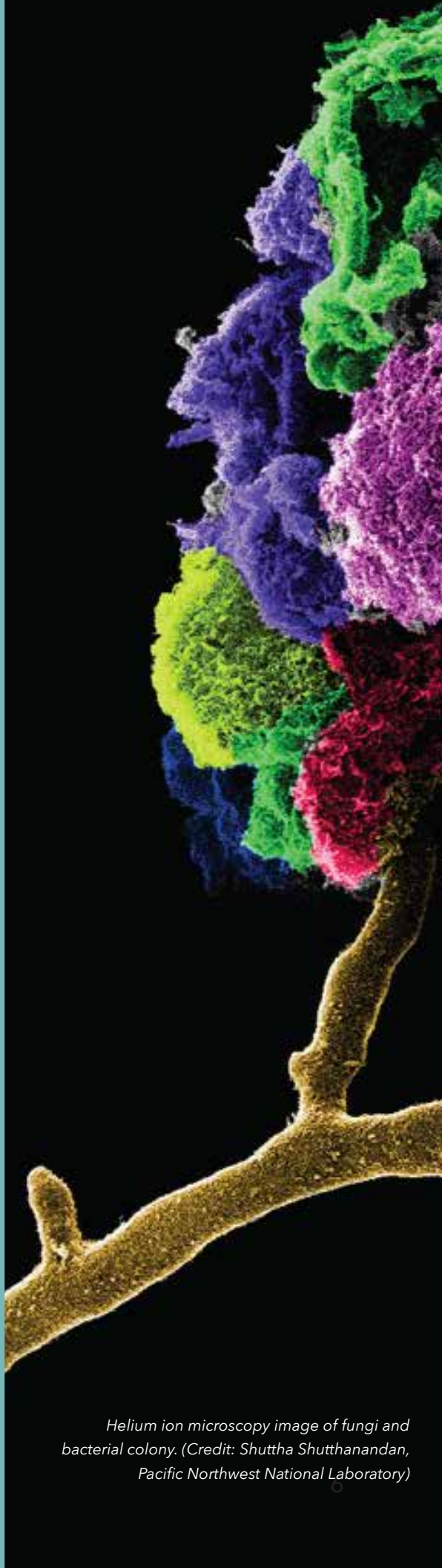
What do you mean by "basic science communication"?

This term includes communication to non-scientist audiences by scientists who focus on basic research and communication to non-scientific audiences by any professional about basic research.

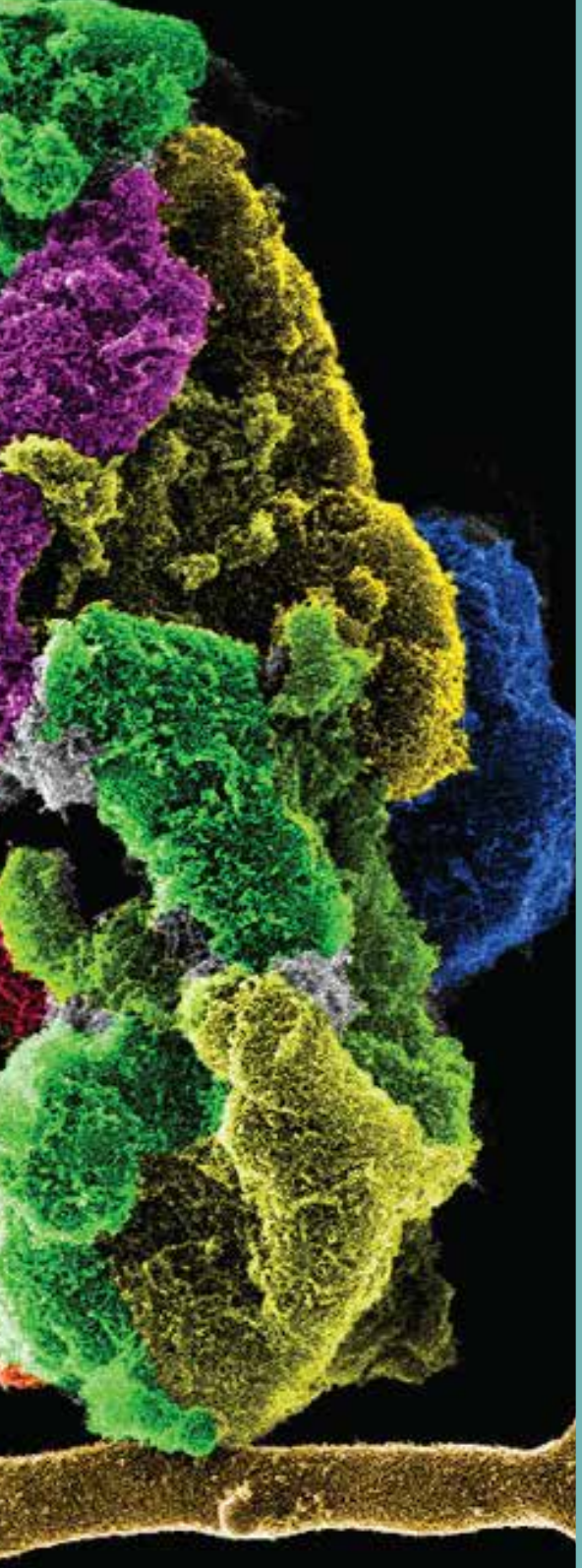
Who is this resource for?

This resource is for anyone exploring the communication of basic research with audiences of non-specialists, including but not limited to:

- Scientists focused on basic research who are interested in science communication.
- Professional communicators, including public affairs specialists and communication and engagement program leaders at institutions that support basic research, such as universities, museums, government agencies, foundations, and nonprofits.
- Trainers who support scientists and professionals in their communication and engagement goals.
- Social science scholars who study science communication and public perceptions of science and technology.



Helium ion microscopy image of fungi and bacterial colony. (Credit: Shuttha Shutthanandan, Pacific Northwest National Laboratory)



How should readers think about its contents?

The foundations of this resource are social science fields that focus on or inform strategic science communication practice and training, such as public engagement in science, science and technology policy, and public relations. Experts in these fields seek to ensure that science communication drives change in the world and that people turn to science when faced with a problem or decision.

Individual articles focus on different dimensions of basic science communication. The resource also contains examples of strategic communication of basic science.

It's not necessary to read the resource cover to cover (though we'd love it if you did!). For those unsure of what content might be most useful to them, "SciPEP Tips" are scattered throughout the resource. These quick takeaways provide an overview of accompanying content so readers can decide where to dive in.

So, is this a toolkit of best practices for communicating basic research?

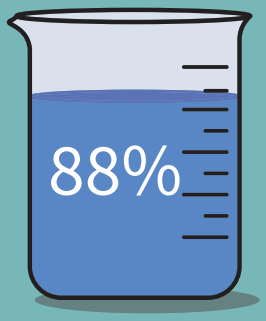
No. Creating best practices takes a large body of scholarly publications and evidence from practitioners. Most of the insights described in this resource are still emerging and don't have extensive backing yet. This resource attempts to explain what the insights mean, or may mean, for communications practice, but the SciPEP team fully acknowledges that more work is needed.

How should this resource be used going forward?

This resource was intended as a springboard for people's explorations that might move the field of basic science communication forward. It's meant to catalyze conversations and new connections among readers and inform their future research, funding, training, and practice. It is for you, however you decide to use it.

Support, key sectors, and funding for basic science: facts & figures

The U.S. public supports funding basic research...



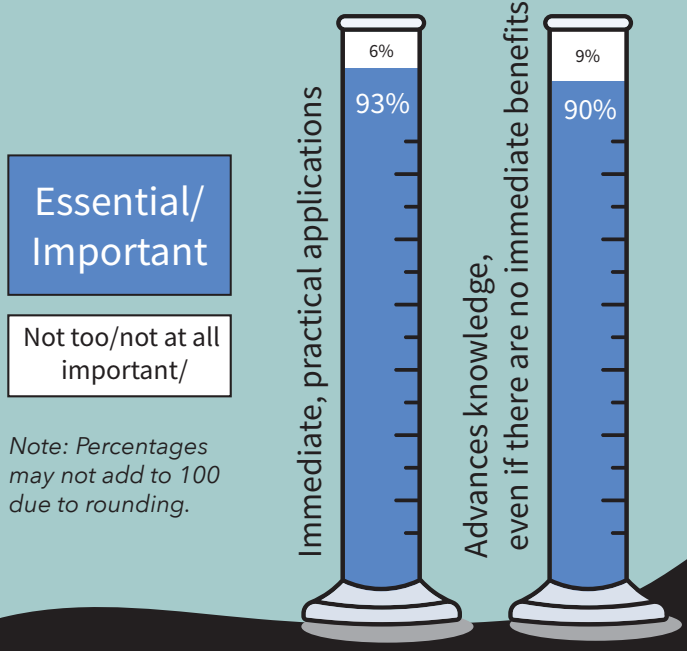
Of adults in the United States polled in 2022, 88% agree that scientific research that advances knowledge deserves federal government funding, even if it brings no immediate benefits.[1]

And support is consistent, remaining above 80% since 1999.[2]

Public support for basic research is high. People think basic research is important.

They also think it matters for society.

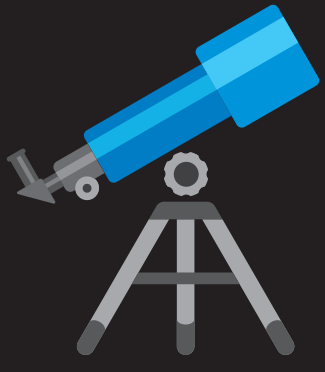
Of U.S. adults surveyed in 2019, 90% or more said that basic and applied research are essential or important.[3]



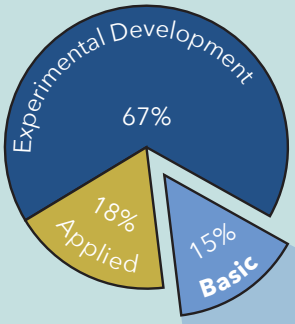
Audience matters

Different audiences can vary somewhat in their support of basic research topics. Additional polling data are available.[4]

Where is basic research conducted?[5]



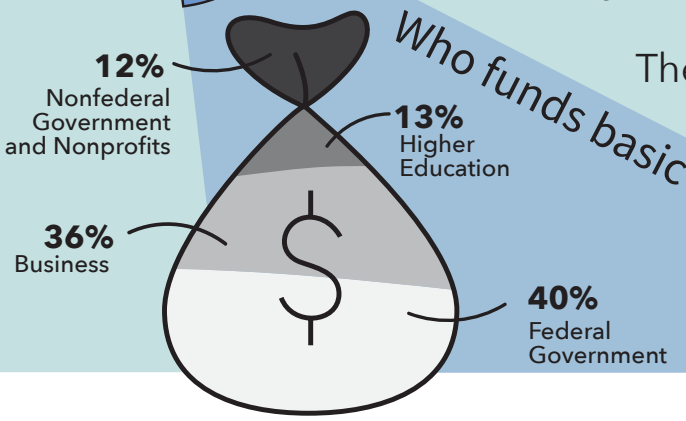
Most basic research took place in the higher education sector in 2021. The business sector, however, is conducting a greater percentage of basic research than in the recent past. For comparison, in 2006, 58% of basic research was performed in higher education institutions, 16% took place in the federal government, and just 14% took place in business. [6]



Basic research funding 101

In 2021, basic research accounted for $118.6 billion in current dollars, about 15% of the $789.1 billion total R&D funding in the U.S.[7] That percentage has remained relatively constant for seven decades.[8]

Who funds basic research?[10]



The federal government is still the largest funder of basic research, but its investment in 2021 was only slightly above business's.[9]

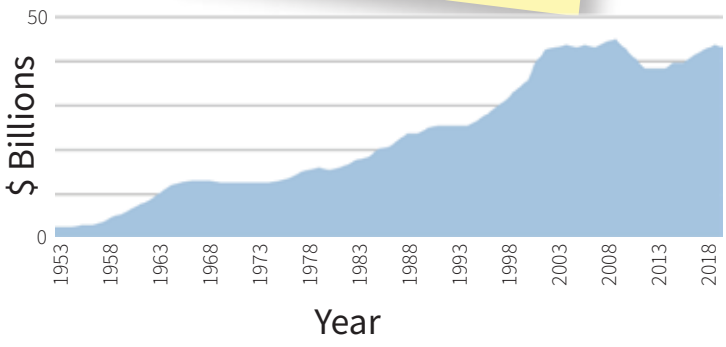
Note: Percentages may not add to 100 due to rounding.

Business is catching up in basic research funding

The federal investment in basic research has been fairly stable since 2003, after adjusting for inflation. In contrast, the private sector has more than tripled its investment since 2003.[11]

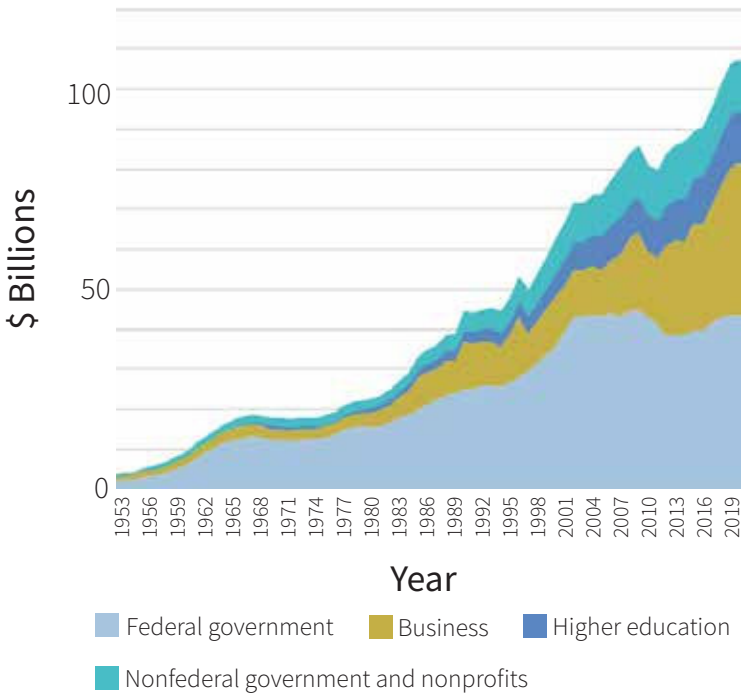
The private sector overtook the federal government in overall R&D spending in 1980.[12]

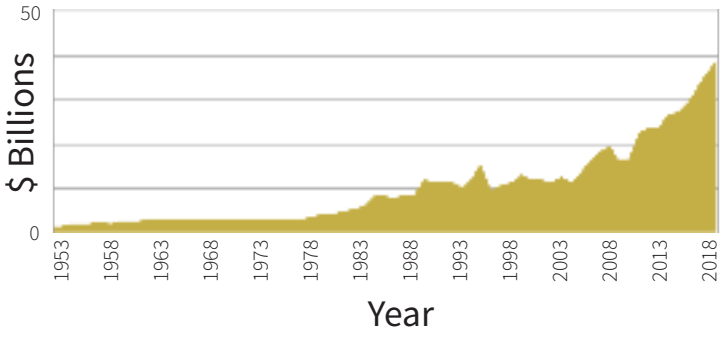
If policymakers are your target audience, make sure you understand trends in federal government support for basic research.



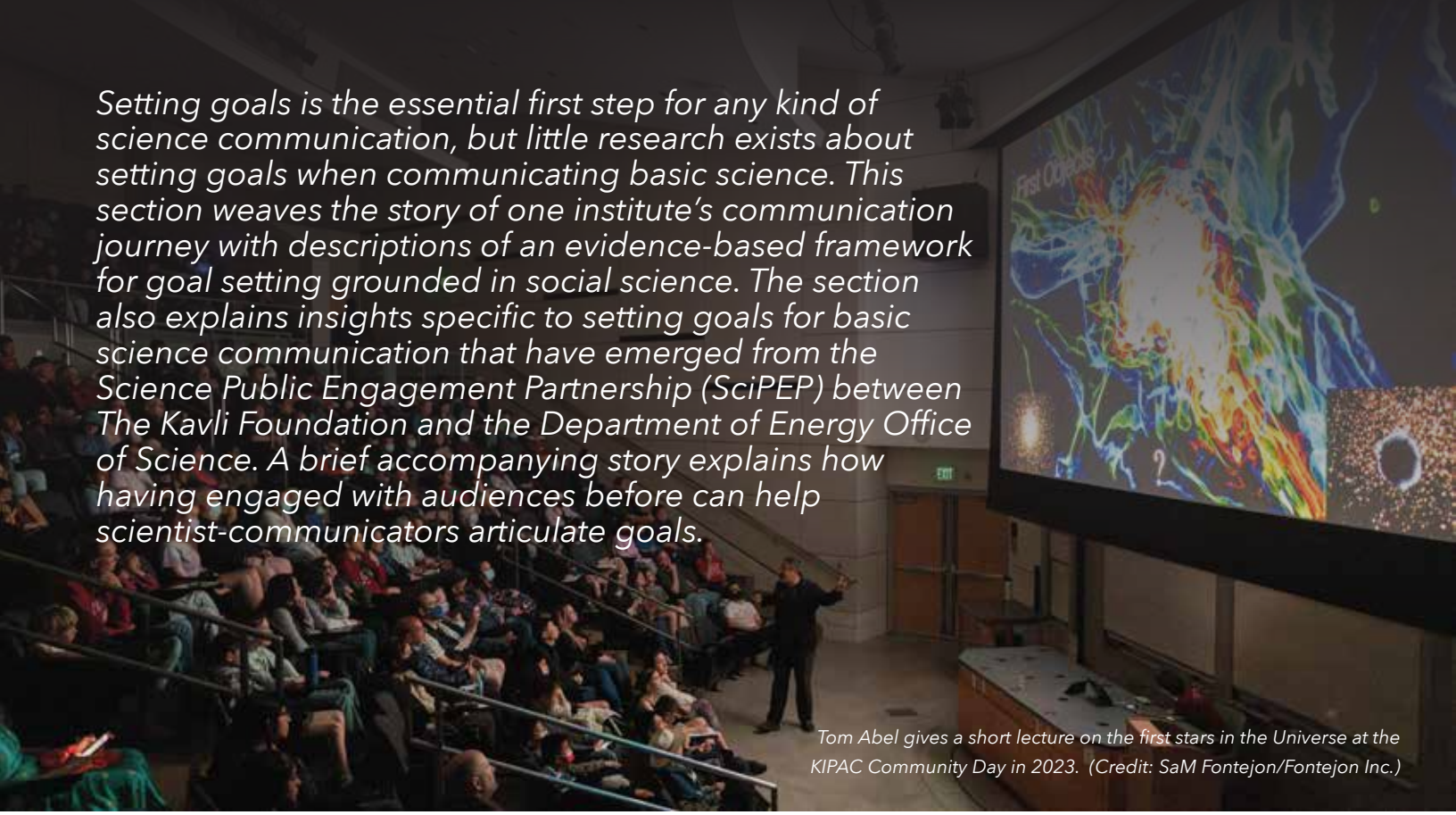
U.S. basic research expenditures, by source of funds:

1953-2021 (Adjusted for inflation)





Setting goals is the essential first step for any kind of science communication, but little research exists about setting goals when communicating basic science. This section weaves the story of one institute's communication journey with descriptions of an evidence-based framework for goal setting grounded in social science. The section also explains insights specific to setting goals for basic science communication that have emerged from the Science Public Engagement Partnership (SciPEP) between The Kavli Foundation and the Department of Energy Office of Science. A brief accompanying story explains how having engaged with audiences before can help scientist-communicators articulate goals.



Tom Abel gives a short lecture on the first stars in the Universe at the KIPAC Community Day in 2023. (Credit: SaM Fontejon/Fontejon Inc.)

At an astrophysics institute, articulating clear communication goals is reshaping relationships with audiences

by Carmen Drahl
Freelance Science Journalist

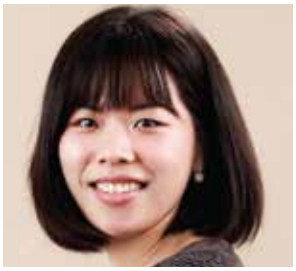
When Xinnan Du joined the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) in the brand-new position of outreach and engagement manager, she was ready for a job with exciting challenges. After all, she was joining in December 2021, amid the Omicron wave of COVID-19, and she knew she'd be tasked with planning post-pandemic outreach at KIPAC. But the challenge she didn't expect would involve changing her understanding about science communication.

Du's new position was part of a rigorous makeover for outreach strategy at KIPAC. The astrophysics powerhouse, located at Stanford University and the SLAC National Accelerator Laboratory, was setting out to build a culture of continuous improvement, with a commitment to learning about the impact of the institute's science engagement. KIPAC's partners in this work, a team of evaluation experts at Catalyst Consulting, would help KIPAC's team create systems to measure success and make informed adjustments to engagement efforts. The first step to that end would be articulating the institute's goals, a lengthy process that involved group discussions and interviews with the institute's leadership, program organizers, and more than 30 scientists.

In mid-2022, Du found herself in a one-on-one interview with someone on the Catalyst team. "They would ask, 'Why are you doing this public lecture?'," Du recalls. She'd respond that KIPAC's team wants to inform the public. "And then they would ask, 'But why is that important? Does it make a difference whether they know or not?'" Du would give an answer, only to be asked why once more.

"It was intense," Du says. As the interviewer kept asking why, "it was almost like some-

QUOTED IN THIS ARTICLE



Xinnan Du
Outreach and Engagement Manager
KAVLI INSTITUTE FOR PARTICLE ASTROPHYSICS AND COSMOLOGY, STANFORD UNIVERSITY

Anthony Dudo
Associate Professor, School of Advertising and Public Relations
THE UNIVERSITY OF TEXAS AT AUSTIN

John Besley
Ellis N. Brandt Professor of Public Relations, Department of Advertising and Public Relations
MICHIGAN STATE UNIVERSITY

Rose Hendricks
Seeding Action Research Director
ASSOCIATION OF SCIENCE AND TECHNOLOGY CENTERS

one pushed me to keep thinking," probing to learn what she felt KIPAC ultimately wanted to achieve by having its experts share findings about astrophysics. In other words, it was transforming her comprehension of what constitutes a communication goal.

Goals, defined

Setting clear goals is critical for successful science communication, says Michigan State University social scientist John Besley, who is part of the team that Catalyst assembled to work with Du and KIPAC. Strategic communication on any topic, including basic science like astrophysics, has a multi-step structure or framework grounded in social science, Besley says.

Goals specific to your audience come first in that framework. Goals are things that a communicator would like people to do, or not to do, as a result of the time, energy, money, and resources the communicator gives to science communication, Besley says. In other words, goals specify the desired behaviors a communicator hopes to prompt in a specific audience, like ensuring that policymakers will support continued funding for astrophysics research. Every other decision about communication follows from these audience-specific behavioral goals, Besley explains.

But it's not as simple as asking policymakers for money. Or if your goal is to encourage teens to pursue science careers, it's not as simple as telling them they should become scientists. "Communication is processed in someone's head and heart before it's acted on," says University of Texas at Austin social scientist Anthony Dudo, who together with Besley wrote a book about this framework, which they call strategic science communication.[1]

To achieve goals, communicators must foster beliefs and feelings that the head and heart internalize over the short term, and that perhaps over the course of many engagements can move the needle on behaviors. For instance, Besley says, "I can communicate that a science career would be enjoyable and useful, and something your colleagues will think positively of, and that it's something my audience has the ability to do." If an audience of teens comes to believe those things, some of them may choose science careers. Besley and Dudo call these sorts of beliefs and feelings "objectives," and they are the second piece of the strategic communication framework.

To accomplish objectives, communicators can turn to tactics, the third layer of the framework. Tactics, Besley says, are the kinds of things that commonly come to mind when pondering science communication efforts, like whether to start a TikTok account or host live events or deciding how much humor and storytelling to inject into content. "Creativity and fun come in at the tactical level," but communication won't be successful if tactics don't match objectives and goals, which need to be specified first, he says.

"If you don't know what you want to happen, you can't make choices about what you need to emphasize," Besley says. "Do I put resources into a public lecture or a podcast? Do I put resources into a youth program, or a program meant to build

Goals

INFLUENCING

Behaviors
- Health choices
- Environmental choices
- Donating
- Voting
- Career choice
- Research approach
- Research topic

Acceptance
- Willingness to trust
- Legitimacy perceptions
- Decision acceptance

Objectives

FOSTERING

Beliefs
- Scientific facts/processes
- Caring/benevolence/warmth
- Honesty/integrity
- Voice/willingness to listen
- Shared identity/shared values
- Competence/ability
- Risk/benefit/response-efficacy
- Self-efficacy
- Normative

Feelings (Surprise, anger, etc.)

Frames (Gain vs. loss, health vs. economic, etc.)

Tactics

Communication Behaviors
- Time for dialogue/listening
- Event structure/setup/site choice

Message Content

Tone/Style/Intensity
- Humorous/aggressive/etc.
- Descriptive/narrative/etc.

Time of Day

Source
- Expert/celebrity/etc.

Channel
- Face-to-face, social media, etc.

This graphic explains a framework for strategic communication, with some examples of goals, objectives, and tactics that could be applied to communicating basic science. (Credit: Courtesy of John Besley, Michigan State University)

relationships with a community group? There's not an infinite amount of money." Without goals, he says, communicators risk making tactical choices that don't lead to where they want to go or that could even backfire.

Besley's role with Catalyst and KIPAC is akin to that of a personal fitness trainer, encouraging KIPAC to do mental weight-lifting to identify clear goals and select appropriate objectives and tactics. "We're trying to be advisors that help Xinnan and her colleagues think about what they're trying to accomplish, and sort of gently pushing and asking questions," he says.

The goal-setting landscape

Goals like encouraging people to get vaccinated or to buy an electric vehicle have to do with applied research. But most research at KIPAC is basic research on astrophysics—it focuses on expanding knowledge without aiming for a specific application. A few special insights about articulating goals for communicating basic science have emerged from the Science Public Engagement Partnership (SciPEP) between The Kavli Foundation and the Department of Energy Office of Science.

First, little research exists on best practices for communicating basic science, let alone setting goals. Besley and colleagues scoured about 2,300 articles in four major science communication journals to see what they had to say about communicating basic science, including astrophysics. Their 2021 report found that only about 5% of the articles had substantive data on basic science communication.[2] Those that did "focused on a small number of ingredients that could go into communication," and made limited connections to audi-

SciPEP Tip

Figuring out behavioral goals for your audience should be the first step in your process for communicating basic science, long before you decide whether to do a podcast or event. This work is likely to require intense reflection. If possible, ask a colleague or expert to push you to break free of your typical thought patterns.

Basic scientists' priority goals for science communication *See Page 16*

Average response to question: "In general, when choosing to communicate with your priority audience(s), how important or unimportant should the following type of goal be for scientists like you?"
(1 = Very low importance, 7 = Very high importance)

See full report for exact question wording and additional analysis.
*Half of respondents saw each version for an embedded experiment.

Besley and Dudo asked basic scientists which goals they prioritize for science communication. They tended to rate all goals highly. (Credit: Courtesy of John Besley and Anthony Dudo)

ence-specific behavioral goals, Besley says. In basic science journals, such articles are rarer still. A separate 2021 report analyzed roughly 1.5 million articles and found 43 that focused on both public engagement and basic science concepts.[3]

Second, communicators of basic science may be setting goals that are unachievable or disconnected from the impacts they desire, says social scientist Rose Hendricks. Hendricks, now with the Association of Science and Technology Centers, and sociolinguist Marissa Fond at Georgetown University interviewed 30 science communication researchers, practitioners, and scientist-communicators for a 2023 report, asking them to reflect on goals and motivations for communicating basic science. Hendricks and Fond got the sense that their interviewees largely believed that others who communicate basic science rarely set strategic goals.[4] What kinds of goals do they set? They may set goals that are disconnected from their actions and tactics, or goals that are unachievable through communication alone. Hendricks gives the hypothetical example of a physicist who wants to increase diversity in their field, and who might decide to record videos of themselves talking about their research and upload them to YouTube, where people from diverse backgrounds can watch them, get inspired, and pursue physics careers. This goal is disconnected from the tactics the physicist is pursuing. It's not clear who will watch the videos, Hendricks says. And it's not clear that watching an enthusiastic expert, even one who comes from a marginalized background, can make an audience feel that a science career is attainable and desirable. An unachievable goal, Hendricks explains, might be thinking that communication alone can fix structural problems like the lack of diversity in physics.

Third, scientists with a substantial focus on basic science tend to think of general audiences for their communication, and as a result, the goals they envision are more general behavioral goals, rather than audience-specific goals. Receiving goal-setting guidance is likely to be helpful to them because they may not have had much opportunity to consider all the possible goal options. This isn't to say that applied scientists have mastered goal setting, Dudo says. But on average, "basic scientists are probably going to have to work a little bit harder than applied scien-

tists to communicate effectively, because it might be harder for them to latch onto a goal that is meaningful to them."

In fall 2022, Besley and Dudo sent a survey to scientists who'd published work in journals focused largely on basic science, asking them, among several things, which of a list of eight goals they prioritize for science communication. Among the eight were goals such as building trust with audiences so they'll consider science when making decisions, ensuring that policymakers fund science, and ensuring the scientific community moves toward greater justice and equity (see figure on page 15). The scientists reported that they had not previously given much consideration to most of the goals the survey listed.[5] They tended to rate all eight goals highly. However, a goal that had to do with getting input from non-scientists about research decisions received a slightly lower priority score.

This conclusion dovetails with work that has not yet been published by communication researcher Todd P. Newman at the University of Wisconsin-Madison. Newman and his team surveyed scientists conducting both basic and applied work. They found only nuanced differences between how basic-focused and applied-focused scientists approach goals. Basic scientists tended to deprioritize goals about public input into the scientific process, but rated goals and objectives related to generating excitement about science highly.[6] Though the Newman study and the Besley/Dudo study both gave survey-takers eight goals to choose from, all three experts say that there is no universally accepted list of communication goals.

While setting goals may seem daunting, scientists don't have to do it alone. "Scientists need someone who can help them dig into why they might want people to feel wonder, or why they feel like they might want to correct misinformation, to get past their first answer and really push towards the behavior change they want to see in the world," Besley says.

Goals, decided

Du's in-depth conversations with the Catalyst team helped refine what she considered an institution-wide communication goal. At first, she was characterizing the goal as inspiring youth through physics and STEM. But after thinking hard about why this mattered, she realized that a desired action could be for high school students to pursue a STEM major in college. "That's a behavioral goal. It's what you want them to do. I think this paradigm change was very valuable," Du says.

Communication is processed in someone's head and heart before it's acted on.

After dozens of conversations, the Catalyst team zeroed in on three goals for KIPAC. The first is for K-12 students to pursue STEM majors and careers. The second is for adults in the Bay Area to trust science and scientists. The third is to make KIPAC scientists feel more confident and comfortable when participating in outreach events.

It's rare for basic science-focused organizations like KIPAC to have articulated audience-specific behavioral goals, Besley says. But in the few projects he's aware of, the goals are usually like KIPAC's. "I think that youth-oriented goals and a broad trust goal make a lot of sense for basic science," he says. "It is a place where they have a unique opportunity to play given their assets."

Every institution has assets in place—personnel, programs such as a lecture series, relationships with other organizations, and scientific equipment like telescopes. Once Catalyst Consulting found common goals in all their conversations with KIPAC's staff and scientists, they had to think about how KIPAC could use its existing assets to better serve the goals.

For instance, Besley says, KIPAC's lecture series could be adapted to better foster

trust in scientists. Social science research demonstrates that people trust others that they see as competent, honest, and caring. Audiences commonly already perceive scientists as competent, Besley says. "But what are they doing to make sure they seem caring and honest?"

Catalyst gave KIPAC checklists with evidence-based tactics to help with that, Du says. "There's a checklist for the speaker, and there's a checklist for the organizer. And basically, the checklist was articulating different small ways that we could just tweak what we already have" to help audiences see KIPAC scientists as honest and caring. For instance, to show caring for online attendees of hybrid lectures, Du ensures there are always a few subject matter experts on hand to answer questions that pop up in the live chat during the lecture.

Short-term objectives like showing honesty can in principle be evaluated after every event. Well-articulated goals, objectives, and tactics make evaluation easier, Besley says. Without them, communication can fall flat. For instance, an examination of the European Space Agency's public-facing communications found that the agency did not define communication goals clearly and consistently, and that there was a mismatch between the agency's communications approach and audiences' interests and attitudes.[7]

A more strategic future

Du says that KIPAC is still developing evaluation processes for its outreach work in consultation with the Catalyst team. Though the planning process is ongoing, there are already changes at KIPAC that visitors might notice. In 2022, the lecture series was the only outreach option. "Now, public lectures are just one of the five regular programs we run," Du says. These include stargazing parties, an annual science fair, a virtual summer program teaching physics and computer programming to high school girls, and a program in Spanish sharing astrophysical discoveries and what it's like to be a scientist. Importantly, with concrete goals in place, precious time and resources go to areas most aligned with goals to maximize impact. "I feel we are empowered to say no" when a request doesn't align with the goals, Du says.

Du talks about her experience with articulating goals at conferences and workshops. Though she acknowledges that she is fortunate to have the funding and bandwidth to undertake the process, she urges her colleagues at museums, nonprofits, and universities to consider making a similar investment. "I had never done anything like defining goals," Du says. "I would recommend it 100%."

Three young participants smile for the camera in between exploring hands-on stations at the KIPAC Community Day in 2023. (Credit: SaM Fontejon/Fontejon Photography, Inc.)

Experience helps with goal-setting

by Carmen Drahl

Olivia Ambrogio's job at the American Geophysical Union (AGU) is to train scientists to communicate effectively with varied audiences. As assistant director of AGU's Sharing Science program, she creates online toolkits for researchers, runs communication workshops, and manages a yearlong training program for scientists committed to conducting regular outreach to policymakers, journalists, or community groups. "Every workshop does start with talking about how you have to know your own goals," Ambrogio says. "And goals beyond 'I want people to know more about rocks.'"

Olivia Ambrogio
Assistant Director, Sharing Science program
AMERICAN GEOPHYSICAL UNION

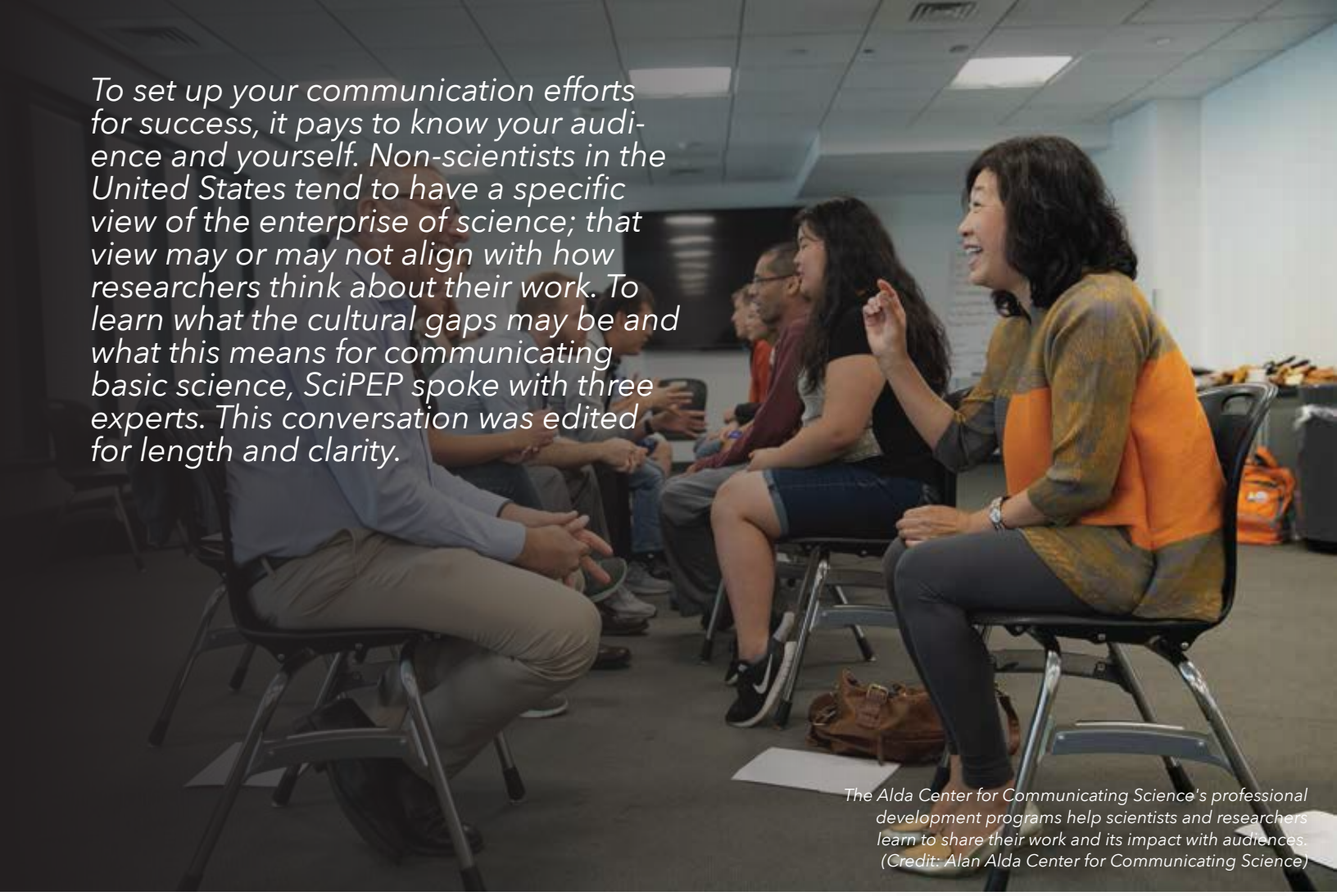
A key aim for AGU is to support discovery science that advances knowledge. Most of the scientists who come to Ambrogio's workshops conduct basic research. But when asked whether these scientists need more help articulating goals than their applied counterparts, she says it isn't quite so simple. "The bigger and more profound distinction is really based on the experience level of scientists rather than the topic or discipline of the research, basic or applied." People focused on basic research tend to interact with non-scientists less than their applied counterparts, she says. Prior experience engaging with audiences enhances researchers' ability to reflect on what worked and what didn't.

The mental lift needed for strategic goal setting becomes easier as researchers interact with non-specialists, she says, though this also depends in part on scientists' ability to self-reflect. She cites the example of an established researcher in AGU's yearlong communication program who set out to collaborate on research with a local Tribe and offer internship opportunities to its students. As the researcher's year in the AGU program progressed, she realized that she was spending most of her time connecting with a trusted messenger for the Tribe, hosting conversations and filling out paperwork instead of planning the actual research. The researcher realized that her work of building trust with and demonstrating respect for the Tribe was a critical first step toward an inclusive research program, so she revised her goals to reflect that.

Image of the moon taken by a digital telescope during one of the KIPAC stargazing nights. (Credit: KIPAC)

Illustrator Reyhaneh Maktoufi (@TheCosmicRey) created this comic to accompany Besley and Dudo's book about strategic science communication, with support from the Rita Allen Foundation. It illustrates a typical line of conversation that Besley and Dudo encounter when discussing goals with a would-be communicator. Additional comics are available.[8]

To set up your communication efforts for success, it pays to know your audience and yourself. Non-scientists in the United States tend to have a specific view of the enterprise of science; that view may or may not align with how researchers think about their work. To learn what the cultural gaps may be and what this means for communicating basic science, SciPEP spoke with three experts. This conversation was edited for length and clarity.



The Alda Center for Communicating Science's professional development programs help scientists and researchers learn to share their work and its impact with audiences. (Credit: Alan Alda Center for Communicating Science)

Q&A

Three experts discuss the importance of knowing your audience's mindset (and your own)

by Carmen Drahl

Christopher Volpe
Executive Director
SCIENCECOUNTS

Todd P. Newman
Assistant Professor, Department of Life Sciences Communication
UNIVERSITY OF WISCONSIN-MADISON

Laura Lindenfeld
Executive Director
ALAN ALDA CENTER FOR COMMUNICATING SCIENCE

Dean and Professor, School of Communication and Journalism
STONY BROOK UNIVERSITY

Q. In 2015, ScienceCounts set out to learn how members of the U.S. public feel about science. Why?

C. Volpe: Most words and concepts evoke emotions. We wanted to explore the emotions that people associate with the word science. If you're going to engage in some form of dialogue or communication, when you present that word or that idea initially, they're going to have a response, and that response may be positive, which means they might lean into the conversation. Or they might be neutral, or they might be repulsed. How can you constructively advocate, promote, message, narrate if you don't know what the initial starting point is for your audience?

Q. And you realized people were expressing a certain feeling about science without putting it into words, right?

C. Volpe: When you ask people, "What is science? Describe science," we were hearing a lot of phraseology like, "It makes the world a better place. It's optimism." We concluded that the word people were wanting to say was *hope*.

Q. And in follow-up surveys, you designed a multiple-choice question to explore this inkling further. What was it?

C. Volpe: We created a very direct question, which was: "Which word best describes what you feel when you hear the word science?" Every time we asked, anywhere from about 45% to about 60% of the respondents picked hope and everything else was a distant second.[1] Other organizations have asked that question as well and got the same response. We felt pretty confident at that point that hope was the right word.

Q. You've said this hope result may mean that the public is payoff minded when it comes to science. Can you explain?

C. Volpe: For most Americans, science isn't a goal unto itself. You do science to accomplish something. You do science to cure a disease. You do science to build rocket ships, to go to other planets. Science is a means to an end. That's where this idea of payoff comes from.

For most Americans, science isn't a goal unto itself. You do science to accomplish something.

Q. So the next step was to ask scientists the same question. And this is where Todd, Laura, and other experts get involved, correct?

T. Newman: Yeah. We wanted to do a survey of scientists on their attitudes and behaviors around communication and engagement. At the time, we said, "We have this branding question that Chris has been asking public audiences. Let's throw it in here and see what scientists think," not really having any idea about what would play out. We fielded that survey in 2017.

SciPEP Tip

Finding joy in doing science is wonderful, but know your audience before communicating. Casting science in terms of a satisfying payoff—like solving a puzzle of the molecular world or the universe—might resonate more with them.

Quantum researchers at Oak Ridge National Laboratory investigate whether trapped ions can be used to encode qubits for quantum networking. (Credit: Carlos Jones/ORNL, U.S. Dept. of Energy)

Q. What did you find?

T. Newman: We saw that the category we called "joy and excitement" was something like 40%.[2] Hope was still 30-ish percent, and a scattering of other emotions as well. That's a stark difference from the public. When we saw that, we thought, "whoa, joy and excitement is really high for scientists."

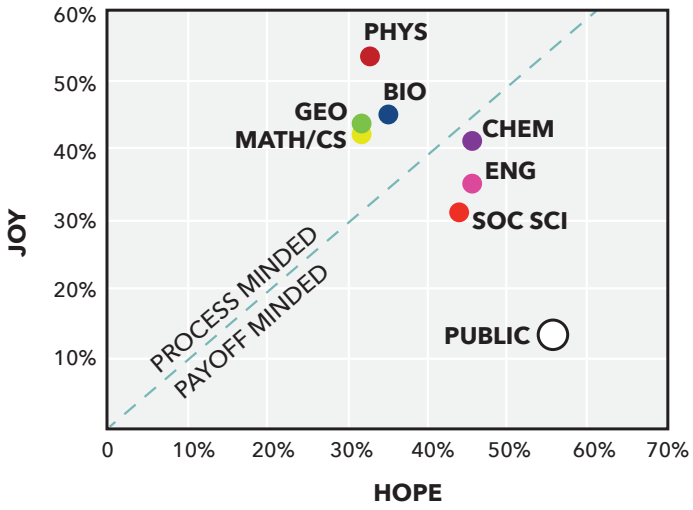
Q. What's your working interpretation of what "joy and excitement" means?

L. Lindenfeld: It's joy in the process and a sense of loving the details and the work of science. This inherently makes sense to me. Why would you go into a field where you hate doing the work when you could choose another field? Most scientists are in it because they really enjoy doing the work. That's not to say some or most don't care about the payoff, but the dominant association is with joy in the research process.

Q. Compared to the public, the scientists were more split between joy and hope. How exactly did their responses vary?

L. Lindenfeld: I'm being careful not to make a causal relationship, because correlation is not causation. What we did identify is that certain fields tend to have a higher propensity toward experiencing science as joy versus hope.

T. Newman: When we mapped joy on the Y axis and hope on the X, and then plotted all the different fields, we saw that those who were in areas like physics, mathematics, were very much in that upper left quadrant, high on joy, low on hope. Scientists who indicated they were in the social



(Courtesy of Christopher Volpe)

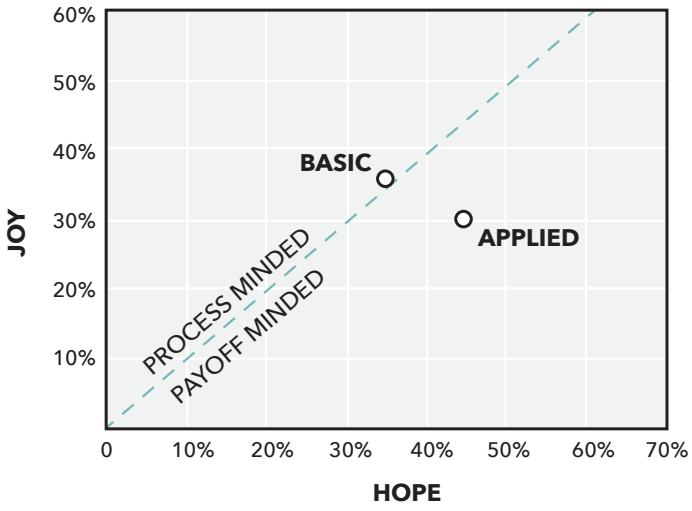
sciences, engineering, were in that lower right quadrant, high on hope, low on joy.

C. Volpe: We immediately questioned our finding and said, "This could be an artifact." Well, we surveyed two different groups of scientists. That second data set produced the same spectrum. That's what gave us the courage to say, "We think this is a real phenomenon."

Q. Once SciPEP began, you built on this result by asking scientists about the nature of their research. Tell me about that.

C. Volpe: Yes. ScienceCounts wasn't officially on that study. We consulted with Todd and his colleagues. They added an insightful question: "How would you define your research? Is it mostly applied? Is it mostly basic? Or is it a mix?"

T. Newman: We used the basic and applied question to create another plot. And boom, the applied researchers fell into that lower right quadrant closer to the



The team mapped survey data and identified that researchers in certain fields tend to have a higher propensity toward associating science with joy rather than hope. (Courtesy of Christopher Volpe)

public where hope was high, joy not as much. And then the basic scientists were much higher on joy, lower on hope.

Q. How cautious should we be in extrapolating these results for all audiences or all fields of science?

C. Volpe: I would be careful of not getting too quantitative with this. I would view this as a guidepost on the road to being a better communicator. Additionally, our data set is exclusively adults. For people who are thinking about communicating with children, it's very possibly a whole different ball game.

Q. And how could this research help someone get better at communicating basic science?

L. Lindenfeld: The basic takeaway is to be mindful of your audience. Who are they? How do they see you and what you do, and what's important to them? If you meet someone who's not a scientist, you might assume that they tend to be more payoff and hope minded. Confirm that. Because it may not be true.

We're not telling you to turn science into something it's not. Just because someone experiences hope doesn't mean you have to promise them a specific outcome. It means you have to understand that's how they perceive science. That's an important distinction.

Q. So, should scientists never talk with audiences about the process of doing science? Should they always focus on their science's potential payoffs?

C. Volpe: No. I would never say that. I think a lot of the personal excitement that comes out from a communicator tends to come from the process of doing the actual work.

L. Lindenfeld: If you want people to listen to you, they have to trust you. If I need my car fixed and I go to a mechanic and I see that she or he takes exceptional joy in the process, it's going to tell me that they really care about their work. It's going to

This is all about building empathy with someone different from you.

make my trust go up.

Q. You've said that joy-minded scientists may need to do more work to connect with audiences. What might that work look like?

L. Lindenfeld: It's what we do at the Alda Center all the time. Someone who draws their energy from the process work has to figure out how to put themselves in the shoes of someone who would have a completely different perspective. Where's the common ground that you can start with? This is all about building empathy with someone different from you.

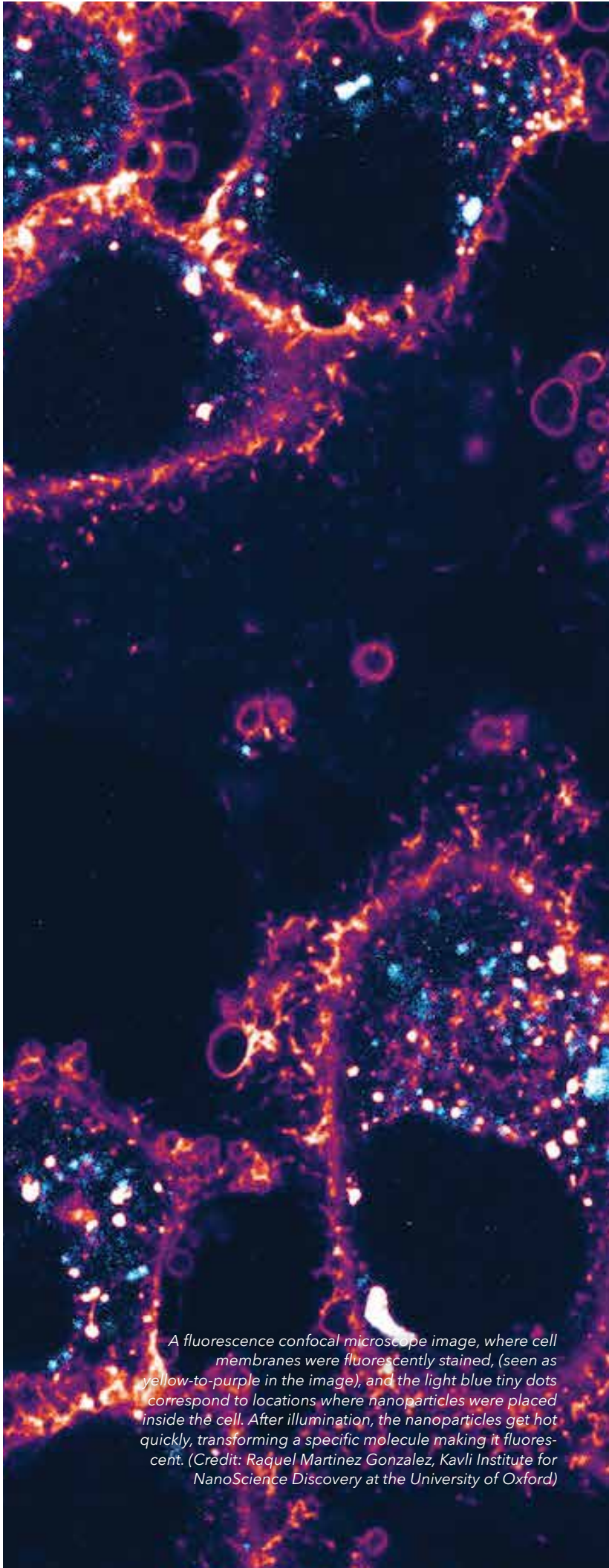
C. Volpe: Embrace the fact that learning for learning's sake and satisfying curiosity are both payoffs. So even if you're process minded and you say, "I love doing this research because I want to unravel the mysteries of the universe," recognize that's a legitimate payoff and embrace it.

Q. What don't we know yet? Where does this research go from here?

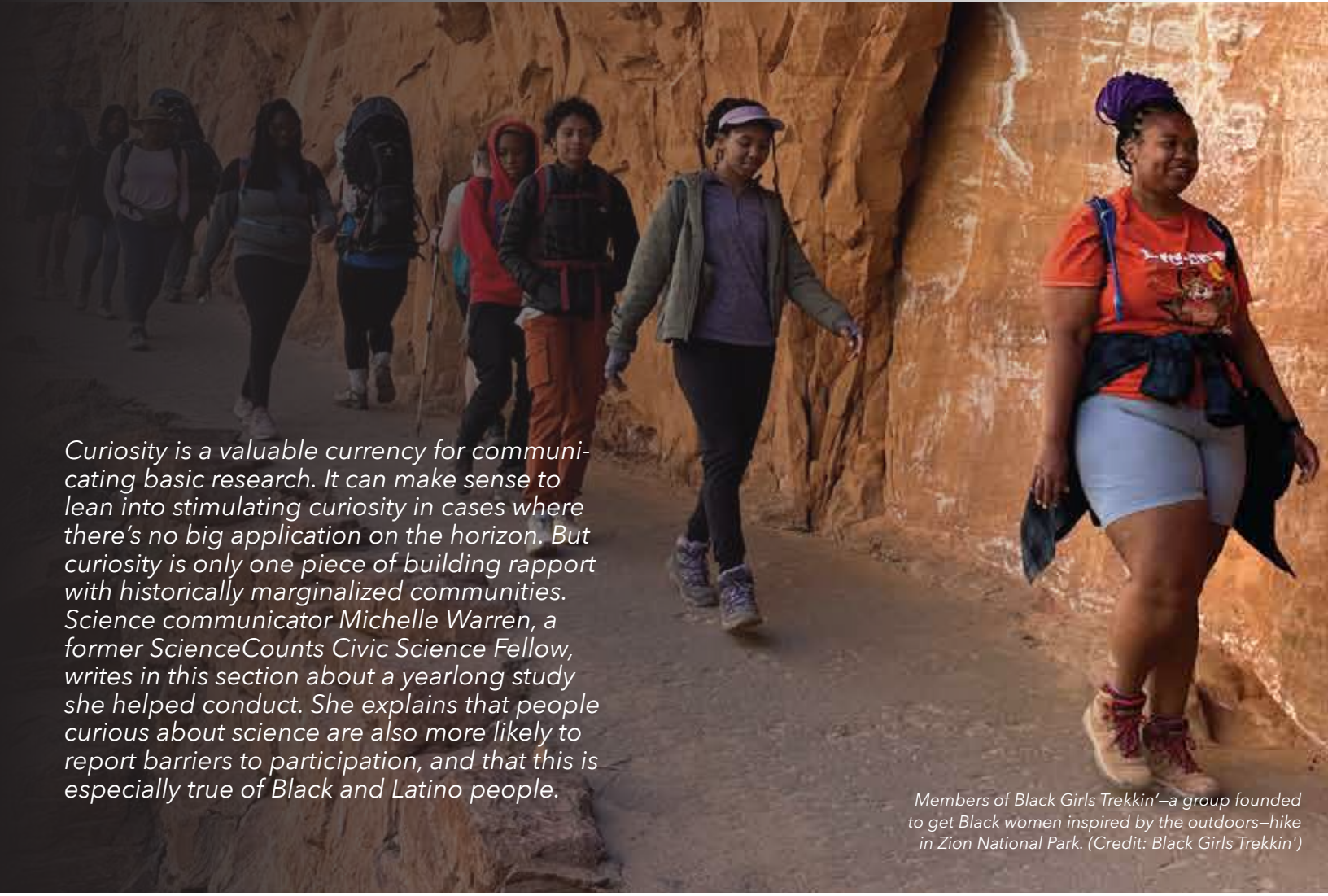
T. Newman: Some work I've been doing with public audiences in opinion surveys is unpacking what does hope mean? What are they hopeful for? Is it hope for society? Is it about medicine? Is it about artificial intelligence? What's the timeline?

L. Lindenfeld: It would be good to see more work that looks at media consumption and public audiences and the role of scientists within that system. We have this general sense of how people feel about science. But do their perceptions change based on who the messenger is and what the medium is? I think we have a great deal more to understand about that.

C. Volpe: ScienceCounts's trajectory was to learn what we felt we needed to learn and then pivot to developing more productive engagement activities. We feel like we've got satisfactory data to engage the public and advocate for the value of science. I genuinely hope, though, that others continue to do more research on this interesting dichotomy and its ramifications because I think there's a whole interesting universe down there.



A fluorescence confocal microscope image, where cell membranes were fluorescently stained, (seen as yellow-to-purple in the image), and the light blue tiny dots correspond to locations where nanoparticles were placed inside the cell. After illumination, the nanoparticles get hot quickly, transforming a specific molecule making it fluorescent. (Credit: Raquel Martinez Gonzalez, Kavli Institute for NanoScience Discovery at the University of Oxford)



Curiosity is a valuable currency for communicating basic research. It can make sense to lean into stimulating curiosity in cases where there's no big application on the horizon. But curiosity is only one piece of building rapport with historically marginalized communities. Science communicator Michelle Warren, a former ScienceCounts Civic Science Fellow, writes in this section about a yearlong study she helped conduct. She explains that people curious about science are also more likely to report barriers to participation, and that this is especially true of Black and Latino people.

Members of Black Girls Trekkin'—a group founded to get Black women inspired by the outdoors—hike in Zion National Park. (Credit: Black Girls Trekkin')

Curiosity: Getting in the door with audiences

by Michelle Warren
Program Manager,
RESOURCES LEGACY FUND

Former Civic Science Fellow,
SCIENCECOUNTS

As the foot-long striped lizard scuttled into view, our park ranger knew it would be a memory-making moment.

"Do you know how alligator lizards mate?" the ranger asked the group on our guided hike. "The male bites the head of the female and holds on to her for several days."

"I see those all the time in my backyard!" someone exclaimed.

"You know," replied the ranger, "there are scientists who are really interested in alligator lizard behavior. They get some of their information from people like you."

It was a brief conversation, but that moment of curiosity and personal connection might be the spark that gets someone more actively interested in science topics and activities.

I am a Black scientist with a degree in marine biology. I'm also an avid hiker—my nonprofit, Black Girls Trekkin', organized that guided trip to get Black women inspired by the outdoors. My interest in addressing obstacles that hinder potential Black scientists led me to the Civic Science Fellows program, which builds connections between science and diverse communities. My focus was improving Black and Latino science engagement—an umbrella term

that includes consuming science content, visiting science-focused spaces, and participating in research. Changing how someone experiences science is no small feat. It requires understanding what motivates interest in science topics and science engagement and what barriers get in the way. As a fellow, I supported research from ScienceCounts and the Association for Science and Technology Centers that sought to improve that understanding.

We asked over 2,500 people in the United States—oversampling for Black and Latino respondents—to share their motivations for their science interests. The results? Curiosity, defined as sparking the imagination or sense of wonder, emerged as a top motivator for science interests across all demographics.[1] When we asked survey takers whether they could see a connection between science and non-science interests, we uncovered a layer of nuance. Approximately three-quarters of Black and Latino adults see some connection versus two-thirds of White adults.

People are putting in extra work to engage despite the barriers they face.

We then looked into motivators for science engagement across communities. Among White adults, curiosity is most influential in determining the number of science activities someone will engage in, while for Black and Latino adults recognizing a connection is the dominant factor.

We then separately found a relationship between curiosity, connection, and the kinds of activities respondents preferred. Survey respondents motivated by curiosity were more likely to show interest in one-time engagements such as watching a science themed TV program, while those who saw

Southern alligator lizards are often seen in yards and garages in Southern California. This one was photographed on the Loop Trail in Corte Madera, California, and not during the Black Girls Trekkin' hike. (Credit: iNaturalist © Jonathan Curley)

connections were more likely to engage in participatory activities like collaborating with scientists. This, to me, was a fascinating takeaway. We're still discussing whether it could mean that while curiosity can provide an initial spark, connection may foster more lasting ties to science.

ScienceCounts executive director Chris Volpe, who co-authored our study, has said that if curiosity and connection are the gas pedal that drives willingness to engage with science, then barriers are the brakes. And we gained a surprising insight when we asked about barriers. Individuals who are both curious and see the most connections, the ones most primed to engage in a range of science activities, are also the most likely to report barriers to participation. This is especially true among Black and Latino adults, who identified 50% more barriers than White adults. That means people are putting in extra work to engage despite the barriers they face.

The majority of respondents across demographics identified at least one barrier. Some logistical barriers like cost impacted demographics equally. However, Black and Latino respondents were more likely than White respondents to choose more than one barrier. And they more commonly cited negative feelings around belonging and identity. One person who rarely saw science show narrators who looked like them said, "I think representation goes a long way in the lack of sort of feeling welcome."

We're all looking to make science more inclusive and accessible. Let's think beyond logistical barriers when reaching out to Black or Latino audiences and design experiences with the needs of our specific communities in mind. It's a challenge worth solving. One barrier may be enough to stop someone from participating in science, but one positive experience can help them get started.

At the close of our four-mile hike, we of Black Girls Trekkin' were feeling accomplished. It was a full morning of learning about plants, animals, and the scientists who help to manage and restore the land. As we said our goodbyes, the ranger asked for any last questions.

"The restoration project we passed. You said that we could come back and help. How can I sign up?" Science engagement, achieved.

Let's think beyond logistical barriers when reaching out to Black or Latino audiences and design experiences with the needs of our specific communities in mind.

SciPEP Tip

Curiosity gets audiences interested in science. **But fostering connection and breaking down barriers related to belonging may lead to long-lasting engagement.**

Four curious insights about curiosity

by Carmen Drahl

For every caregiver exasperated by a child's incessant asking why, there's a communicator who'd be thrilled to stimulate that kind of curiosity about astronomy, chemistry, or another basic science in their target audiences. At SciPEP's 2021 conference, psychologist Tania Lombrozo of Princeton University shared four findings from her group that zero in on just what aspects of a message make people curious. Some of her findings, however, suggest that stimulating curiosity about basic science research could be more challenging than for applied work.

1 The potential to learn some new or useful knowledge triggers curiosity

What factors prompt people to ask why? Lombrozo and then-graduate student Emily Liquin recruited over 850 participants through a crowdsourcing website. Each person rated their curiosity level about a selection of eight questions, mostly about science, drawn from different sources online. For example, they scoured a popular forum where people ask one another questions like "Why do ice cubes crackle when liquid is poured on them?" After rating their curiosity, participants answered additional queries designed to tease out what aspects best predicted their curiosity levels. The researchers reported three strong predictors of curiosity in the journal *Cognitive Psychology*:[2]

- How much participants expected to learn.
- How much participants felt could be learned in principle (even when they already knew the answer to a question).
- The chance to get knowledge that would be useful to them later.

2 If you build the case for value, curiosity will come

Just what knowledge is "useful" is in the eye of the beholder. People's curiosity about the fruit fly—an organism common to basic genetics research—grew more when researchers explained how the insects matter to medicine compared to when researchers simply presented interesting fruit fly facts. Lombrozo, computational cognitive scientist Thomas L. Griffiths, and then-graduate student Rachit Dubey hypothesized that people's curiosity about a topic might increase if they had evidence that information about the topic could benefit society. The team randomly assigned 200 participants recruited from a crowdsourcing website to receive one of three short articles about fruit flies. Some participants read surprising fruit fly facts. A second group learned about fruit flies' importance in the food chain and in decomposing waste. The third group read that fruit fly research has led to new treatments for human diseases such as Parkinson's. All the reading material boosted survey takers' curiosity, but the passage about medical applications worked best by far, the team reported in the journal *Cognition*.[3] Relying only on practical applications to stimulate curiosity "could reinforce the idea that science is only valuable and only worth pursuing when it has immediate practical benefits," so this result puts forth a puzzle for basic science communication, Lombrozo said at SciPEP 2021.

3 Curiosity is contagious

A little bit of peer pressure might be a good thing for curiosity. People's interest in learning answers to everyday science questions could be manipulated in surveys by how popular the questions seemed to be among others online. Lombrozo, Dubey, and then-University of California, Berkeley undergraduate Hermish Mehta set out to see whether social cues could influence curiosity. The team chose to define popularity in a way that the internet-savvy would recognize; they artificially assigned the questions a random number of up-votes and told survey-takers that the questions had received the up-votes on a well-known social media platform. Each of the roughly 900 survey takers rated their curiosity about ten of the questions and then picked the five questions they'd like to see answered. Questions with plenty of up-votes triggered the highest levels of curiosity. And low numbers of up-votes had an even more dramatic effect at reducing people's curiosity, the team reported in the journal *Cognitive Science*.[4] The researchers caution that it's not clear how to translate this study's artificial manipulation of social media up-votes to more traditional environments where someone might want to stimulate curiosity, like in a classroom or at a science event.

4 Curiosity sparks more curiosity

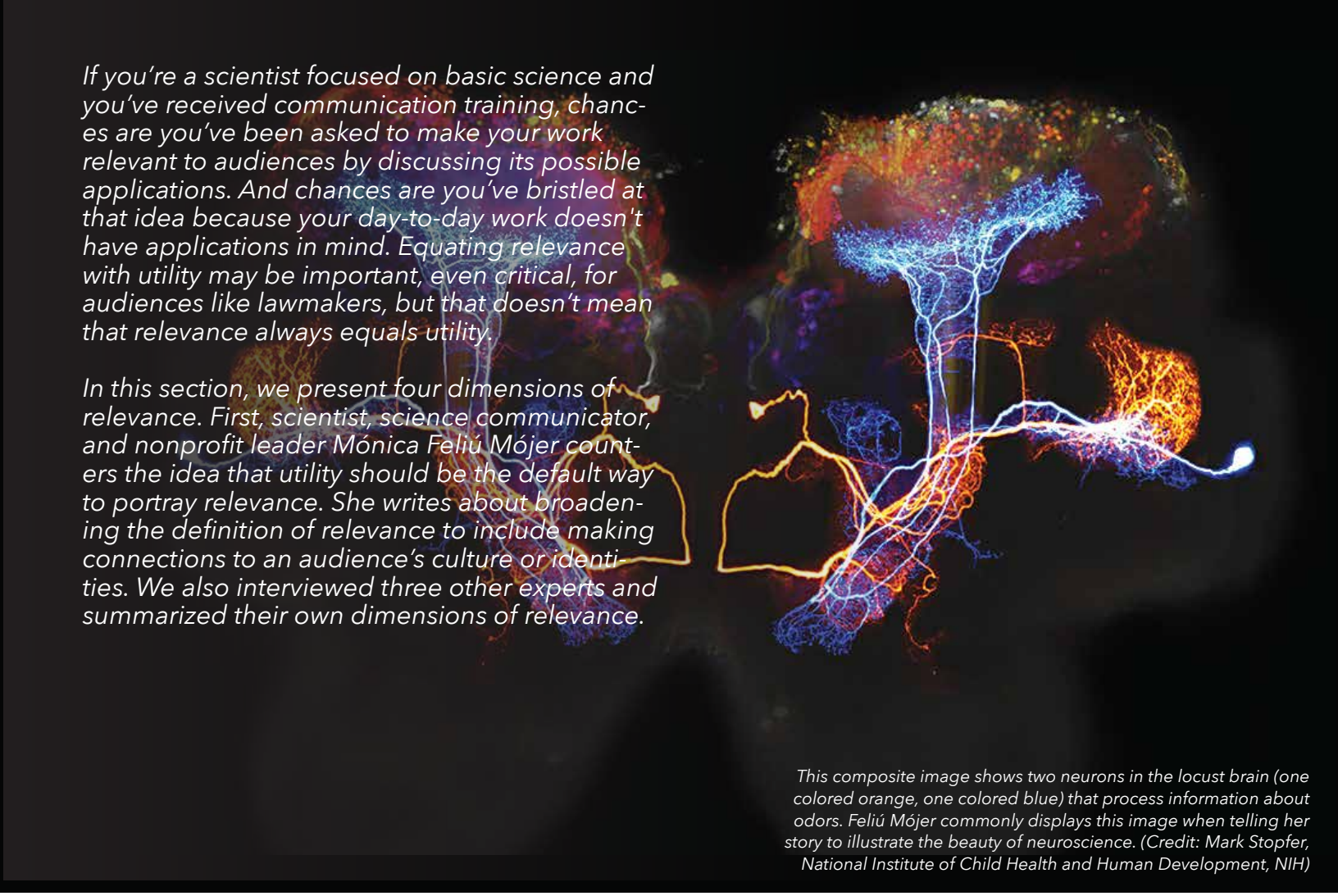
Getting a gratifying answer to a burning question doesn't douse the flame of curiosity—it stokes it. In research published in *Cognitive Psychology*, Lombrozo and Liquin asked study participants how curious they were about the answers to a variety of questions about science, history, and other topics. With those ratings recorded, the pair then asked how satisfying the answers they provided were. Finally, they supplied participants with related follow-up questions. They found that greater curiosity about an initial question tended to lead to more satisfaction with its answer and then propelled even more curiosity about the next round of questions.[5]

Your awe may differ from someone else's

Anecdotally, scientists who communicate their basic research say that they communicate to inspire awe and wonder. For someone used to ooh-ing and aah-ing at the latest telescope images, it can be easy to believe that their feelings are an innate human emotion, and that if they could only trigger that same emotion in their audiences, it would spark lifelong interest in and excitement for basic science. While some social scientists maintain that emotions like awe are innate and universal, others challenge this view. Drawing on that latter body of work, Daniel Silva Luna, now at the University of Augsburg, argues that a person's lifetime of experiences shapes their expression and experience of emotions like awe.[6,7] In other words, people learn awe because of repeated encounters with it in their culture, and what triggers awe for that person will reflect their culture's values. It's misleading to assume that everyone will react similarly to scientific content, Silva Luna says. He argues that there are many flavors of awe in science communication, including thrilling, entertaining, or meditative.[8] Science communicators can learn to strategically utilize these varieties to achieve specific goals and objectives (see page 12), such as building trust or creating a sense of connection to nature, beyond merely stimulating excitement for science. "It's thinking, 'what are the best emotions for the particular goals that I have with my communicative activity?' and thinking backwards from that," Silva Luna says.

If you're a scientist focused on basic science and you've received communication training, chances are you've been asked to make your work relevant to audiences by discussing its possible applications. And chances are you've bristled at that idea because your day-to-day work doesn't have applications in mind. Equating relevance with utility may be important, even critical, for audiences like lawmakers, but that doesn't mean that relevance always equals utility.

In this section, we present four dimensions of relevance. First, scientist, science communicator, and nonprofit leader Mónica Feliú Mójer counters the idea that utility should be the default way to portray relevance. She writes about broadening the definition of relevance to include making connections to an audience's culture or identities. We also interviewed three other experts and summarized their own dimensions of relevance.



This composite image shows two neurons in the locust brain (one colored orange, one colored blue) that process information about odors. Feliú Mójer commonly displays this image when telling her story to illustrate the beauty of neuroscience. (Credit: Mark Stopfer, National Institute of Child Health and Human Development, NIH)

Relevance: Going beyond utility to connect basic science with audiences

by Mónica Feliú Mójer
Director of Public Engagement with Science,
CIENCIA PUERTO RICO

Director of Inclusive Science Communication and Engagement,
SCIENCE COMMUNICATION LAB

While earning my Ph.D., I did research to understand cell-to-cell communication in neurons, which are essential building blocks of the nervous system. I studied the role of a type of molecular switch (small GTPases, if you are curious) in synaptic transmission, using the tiny worm *C. elegans* as a model organism. What excited me most about this work was the possibility of unraveling the mysteries of a tightly orchestrated process that underlies many of the things that make us human, from muscle contractions to learning and memory. Yet, I was frequently encouraged to explain how studying neuronal communication could potentially lead to breakthroughs in treating neurological diseases. I felt a persistent pressure to justify the relevance of my work by communicating its utility or value to human health.

I was not alone. When it comes to communicating their research, scientists are commonly advised to "make it relevant." Often, that is equated to explaining its "usefulness" to a given audience. We are urged to emphasize how our work can directly benefit society, how it can address pressing issues or alleviate human suffering. This can be challenging for researchers in basic science, where the applicability of findings may not be immediately apparent or can be hard to grasp.

This relevance-equals-utility framework is limiting. Relevance can be but is not always equivalent to utility. While utility implies a direct practical benefit, relevance transcends applications, encompassing a broader connection to people's lives, cultures, and identities. Making basic science relevant involves more than just demonstrating its potential usefulness; it requires weaving scientific concepts into the fabric of society, embedding them within the contexts of people's everyday experiences. This expanded meaning of relevance as connection can help people make sense of science, spark their awe and curiosity (see page 28), and inspire a sense of belonging.

Consider the example of Corey Gray, a physicist at the Laser Interferometer Gravitational-Wave Observatory (LIGO) in eastern Washington in the United States. In 2015, Gray and his LIGO colleagues directly observed gravitational waves for the first time—a phenomenon predicted by Albert Einstein in 1916. Detection of gravitational waves was a triumph of basic science. Its significance reverberated around the world and expanded our understanding of the universe.

The announcement of this breakthrough was an opportunity for Gray to connect his science to his identities, culture, and community. Gray and Sharon Yellowfly, his mother, are members of the Siksika (Blackfoot) Nation. Yellowfly is one of a handful of people who have helped preserve their indigenous language. Mother and son collaborated to translate the news into their endangered language.[1] The act was more than mere translation. In many ways, it was Gray taking his science home.

While utility implies a direct practical benefit, relevance transcends applications, encompassing a broader connection to people's lives, cultures, and identities.

By communicating about gravitational waves in the Blackfoot language, Gray and Yellowfly made science more accessible, understandable, and thus, more relevant to the lives of Blackfoot people. Furthermore, the collaboration highlights the scientific contributions of Indigenous people—communities that, past and present, have been oppressed and overlooked by science. The prominent announcement positioned them as culturally similar role models, which can help others in science from marginalized identities feel represented.

Beyond disseminating science in an audience's language and presenting culturally similar role models, there are many other tactics communicators can use to make basic science relevant. We can convey science in practical ways, eliminating jargon and connecting technical knowledge to a person's everyday life using familiar concepts. That's what Miguel Morales Silva, a computational quantum physicist, did when I interviewed him for my weekly science radio segment. When I asked him to describe his field, he said that quantum physics "allows us to understand why iron conducts electricity, but wood does not." By explaining how his field can help us understand the properties of objects, Morales Silva made quantum physics feel more approachable.

Communicators can also strive to find common ground with audiences through shared identities. For instance, Katharine Hayhoe, a climate scientist who is an evangelical Christian, engages religious—and often politically conservative—communities that are skeptical of climate change, by leaning on their shared faith and values to provide openings for conversation.[2] Although Hayhoe's work leans in the applied direction, the strategies she uses can connect audiences to basic research, too.

The pursuit of scientific knowledge is inherently valuable, irrespective of its immediate practical applications. When science communication is rooted in connection, and not just utility, it becomes a powerful tool for engagement and understanding. Just as a neuron's true power lies in its connections to other neurons and cells, the strength of basic science communication lies in its ability to forge connections with people's lives. By building ties between discovery and diverse experiences, science communication—and science itself—will become more impactful and effective.

When science communication is rooted in connection ... it becomes a powerful tool for engagement and understanding.

Three additional dimensions of relevance

by Carmen Drahl

1 Relevance to human relationships

The further Beronda Montgomery advances in her career, the more she finds herself talking with non-scientists about her favorite subject: plants. In the lab, she studies how living things that require light to make food, including plants and cyanobacteria, adapt when the availability or quality of light changes. In her book, *Lessons from Plants*,[3] and in other writing and public-facing talks, she explains how plants make decisions, communicate, and cooperate while most people barely notice. Though much of plant science has utility for agriculture, her communication focuses on curiosity-driven observations about plants and makes them relevant by describing how they can help people rethink their human relationships. She cites the example of the indigenous "three sisters" approach to growing crops.[4] Corn, beans, and squash support each other by providing shade, nitrogen, or protection from weeds. Does understanding that lead to an application like increased corn production? "Maybe not," Montgomery says. "But studying corn has allowed me to be a more thoughtful and effective mentor and leader" by building analogous reciprocal relationships among people. Montgomery has a lot of interest in discussing equity, mentoring, and other topics that she says can quickly become fraught with tension. "People think they're going to be accused of having an 'ism': racism, sexism, genderism." In her experience, using insights from plants or cyanobacteria[5] to broach sensitive topics can circumvent, or at least delay, knee-jerk emotional responses. She thinks of it this way: "Science can teach me something about how to be a human on this planet."

Beronda Montgomery
Vice President of Academic Affairs and Dean of the College, Professor of Biology
GRINNELL COLLEGE

Co-founder and Co-organizer
BLACK BOTANISTS WEEK

2 Applications can demonstrate relevance

For some audiences, it's essential to start off conversations about basic science with its potential applications, says Ben Shouse. As a communications analyst at the U.S. Government Accountability Office, the congressional watchdog, Shouse's job is to help members of Congress and other decision makers grasp the societal impact of science topics—including basic research. "When you're dealing with a policymaker, the overriding concern is how busy they are," Shouse explains. In 2019, with that overscheduled audience in mind, GAO launched "Science & Tech Spotlights," two-page summaries about topics like quantum entanglement and their potential economic or national security implications. The Spotlight on quantum technologies[6] includes a few sentences explaining how quantum properties like entanglement work, but top billing goes to potential applications of the science, like protecting classified information. This structure, Shouse says, tells policymakers "'Here's a problem you could solve. Or here's a way that you could make your constituents' lives better. And it has to do with this technology or this scientific topic.' And then you've got them interested." Shouse says that congressional staffers have called the summaries useful, and that Congress has requested larger reports on some topics, but he cautions that scattered feedback isn't enough to conclude that the Spotlights are influencing policy decisions. Shouse says he can understand that scientists might find it misleading to focus on utility when communicating basic research. But he thinks the point of contention is feeling forced to be certain of their work's applications and to produce them by a deadline. "Science to some degree needs to operate without that time pressure," Shouse says. "I think when people object to being held to producing results, they're more objecting to the timescale of that than they are to the idea that science should benefit society."

Ben Shouse
Communications Analyst
U.S. GOVERNMENT
ACCOUNTABILITY OFFICE

SciPEP Tip

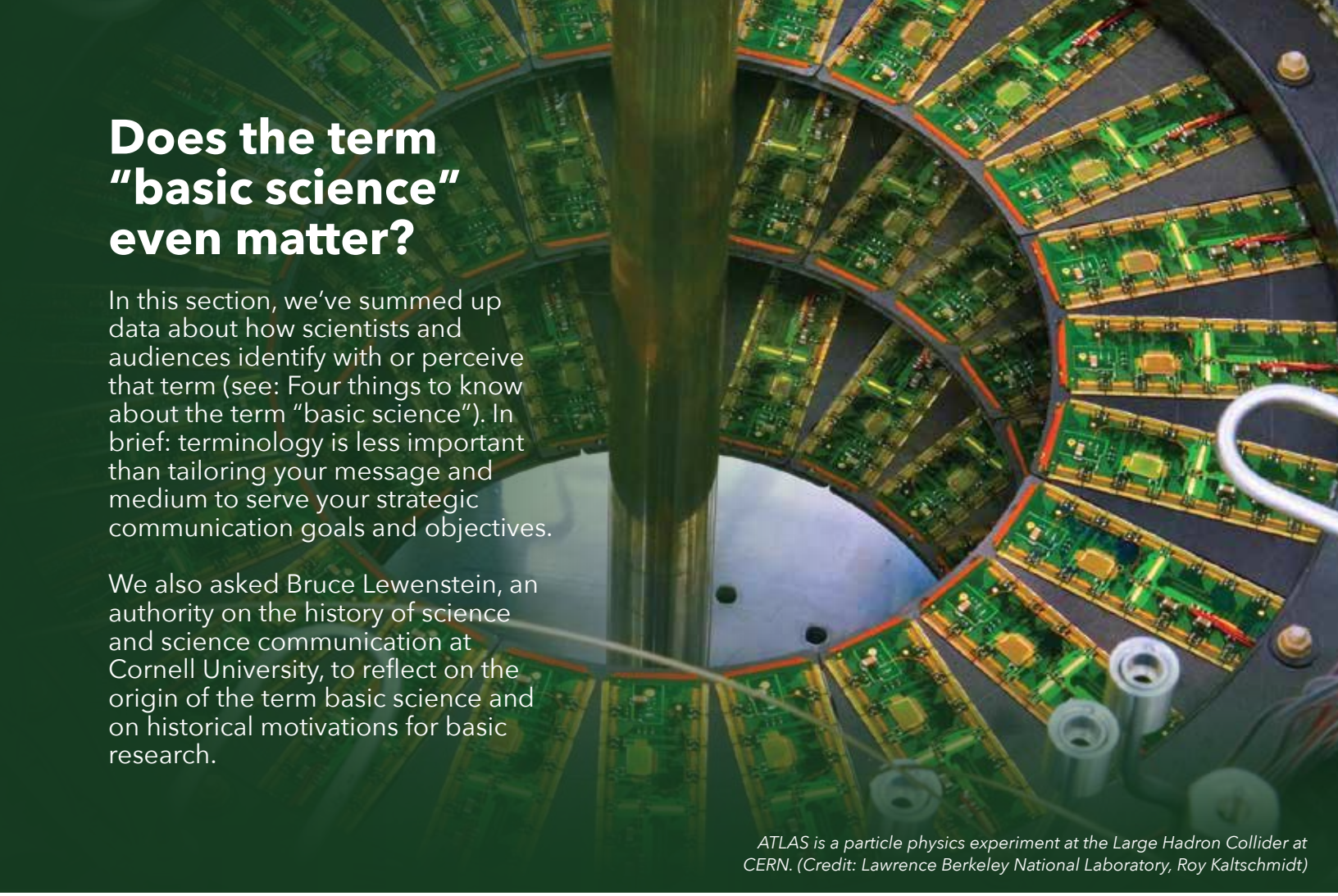
Describing basic research's maybe-someday applications is just one way to make it relevant. Your audience might instead click with a message about how basic research knowledge serves our humanity.

3 Relevance as value to society

When Cary Funk worked at the Pew Research Center, she conducted a lot of opinion polling on science issues. But one 2018 poll sparked a hypothesis in her mind about how Americans evaluate research when they don't know very much about it, something that's common where basic science is concerned. The survey asked a representative sample of over 2,500 Americans questions about genetic engineering of animals. It listed a series of possible applications, then asked whether each was an appropriate use of the technology or taking the technology too far. Survey takers gave the most support to applications that would improve human health, such as limiting mosquito reproduction to blunt the spread of mosquito-borne diseases.[7] But nearly four out of five of those polled thought that creating glowing aquarium fish with genetic engineering (the only commercially available application in the survey) took the technology too far. Funk's team asked survey takers to describe in their own words why they felt the way they did. "You heard these quotes like, 'it's frivolous, it's trivial. I don't see the benefit for society. I don't see the benefit for the fish'," Funk says. She surmised that people were looking for something they perceived as valuable. Funk says that's a little different from saying it's relevant. Different audiences may assign value differently for cultural reasons, but more research is needed. Funk offers several possible research questions that could follow up on this observation. "Whose value matters? Does it always have to be for society? Should it be for individuals? Should it be for groups you care about? Should it be for animals? There's a lot we don't know because we really haven't done that much systematic research," Funk says. "We need to show the value of discovery science," even if direct relevance to our lives is limited, she adds. "The question is how and could there be more than one way."

Cary Funk
Former Director of Science and Society Research
PEW RESEARCH CENTER

At the annual Stellafane convention in Vermont, a young attendee peers through a large telescope for the first time. (Image credit: Gabor Furesz, MIT Kavli Institute for Astrophysics and Space Research)



Does the term "basic science" even matter?

In this section, we've summed up data about how scientists and audiences identify with or perceive that term (see: Four things to know about the term "basic science"). In brief: terminology is less important than tailoring your message and medium to serve your strategic communication goals and objectives.

We also asked Bruce Lewenstein, an authority on the history of science and science communication at Cornell University, to reflect on the origin of the term basic science and on historical motivations for basic research.

ATLAS is a particle physics experiment at the Large Hadron Collider at CERN. (Credit: Lawrence Berkeley National Laboratory, Roy Kaltschmidt)

The semantics of basic science:

Four things to know about the term "basic science"

1 It may not be familiar to your audience

It's possible that your audience hasn't come across the label of "basic science." A 2015 survey by ScienceCounts, a nonprofit that promotes awareness and support of science, asked more than 450 Americans whether they had a positive, neutral, or negative association with a list of science-related terms.

- About 40% had neutral associations with the terms "basic scientific research" and "applied scientific research."
- About 28% of those surveyed were neutral to the word "science."
- Responses were similar from people with different political persuasions and education levels.

This potentially means survey participants lacked familiarity with the ideas of basic or applied science, according to a 2021 analysis.[1] It's not possible to conclude from this lone survey whether Americans think equally highly of basic and applied science, or whether they don't differentiate between the two. But based on the results, ScienceCounts made language recommendations: it's not necessary to avoid the phrase "basic science" altogether, but whenever possible, science communicators should choose terms that polled best with the public, like discovery and invention, when sharing basic research.[2]

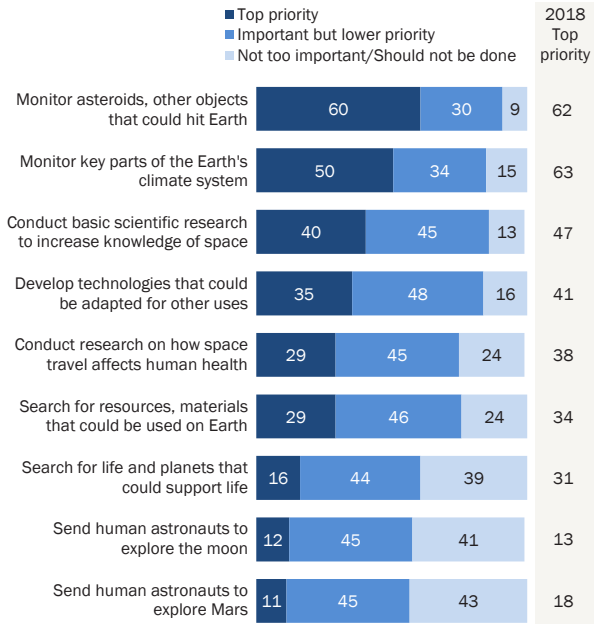
2 Context might help, or not

If you're trying to figure out what your audience thinks about the basic science you're communicating, a direct question about basic science is unlikely to give a complete picture. If you drew your impressions solely by asking Americans how essential basic and applied research are for the world, you'd find stronger support for applied research, as happened in a 2019 survey from the Pew Research Center. But the poll didn't describe how basic research can benefit society, according to Cary Funk, Pew's former director of science and society research.

In contrast, a pair of Pew polls about the U.S. space agency NASA asked about "basic scientific research to increase knowledge of space," putting the question in a specific context. The surveys, released in 2018 and 2023, tasked Americans with deciding what should top NASA's priority list. And support for basic research in these polls was strong. It ranked a consistent third out of nine priorities, above applied work like searching for materials that would be useful on Earth.[3,4] Context gives audiences a way to assess basic science. However, it doesn't guarantee more support. Most Americans surveyed by Pew in 2021 are wary that technology to rein in climate change, like modifying solar radiation, will be used before all their environmental impacts are understood.[5]

Americans place monitoring asteroids that could hit Earth at top of NASA's priority list

% of U.S. adults who say each of the following should be ___ for NASA



Note: Respondents who did not give an answer are not shown.
Source: Survey of U.S. adults conducted May 30–June 4, 2023.
"Americans' Views of Space: U.S. Role, NASA Priorities and Impact of Private Companies"

PEW RESEARCH CENTER

3 Audiences probably won't enjoy hearing that basic research has no application

It may be true that the science you're communicating is so fundamental that it doesn't have an application yet, nor perhaps will it ever. But saying that is not the way to endear yourself to an audience. Public opinion data show that when Americans are asked what they feel when they hear the word science, the most common response is hope (see page 21).

The working interpretation is that non-scientists see science as a path to a brighter future and value its potential discoveries and payoffs. Furthermore, poll data from the Pew Research Center suggest that people judge unfamiliar science based on what they perceive to be its value to society (see page 34). When scientists tell audiences that they're doing research without any application in mind, it's not useful from a communications point of view, ScienceCounts executive director Christopher Volpe said at SciPEP's 2023 conference.

SciPEP Tip

When communicating about basic research, focus on exploration of the unknown, wherever it may lead. Avoid saying that basic research has no application.

4 Few scientists do basic research exclusively

Most scientists characterize their life's work on a continuum somewhere between basic and applied, according to two studies that have not yet been peer-reviewed that were presented at SciPEP's 2023 conference and a report commissioned by SciPEP.

A team at the University of Utah asked scientists at big research universities to categorize their research on a seven-point scale, from mostly basic science to mostly applied science. The most common of the 1,300 responses they received was "equal parts basic and applied." And more than half of the scientists overall fell in this category.[6] The researchers note that they did not send the survey to engineers, who tend to focus on applied work.

Meanwhile, a multi-institution team asked nearly 450 scientists at major research universities how frequently they focus on basic or applied science. The scientists were given five options, ranging in frequency from "never" to "a great deal." Once again, the most common response represented a roughly equal mix of basic and applied work.[7]

And finally, for a report commissioned by SciPEP, researchers asked

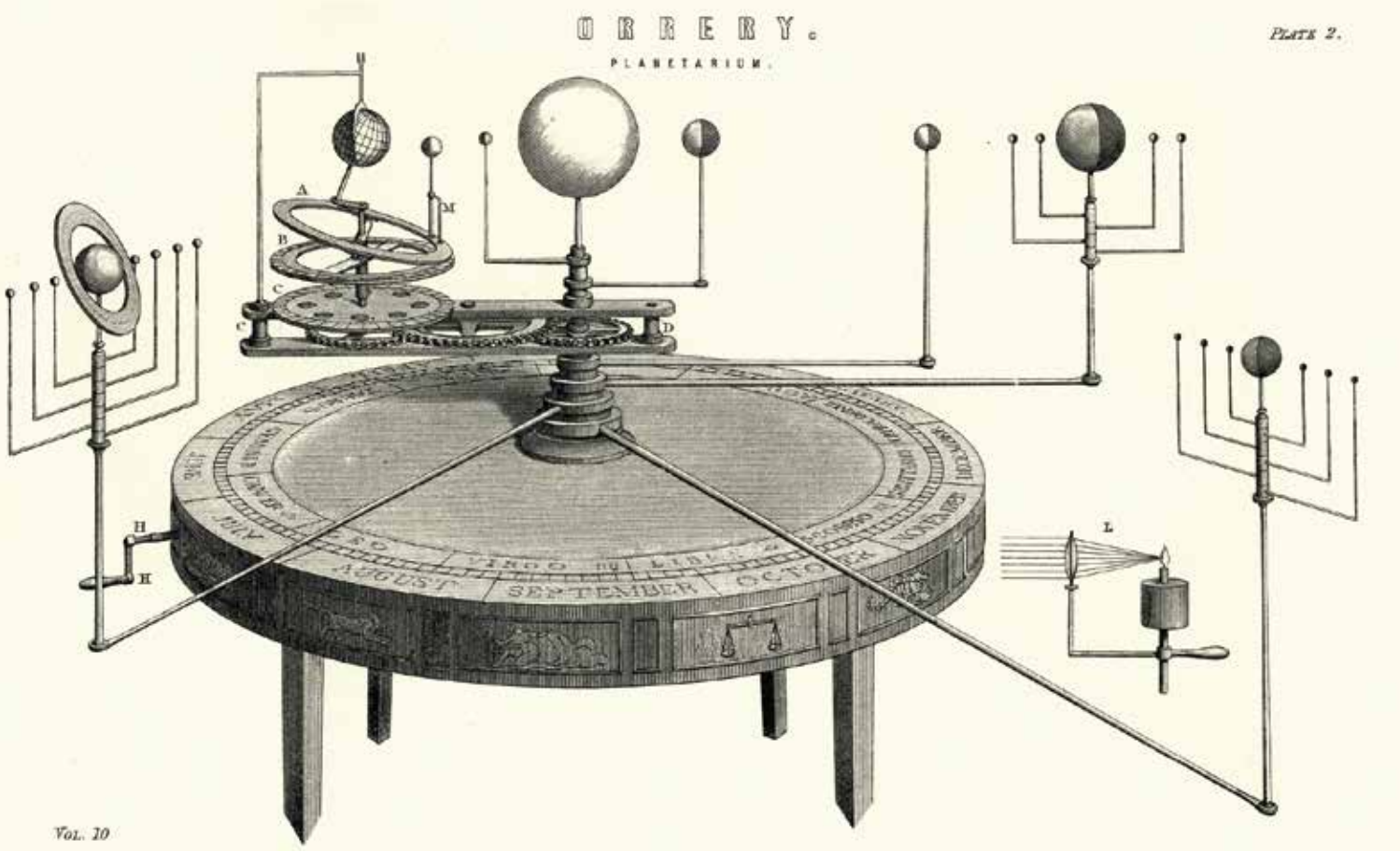
30 scientists, social scientists, and professional communicators at institutions like universities for their thoughts on distinguishing basic and applied science. During in-depth interviews, all the experts could clearly define what basic science is, but they felt that scientific work is rarely all basic or all applied.[8]

Instead, they felt that different topics and different research activities fell somewhere along a continuum between the two extremes of basic and applied. Interviewees had difficulty providing examples of public outreach for basic science, instead using terms like "all science" or defaulting to applied topics like COVID-19. They also struggled to come up with ways to share basic science that give audiences a more active role than a one-way lecture. They expressed uncertainty and skepticism that distinguishing basic and applied science is always helpful. The report authors predict that distinguishing basic and applied science might sometimes be useful, and they call for more research designed to probe when and whether that's the case.

SciPEP Tip

It's OK to just call it "science;" you don't have to say "basic" all the time. But try adding words that have more pizzazz in the public's eyes.

A Yale graduate student presents his research interests to middle school students during the Flipped Science Fair. (Credit: Lorena Benedetti)



Vintage engraving of a Orrery, Planetarium, mechanical model of the Solar System, 19th Century. (Credit: iStock duncan1890)

Why I don't use the label "basic science"

by Bruce V. Lewenstein
Professor of Science Communication,
CORNELL UNIVERSITY

In May 2023, I attended a SciPEP workshop about whether training for basic science communications has unique needs compared to applied science. The organizers announced an interactive activity. They asked us to place ourselves along a figurative line in the conference room according to how much we agreed or disagreed with this statement: "It is important to distinguish basic from applied science in science communication."

But I like to provoke. So instead of joining the line, I walked to the other side of the room.

The question didn't make sense to me. Although most of my teaching and research involves contemporary issues of public communication of science and technology, my training is in the history of American science. As a historian, I know that the label of "basic" science (and the contrast with "applied" science) does not describe a real distinction in science. Instead, the labels appeared in history primarily for rhetorical reasons, as part of an argument about how to treat science.

When science in the 19th century emerged from the earlier "natural philosophy," its practitioners (newly called "scientists") needed ways they could accept patronage (from wealthy families, from royalty, from governments) without giving up control over their work. They wanted to describe work that was not done for immediate financial or industrial purposes.[9,10]

As a historian, I know that the label of "basic" science (and the contrast with "applied" science) does not describe a real distinction in science.

As a result, scientists at the new research universities in Europe and the United States adopted the term "basic science." They identified their work with ideals of classical education (which did not traditionally include science), and as distinct from the utilitarian goals of newer schools associated with farmers and mechanics.[11,12] "Scientists used the concept [of basic science] in order to try to bridge the gap between the promise of utility and the uncertainty of the academic endeavor," according to historian Désirée Schauz.[13]

But even as scientists tried to defend their independence, they simultaneously used the rhetoric to claim value by calling on the "applications" that could eventually result. By the mid-20th century, government was the dominant patron of U.S. scientific research. Vannevar Bush's Endless Frontier—an influential 1945 report to the U.S. president—promised that by giving scientists free rein to choose research problems, benefits would accrue to society.[14] It cited recent innovations critical to winning World War II—atomic energy, radar, jet engines, and penicillin—that emerged from "basic" research.

Labels of pure or basic were also sometimes invoked to claim that science is driven only by "curiosity." But examples are easy to find of iconic scientists throughout history who were driven by powerful forces such as "progress" or "utility"—or, in many cases, religious fervor.[9,15] Yes, Isaac Newton was "curious." But Newton's curiosity was driven in part by his desire to show the power of God. Biographers have shown that his investigations into optics, gravity, alchemy, and his management of the Royal Mint were all driven by his search for deeper theological meanings,[16,17] not only by a simple "curiosity." Similarly, Johannes Kepler's curiosity about the natural world was not "pure," but was driven by a desire to discover God's plan.[18]

Curiosity can also be driven by more immediate forces. Galileo wanted to know more about the heavens, but he also needed money. His reports about his astronomical finds were deeply shaped by his relationships with his financial patrons.[19]

Perhaps more evident today are the ways that family history or concerns about food security and climate change can shape scientific work. A scientist exploring fundamental cell biology could be inspired by someone with cancer in their family. Researchers looking at how water flows through xylem in plants are indeed curious—but may also choose their projects because they want to find ways to make agriculture more efficient and climate-friendly. Some researchers will also find financial benefits, if their work happens to lead to start-ups exploring applications of their ideas. They may be motivated by curiosity, but they are not unaware (if only because their employer constantly reminds them to file intellectual property disclosures) of the possibility of applications.

These examples show that attempts to distinguish between basic or "pure" research motivated solely by curiosity and applied science are not—and probably never were—meaningful. As Schauz and others argue, the label does not accurately describe either historical or modern scientific practice.[9,15,20,21,22] Today, work that illuminates fundamental principles of nature, such as a molecular structure, can also be useful in cancer drug discovery—and may well have been motivated by biomedical interests of both funders and researchers.

Thus, I find that attempts to create a unique form or process for public communication of "basic" or "discovery" science are based on a flawed belief that such a category exists. Science communication and public engagement need to be based on the scientific work that actually happens, not on labels that emerged to serve political and ideological needs.

Five basic science communication projects that inspire

At Guerilla Science's Flavor Feast, a food stand tricks visitors' senses with edible experiments. (Credit: Mark Rosin)

The creative ways that communicators are sharing basic science with audiences could fill a book on their own. To give you a taste of what's inspiring us, we here highlight five projects from among the accepted abstracts from the 2021 SciPEP conference, *Communicating the Future: Engaging the Public in Basic Science*. Initiatives were chosen based on reviewer evaluations of abstracts, novelty of methods and audiences, and alignment with basic science communication insights highlighted in this resource.

BREAKOUT SCIENCE

zuckermaninstitute.columbia.edu/breakout-science

COLUMBIA | Zuckerman Institute

WHERE
New York City

TIMELINE
2019 - Ongoing

BASIC RESEARCH FIELDS

Neuroscience

STRATEGY
Breakout Science events meld brain research with the arts to stimulate wonder and curiosity. For example, a virtual ballet performance included neuroscientists, a choreographer, and an artistic director, who each provided commentary so attendees would learn how the brain and body intersect in dance.[1] Columbia University's Zuckerman Institute collaborates equitably with neighboring arts organizations in Upper Manhattan and the South Bronx to plan and test event ideas. Gatherings, whether in-person or virtual, are often hosted in partners' spaces. Most of the attendees aren't scientists, surveys show, suggesting these partnerships reach new audiences.

SciPEP Tip

Respect other forms of knowledge outside of science that resonate with your audience. Build relationships with your audience's trusted organizations and partner with them to deliver messages.

COVID-19 PREQUELS

covid19prequels.com

SCIENCE PHILANTHROPY ALLIANCE

WHERE
Online

TIMELINE
2021

BASIC RESEARCH FIELDS

Ecology Genetics Mathematics

STRATEGY
The Science Philanthropy Alliance works to increase support for basic science research. After the COVID-19 pandemic hit, the organization launched a collection of stories aimed at advocates for basic research funding and philanthropic funders. Each piece illustrated how basic research, some of which was conducted decades ago, prepared experts to take on the virus with unprecedented speed. With support from The Kavli Foundation and The Simons Foundation, the Alliance teamed with science writers who crafted gripping prose. Tales explained how studying bacteria in a hot spring made "gold standard" COVID tests possible, or how mathematical concepts once used to analyze Russian poetry helped public health officials anticipate shortages of ventilators.

SciPEP Tip

Depending on the audience and goals in mind, cases exist where it makes sense to convey the relevance of basic science by emphasizing its practical applications.

ENGAGEMENT AT LONG-TERM ECOLOGICAL RESEARCH SITES

lternet.edu/apeal-main

WHERE

Long-Term Ecological Research Network, throughout the United States

TIMELINE

2014 - Ongoing

BASIC RESEARCH FIELDS

Ecology

STRATEGY

The scientists at Long Term Ecological Research Sites (LTERs) seek fundamental knowledge about how ecosystems function and how human impacts or major natural disturbances like droughts and other extreme events change forests, deserts, ocean reefs, and other ecosystems over many decades. Because research is funded and conducted over long periods of time at these sites, they are great places to conduct regular outreach to public audiences and decision makers rather than one-off engagements. That regular contact means these sites are well-suited to studying how researchers can best build meaningful long-term connections with people.

LTER projects have included listen and learn sessions with Tribal leaders;[2] a dialogue on invasive pests[3] that brought together scientists, manufacturers of wooden pallets, and staff from state and federal agencies; and art and science initiatives at many sites.[4] Through the Advancing Public Engagement across LTERs (APEAL) Project, a team of collaborators including social scientists, engagement professionals, LTER site and network leaders, and evaluation professionals is helping a group of locations develop site-wide strategies for evidence-based engagement. The teams have also learned about ecologists' attitudes and beliefs about engagement. For example, the scientists' top goals for engagement are to ensure that policymakers and landowners consider scientific evidence when making decisions.

SciPEP Tip

Articulate concrete, actionable goals. Involve community members in conversations that can meaningfully shape the work.

A tricolored heron at the Georgia Coastal Everglades Long Term Ecological Research site. (Credit: Erika Zambello/LTER)

GUERILLA SCIENCE

guerillascience.org

WHERE
United Kingdom and United States

TIMELINE
2008 - Ongoing

BASIC RESEARCH FIELDS

Astronomy, Chemistry, Ecology, Neuroscience

STRATEGY
Science museums tend to attract people who are already interested in science. Guerilla Science works to insert lighthearted science, including basic science, into unexpected places, like concerts. For instance, attendees at Glastonbury Music Festival had the chance to traverse a human-sized version of a maze that lab rats commonly encounter, while exploring their feelings about animal welfare and learning how animal models drive science forward.[5] A team at Guerilla Science and Oregon State University carried out two studies to determine whether their efforts truly reach beyond typical science content consumers. Researchers interviewed people at two different festivals—some who visited Guerilla Science booths and others who did not. They aimed to determine whether the groups had different affinities for science. The boothgoers were no different from the average festival attendee and included people with little connection to science. The quirky, carnival-like experiences were crucial for engaging festival goers, interviews suggested.

SciPEP Tip

Remove barriers to participation by embedding science in atypical locations. Be inclusive by sharing messages in ways that mesh with your audience's identities.

STEM AMBASSADOR PROGRAM

stemap.org

WHERE
Utah and across the U.S.

TIMELINE
2016 - Ongoing

BASIC RESEARCH FIELDS

Chemistry, Ecology, Mathematics, Ornithology, Physics

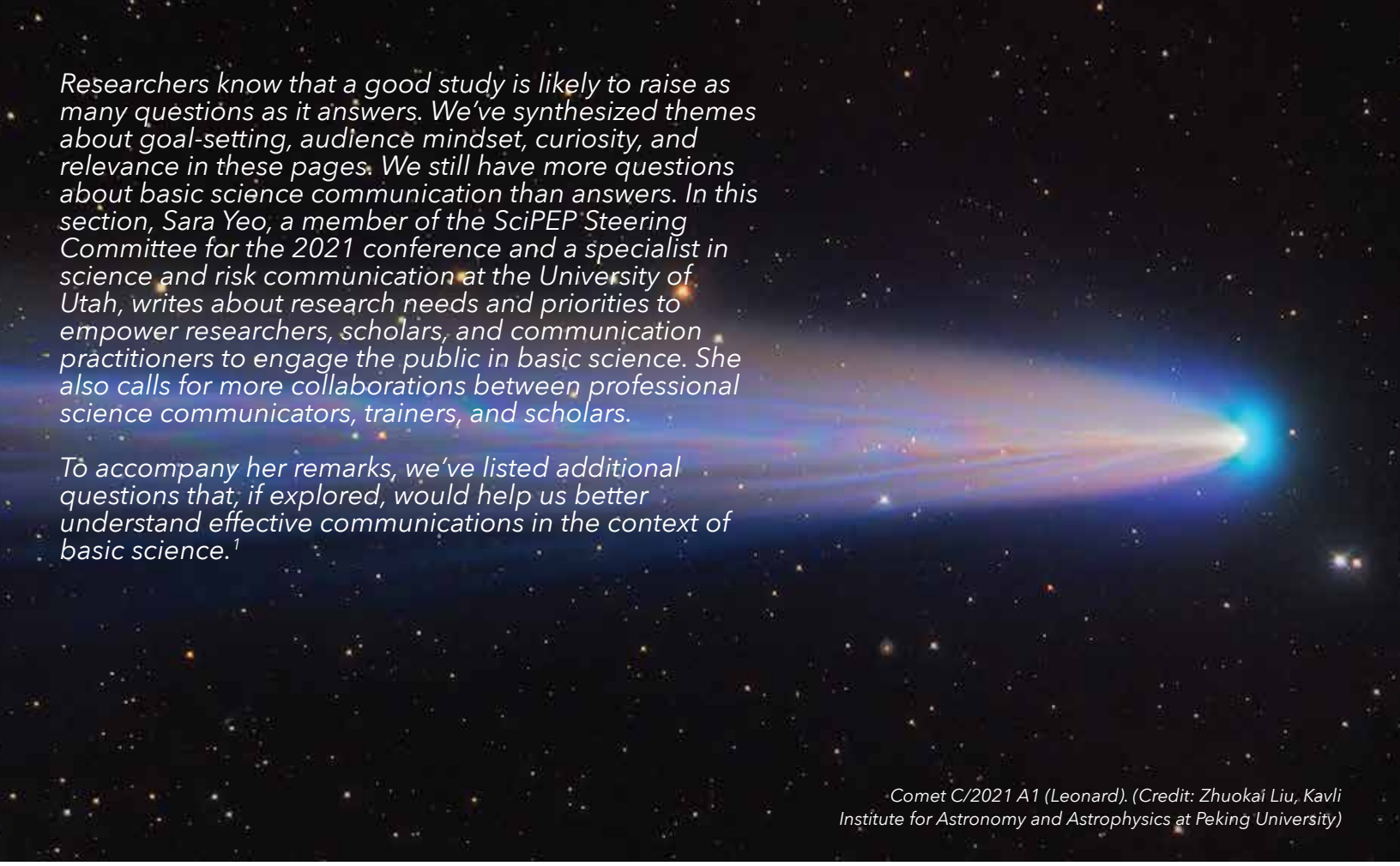
STRATEGY
The STEM Ambassador Program trains scientists to reflect on their research, personal interests, and life experiences to zero in on communities to engage.[6] Researchers spend time getting to know their intended audience and gathering input from individuals to design activities together, then carry out activities in that community's gathering spaces. For instance, an urban planner met with people in a county jail's horticulture job-training program and discussed how to create attractive landscapes that conserve water and are tailored to environmental conditions. More than 300 ambassadors in the U.S. and U.S. territories have completed the program and reached thousands of participants.

SciPEP Tip

Making basic research relevant to an audience can involve finding connection to that audience's identities and everyday lives rather than focusing on a far-off application that might not materialize.

Researchers know that a good study is likely to raise as many questions as it answers. We've synthesized themes about goal-setting, audience mindset, curiosity, and relevance in these pages. We still have more questions about basic science communication than answers. In this section, Sara Yeo, a member of the SciPEP Steering Committee for the 2021 conference and a specialist in science and risk communication at the University of Utah, writes about research needs and priorities to empower researchers, scholars, and communication practitioners to engage the public in basic science. She also calls for more collaborations between professional science communicators, trainers, and scholars.

To accompany her remarks, we've listed additional questions that, if explored, would help us better understand effective communications in the context of basic science.[1]



Comet C/2021 A1 (Leonard). (Credit: Zhuokai Liu, Kavli Institute for Astronomy and Astrophysics at Peking University)

We have more questions than answers. Collaboration is the way forward.

by Sara K. Yeo
Associate Professor, Department of Communication
THE UNIVERSITY OF UTAH

Director and PI
STEM AMBASSADOR PROGRAM

Scouring my mountain of emails is not my typical idea of fun. But searching for the term "SciPEP" brought back happy memories. The oldest message, dated November 20, 2020, invited me to join SciPEP's Steering Committee. I'd worked with two SciPEP leaders on previous projects; I was delighted at the opportunity to collaborate again while getting to know the full team. The invitation laid out objectives for SciPEP. Notably, the partnership would explore characteristics and challenges unique to communicating basic research, develop resources for scientists and practitioners (professional science communicators and trainers), and stimulate scholarship in basic science communication.

That scholarship-related objective appealed to me as a researcher studying the science of science communication. Moreover, as someone who collaborates with science communication practitioners, I was thrilled to see that the vision for SciPEP included both practitioners and researchers. I am keenly aware of the walls that we academics inadvertently and sometimes necessarily build around ourselves, resulting in disciplinary, methodological, and other types of silos that impede collaboration. The plans for SciPEP crossed these boundaries, encompassing the science communication ecosystem of training, practice, and research.

We didn't ease into our roles on the Steering Committee. Our first task: plan the inaugural SciPEP conference during a global pandemic. Together with the SciPEP team, we organized *Communicating the Future: Engaging the Public in Basic Science*. More than 1,200 attendees at this 2021 virtual conference were eager to learn more about the social science underpinning the communication of basic science. The conference surfaced more questions than answers.[2] The two questions that most piqued my interest were:

Do public audiences perceive a distinction between applied and basic science?

Does public communication and engagement around basic science differ from that of applied science? In other words, are the goals, objectives, and tactics (see pages 13 and 14) that are employed when communicating about basic and applied science different?

There are, I believe, empirical answers to these questions that can be addressed by the science of science communication. During the Public Communication of Science and Technology Network (PCST) conference in April 2023 and a SciPEP workshop in May 2023, a cadre of us who had been involved in SciPEP discussed a long-term plan for research specific to basic science communication.

By that point, the partnership had already uncovered some insights. For instance, we learned more about how public audiences perceive basic science (see page 21). And later in 2023, we gained knowledge about goals that motivate communicators of basic science (see pages 15 and 16).

We need more joint efforts between research and practice in science communication.

	Descriptive: What's the current situation?	Injunctive: What would move the field forward?
Public Perceptions	How do public audiences perceive basic sciences? What values or predispositions help form these perceptions?	How would scientists and others in science communication like public audiences to perceive basic sciences?
Strategic Goals and Motivations	What goals, objectives, and tactics motivate communication about basic science topics?	What goals, objectives, and tactics facilitate effective science communication?
Training	What training programs specific to communication and engagement with basic science currently exist?	What training programs can we imagine that could or should exist?

Drawing on conversations at various conferences and interactions with the SciPEP leadership team and Steering Committee, as well as existing scholarship in the field, I created a table with the questions that I thought might drive a research agenda.

The table above includes two terms from the psychology literature on social norms—"descriptive" and "injunctive"—to categorize the types of research questions.[3] Descriptive norms describe something that is typical; injunctive norms specify what ought to be. In the context of a research agenda for basic science communication, I conceptualized descriptive questions as those intended to

catalog the current state of basic science communication while injunctive questions are about what the science communication community needs to know to advance this area.

SciPEP got us off to a great start. We now have some insights, but this table's questions are in no way fully addressed. To do so, we need more joint efforts between research and practice in science communication. The questions organized in the table and the section accompanying this story (see page 49) are by no means exhaustive. They are intended as a starting point to spur necessary collaborations between practitioners and researchers that can empirically answer questions about how we best communicate to specific audiences in service of clear goals and objectives.

There is no one-size-fits-all solution to science communication, regardless of whether the context is in the basic or applied sciences. Through practice-research partnerships, scholars can apply relevant theoretical frameworks in service to practical questions that communicators have about specific topics, for certain audiences, and to achieve specific short-term objectives and longer-term goals.

For example, one focus of my own research agenda is on humor as a tactic for science communication. I have partnered with organizations such as PBS Digital Studios and Hello SciCom to study how they can effectively use humor in their communications. More partnerships such as these will advance science communication both practically and theoretically. I strongly suspect that the goals, objectives, and tactics for communicating about an applied science topic will be distinct from those of a basic science topic. But we won't know for certain until practitioners, trainers, and researchers amass evidence together. Let's get collaborating!

There is no one-size-fits-all solution to science communication, regardless of whether the context is in the basic or applied sciences.

SciPEP Tip

You don't need to plan a new engagement or communication strategy alone. Consider partnering with a social scientist or evaluator who could study and even publish about your work.

More questions to explore

Note: While we have learned a great deal, many questions still remain. This is not a formal research agenda or a comprehensive list of questions. We look forward to learning about the community's further explorations.

How can we use the literature of positive media psychology to design messages that evoke a sense of inspiration?

How can we use the literature of public relations to increase basic scientists' confidence in a communication strategy? What types of collaboration are helpful and what expertise is useful in a communications professional?

To what extent do the institutions where basic science is conducted value basic science communication? Can an institution's definition of impact be redefined to include basic science engagement as part of that impact?

How can the literature of organizational and institutional communication help understand how places are organized to do basic science communication work and what the implications are for public engagement?

How can we design engagement and communications strategies in ways that actively resist reproducing systems of oppression?

How do we evaluate the impact that participating in basic science engagement has on audiences themselves?

How do we include audience voices in the basic science communication research agenda?

How can we increase and maintain channels of communication between practitioners of basic science communication and science communication researchers to share best practices?

Who is included and given power with the ways that we currently do basic science communication and what measures can we take to change that?

How can we better harness other knowledge bases outside of basic science communication to answer research questions?

What interventions and strategies are effective for getting communicators of basic science to shift, from one-way lectures that assume an information deficit on the part of an audience, to genuine, two-way engagement?

SciPEP Tip

If you're doing research on basic science communications or engagement, **publish to grow the body of literature and share your work in jargon-free ways with practitioners.**

REFERENCES

Letter from the SciPEP team

1. Borchelt, R., Sawyer, K., & Smith, B. (2022). *Charting a path for public engagement in basic science: A prospectus.* Report for the Department of Energy Office of Science and The Kavli Foundation as part of the Science Public Engagement Partnership. https://doi.org/10.17605/OSF.IO/PYJAX
2. Sawyer, K., Church, M., & Borchelt, R. (2021). *Basic research needs for communicating basic science.* https://doi.org/10.2172/1836074
3. Besley, J. C., Peterman, K., Black-Maier, A., & Robertson Evia, J. (2021). *The (very limited) evidence base for basic-science-specific science communication in key communication journals.* Report for The Kavli Foundation as part of the Science Public Engagement Partnership. https://doi.org/10.17605/OSF.IO/UECXN
4. Newman, T. P., Brossard, D., Scheufele, D. A., Chen, K., Qian, Y., Cate, A., & Middleton, L. (2021). *Assessing the scholarship of public engagement with basic science.* Report for The Kavli Foundation as part of the Science Public Engagement Partnership. https://doi.org/10.17605/OSF.IO/K93CJ
5. SciPEP. (2021, July 27-28). *Communicating the future: Engaging the public in basic science virtual conference* [Playlist]. YouTube. https://www.youtube.com/playlist?list=PLX-OjlVs8NUIZUATtVnnAj5aDuoNrgJ06
6. SciPEP. (2023, July 25-26). *New insights for communicating basic science virtual conference* [Playlist]. YouTube. https://www.youtube.com/playlist?list=PLX-OjlVs8NULrIKHg8gEWZY9XBo-1MY2T
7. Budenholzer, L., Sawyer, K., Borchelt, R., & Smith, B. (2023). *Science communication training: What is needed for basic science and basic scientists? Synthesis report of a SciPEP workshop.* https://doi.org/10.17605/OSF.IO/P7S9R
8. Besley, J. C., & Dudo, A. (2023). *Basic scientists' views about potential engagement goals: Project report.* https://doi.org/10.17605/OSF.IO/R4AQ5
9. Hendricks, R., & Fond, M. (2023). *Basic and beyond: Next steps on the path to effective and meaningful science communication.* https://doi.org/10.17605/OSF.IO/4YJW7
10. Volpe, C. M. (2023). *Communicating about basic science: Evidence-based recommendations for more effective communication with the public about basic scientific research.* Report for The Kavli Foundation as part of the Science Public Engagement Partnership. https://doi.org/10.17605/OSF.IO/3K6YU

Introduction to this resource

1. Besley, J. C., Peterman, K., Black-Maier, A., & Robertson Evia, J. (2021). T*he (very limited) evidence base for basic-science-specific science communication in key communication journals*. Report for The Kavli Foundation as part of the Science Public EngagementPartnership. https://doi.org/10.17605/OSF.IO/UECXN
2. Newman, T. P., Brossard, D., Scheufele, D. A., Chen, K., Qian, Y., Cate, A., & Middleton, L. (2021). *Assessing the scholarship of public engagement with basic science*. Report for The Kavli Foundation as part of the Science Public Engagement Partnership. https://doi.org/10.17605/OSF.IO/K93CJ

Support, key sectors, and funding for basic science: facts and figures

1. Southwell, B. G., & Schneider, B. (2024). *Science and Engineering Indicators 2024: Science and technology: Public perceptions, awareness, and information sources* (NSB-2024-4). National Science Board, National Science Foundation. Alexandria, VA. Figure PPS-1. https://ncses.nsf.gov/pubs/nsb20244/figure/PPS-1
2. Ibid.
3. Funk, C., Hefferon, M., Kennedy, B., & Johnson, C. (2019). *Trust and mistrust in Americans' views of scientific experts*. Pew Research Center. Page 88. https://pewrsr.ch/3TGPQWJ
4. Southwell, B. G., & Schneider, B. (2024). *Science and Engineering Indicators 2024: Science and technology: Public perceptions, awareness, and information sources* (NSB-2024-4). National Science Board, National Science Foundation. Alexandria, VA. https://ncses.nsf.gov/pubs/nsb20244/public-perceptions-of-science-and-technology
5. Deitz, S., & Freyman, C. (2024). *Science and Engineering Indicators 2024: The state of U.S. science and engineering* (NSB-2024-3). National Science Board, National Science Foundation. Alexandria, VA. Figure 15. https://ncses.nsf.gov/pubs/nsb20243/figure/15
6. National Center for Science and Engineering Statistics (NCSES), National Science Foundation. (2024). *National patterns of R&D resources: 2021–22 data update* (NSF 24-318). Alexandria, VA. Table 3. https://ncses.nsf.gov/pubs/nsf24318/table/3
7. Anderson, G. (2024). *U.S. R&D increased by $72 billion in 2021 to $789 billion; Estimate for 2022 indicates further increase to $886 billion* (NSF 24-317). National Center for Science and Engineering Statistics (NCSES), National Science Foundation. Alexandria, VA. https://ncses.nsf.gov/pubs/nsf24317
8. National Center for Science and Engineering Statistics (NCSES), National Science Foundation. (2024). *National patterns of R&D resources: 2021–22 data update* (NSF 24-318). Alexandria, VA. SciPEP analysis of Table 2 and Table 3. https://ncses.nsf.gov/pubs/nsf24318/table/2 and https://ncses.nsf.gov/pubs/nsf24318/table/3

9. Deitz, S., & Freyman, C. (2024). *Science and Engineering Indicators 2024: The state of U.S. science and engineering* (NSB-2024-3). National Science Board, National Science Foundation. Alexandria, VA. Figure 15. https://ncses.nsf.gov/pubs/nsb20243/figure/15
10. Ibid.
11. National Center for Science and Engineering Statistics (NCSES), National Science Foundation. (2024). *National patterns of R&D resources: 2021–22 data update* (NSF 24-318). Alexandria, VA. Table 7. https://ncses.nsf.gov/pubs/nsf24318/table/7
12. National Center for Science and Engineering Statistics (NCSES), National Science Foundation. (2024). *National patterns of R&D resources: 2021–22 data update* (NSF 24-318). Alexandria, VA. Table 6. https://ncses.nsf.gov/pubs/nsf24318/table/6

At an astrophysics institute, articulating clear communication goals is reshaping relationships with audiences

1. Besley, J. C., & Dudo, A. (2022). *Strategic science communication: A guide to setting the right objectives for more effective public engagement.* Johns Hopkins University Press. https://doi.org/10.56021/9781421444215
2. Besley, J. C., Peterman, K., Black-Maier, A., & Robertson Evia, J. (2021). *The (very limited) evidence base for basic-science-specific science communication in key communication journals.* Report for The Kavli Foundation as part of the Science Public Engagement Partnership. https://doi.org/10.17605/OSF.IO/UECXN
3. Newman, T. P., Brossard, D., Scheufele, D. A., Chen, K., Qian, Y., Cate, A., & Middleton, L. (2021). *Assessing the scholarship of public engagement with basic science.* Report for The Kavli Foundation as part of the Science Public Engagement Partnership. https://doi.org/10.17605/OSF.IO/K93CJ
4. Hendricks, R., & Fond, M. (2023). *Basic and beyond: Next steps on the path to effective and meaningful science communication.* https://doi.org/10.17605/OSF.IO/4YJW7
5. Besley, J. C., & Dudo, A. (2023). *Basic scientists' views about potential engagement goals: Project report.* https://doi.org/10.17605/OSF.IO/R4AQ5
6. Middleton, L., Cate, A., Newman, T. P., & Brossard, D. (2024). Understanding scientists' perspectives on the basic and applied research distinction. *Manuscript in preparation.*
7. Pfleger, A., Gerber, A., & Struck, A. (2022). Strategic communication at the European Space Agency: Juxtaposing strategy and public attitudes. *Journal of Science Communication, 21*(06), Article A02. https://doi.org/10.22323/2.21060202
8. Besley, J. C., Dudo, A., & Maktoufi, R. (2022). Comics by @TheCosmicRey. The Strategic Science Communication Project. http://strategicsciencecommunication.com/stratscicomm-comics/

Q&A: Three experts discuss the importance of knowing your audience's mindset (and your own)

1. Volpe, C. M. (2023). *Communicating about basic science: Evidence-based recommendations for more effective communication with the public about basic scientific research*. Report for The Kavli Foundation as part of the Science Public Engagement Partnership. https://doi.org/10.17605/OSF.IO/3K6YU
2. Newman, T. P., Volpe, C., Lindenfeld, L., Besley, J. C., Dudo, A., & Leavey, N. (2019). *Assessing scientists' willingness to engage in science communication*. ScienceCounts & Alan Alda Center for Communicating Science at Stony Brook University. https://www.stonybrook.edu/commcms/alda-center/_pdf/WillingnessToEngage.pdf

Curiosity

1. Volpe, C., Klein, E., & Race, M. (2022). *Americans' motivations for and barriers to engaging with science: Executive report*. ScienceCounts, Association of Science and Technology Centers, Leaders in Science and Technology Engagement Networks, LabX, & Edge Research. https://bit.ly/EngagingWithScience
2. Liquin, E. G., & Lombrozo, T. (2020). A functional approach to explanation-seeking curiosity. *Cognitive Psychology, 119*, Article 101276. https://doi.org/10.1016/j.cogpsych.2020.101276
3. Dubey, R., Griffiths, T. L., & Lombrozo, T. (2022). If it's important, then I'm curious: Increasing perceived usefulness stimulates curiosity. *Cognition, 226*, Article 105193. https://doi.org/10.1016/j.cognition.2022.105193
4. Dubey, R., Mehta, H., & Lombrozo, T. (2021). Curiosity is contagious: A social influence intervention to induce curiosity. *Cognitive Science, 45*, Article e12937. https://doi.org/10.1111/cogs.12937
5. Liquin, E. G., & Lombrozo, T. (2022). Motivated to learn: An account of explanatory satisfaction. *Cognitive Psychology, 132*, Article 101453. https://doi.org/10.1016/j.cogpsych.2021.101453
6. Silva Luna, D. (2021). *The nature of awe in science communication* [Doctoral dissertation, University of Otago]. OUR Archive. https://hdl.handle.net/10523/12476
7. Silva Luna, D., & Bering, J. M. (2021). The construction of awe in science communication. *Public Understanding of Science, 30*(1), 2–15. https://doi.org/10.1177/0963662520963256
8. Silva Luna, D., & Bering, J. M. (2022). Varieties of awe in science communication: Reflexive thematic analysis of practitioners' experiences and uses of this emotion. *Science Communication, 44*(3), 347–374. https://doi.org/10.1177/10755470221098100

Relevance

1. Boor, A. S. (2019, October 21). Corey Gray / Siksika Nation (Blackfoot) / Laser Interferometer Gravitational-Wave Observatory (LIGO) / Gravitational-Wave Astronomy. *Winds of Change*. https://read.nxtbook.com/aises/winds_of_change/fall_2019/aises_people_1.html
2. Hayhoe, K. (2021). *Saving us: A climate scientist's case for hope and healing in a divided world*. Atria/One Signal Publishers.
3. Montgomery, B. L. (2021). *Lessons from plants*. Harvard University Press.
4. Montgomery, B. L. (2017). Three sisters and integrative faculty development. *Plant Science Bulletin, 63*(2), 78–85. https://issuu.com/botanicalsocietyofamerica/docs/webpsb63_2_2017/25
5. Montgomery, B. L. (2022). Reflections on cyanobacterial chromatic acclimation: Exploring the molecular bases of organismal acclimation and motivation for rethinking the promotion of equity in STEM. *Microbiological and Molecular Biology Reviews, 86*(3), Article e0010621. https://doi.org/10.1128/mmbr.00106-21
6. U.S. Government Accountability Office (GAO). (2020). *GAO science & tech spotlight: Quantum technologies* (GAO-20-527SP). https://www.gao.gov/products/gao-20-527sp
7. Funk, C., & Hefferon, M. (2018). *Most Americans accept genetic engineering of animals that benefits human health, but many oppose other uses*. Pew Research Center. https://pewrsr.ch/3THreNI

The semantics of basic science

1. Newman, T. P., Brossard, D., Scheufele, D. A., Chen, K., Qian, Y., Cate, A., & Middleton, L. (2021). *Assessing the scholarship of public engagement with basic science*. Report for The Kavli Foundation as part of the Science Public Engagement Partnership. Page 10. https://doi.org/10.17605/OSF.IO/K93CJ
2. Volpe, C. M. (2023). *Communicating about basic science: Evidence-based recommendations for more effective communication with the public about basic scientific research*. Report for The Kavli Foundation as part of the Science Public Engagement Partnership. https://doi.org/10.17605/OSF.IO/3K6YU
3. Funk, C., & Strauss, M. (2018). *Majority of Americans believe it is essential that the U.S. remain a global leader in space*. Pew Research Center. https://pewrsr.ch/2JA9Lni
4. Kennedy, B., & Tyson, A. (2023). *Americans' views of space: U.S. role, NASA priorities, and impact of private companies*. Pew Research Center. https://pewrsr.ch/44Qu85U
5. Johnson, C., & Kennedy, B. (2021). *U.S. adults have mixed views on whether geoengineering would help reduce effects of climate change*. Pew Research Center. https://pewrsr.ch/2Sr9Kso
6. SciPEP. (2023, July 25). *3: Identity and inspiration - What do we know about "basic" scientists? New insights for communicating basic science virtual conference* [Video]. YouTube. Time 24:22. https://youtu.be/pWKIxmFlJOw?feature=shared&t=1462

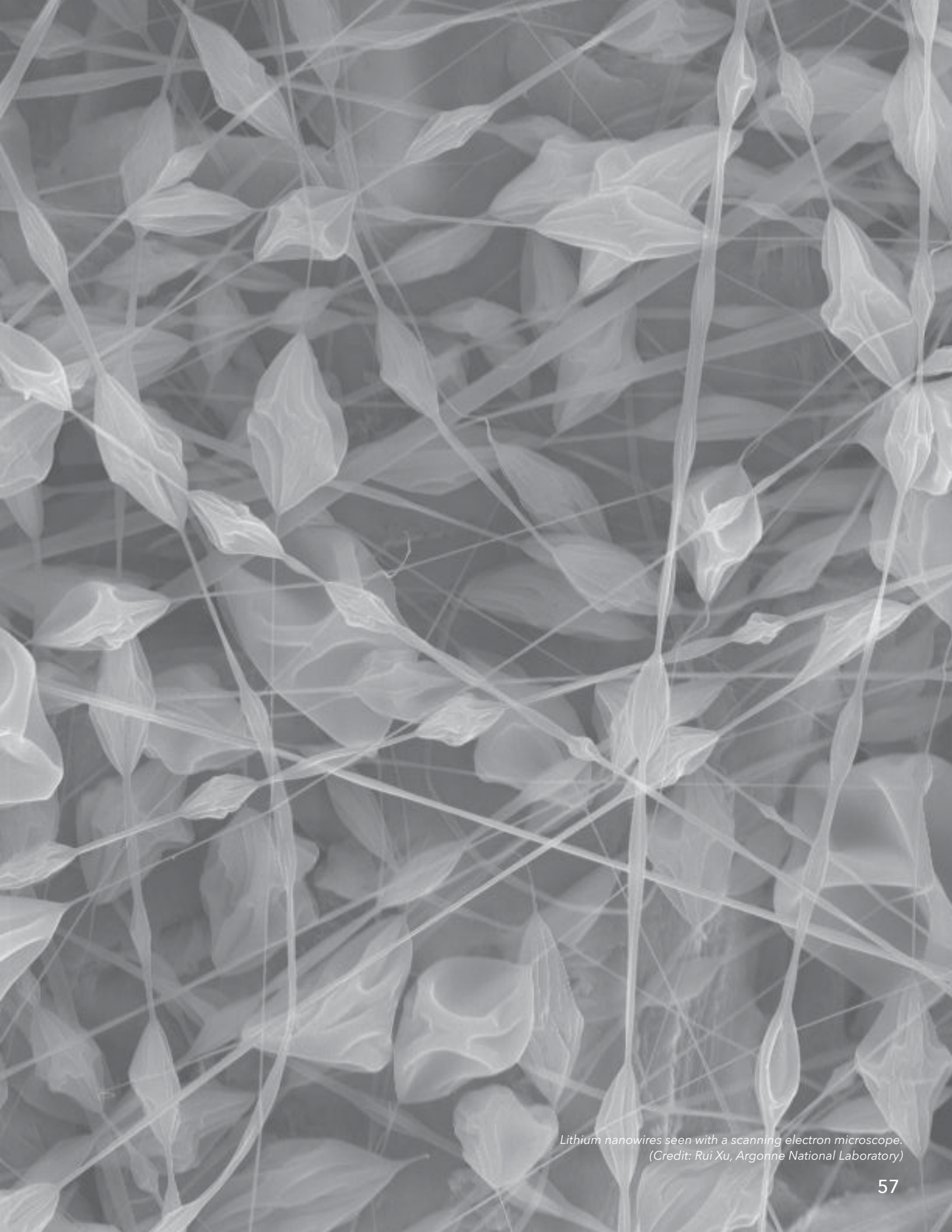
7. SciPEP. (2023, July 25). *3: Identity and inspiration - What do we know about "basic" scientists? New insights for communicating basic science virtual conference* [Video]. YouTube. Time 33:39. https://youtu.be/pWKIxmFlJOw?feature=shared&t=2019
8. Hendricks, R., & Fond, M. (2023). *Basic and beyond: Next steps on the path to effective and meaningful science communication.* https://doi.org/10.17605/OSF.IO/4YJW7
9. Douglas, H. (2014). Pure science and the problem of progress. *Studies in History and Philosophy of Science, 46*, 55–63. https://doi.org/10.1016/j.shpsa.2014.02.001
10. Roll-Hansen, N. (2017). A historical perspective on the distinction between basic and applied science. *Journal for General Philosophy of Science, 48*(4), 535–551. https://doi.org/10.1007/s10838-017-9362-3
11. Bud, R. (2014). 'Applied science' in nineteenth-century Britain: Public discourse and the creation of meaning, 1817–1876. *History and Technology, 30*(1–2), 3–36. https://doi.org/10.1080/07341512.2014.921416
12. Hannaway, O. (1976). The German model of chemical education in America: Ira Remsen at Johns Hopkins (1876-1913). *Ambix, 23*(3), 145–164. https://doi.org/10.1179/amb.1976.23.3.145
13. Schauz, D. (2014). What is basic research? Insights from historical semantics. *Minerva, 52*(3), 273–328. https://doi.org/10.1007/s11024-014-9255-0
14. Bush, V. (1945). *Science: The endless frontier: A report to the president.* U.S. Office of Scientific Research and Development. U.S. Government Printing Office. https://www.nsf.gov/about/history/vbush1945.htm
15. Kitcher, P. (2004). On the autonomy of the sciences. *Philosophy Today, 48*(Supplement), 51–57. https://doi.org/10.5840/philtoday200448Supplement6
16. Westfall, R. S. (1981). *Never at rest: A biography of Isaac Newton.* Cambridge University Press.
17. Dobbs, B. J. T. (1991). *The Janus faces of genius: The role of alchemy in Newton's thought.* Cambridge University Press.
18. Holton, G. (1973). Johannes Kepler's universe: Its physics and metaphysics. In *Thematic origins of scientific thought: Kepler to Einstein* (pp. 69–90). Harvard University Press.
19. Westfall, R. S. (1985). Science and patronage: Galileo and the telescope. *Isis, 76*(1), 11–30. https://doi.org/10.1086/353735
20. Douglas, H. (2015). Politics and science: Untangling values, ideologies, and reasons. *The ANNALS of the American Academy of Political and Social Science, 658*(1), 296–306. https://doi.org/10.1177/0002716214557237
21. Douglas, H., & Branch, T. Y. (2024). The social contract for science and the value-free ideal. *Synthese, 203*(2), Article 40. https://doi.org/10.1007/s11229-023-04477-9
22. Godin, B., & Schauz, D. (2016). The changing identity of research: A cultural and conceptual history. *History of Science, 54*(3), 276–306. https://doi.org/10.1177/0073275316656007

Five basic science communication projects that inspire

1. Dance Theatre of Harlem. (2021, March 11). *The brain at the barre: Dance performance and panel* [Video]. YouTube. https://www.youtube.com/live/IlrB7Ij6Px4
2. National Science Foundation Long Term Ecological Research Network. (2022, October 28). *APEAL case studies.* https://lternet.edu/apeal-cases/
3. Hubbard Brook Research Foundation. (2019). *Invasive pests and the future of New England forests and forest products: A Hubbard Brook roundtable.* Hubbard Brook Research Foundation, Woodstock, VT. https://hubbardbrook.org/wp-content/uploads/Invasive_Pests_Roundtable.pdf
4. National Science Foundation Long Term Ecological Research Network. (2024, July 22). *LTER arts and sciences.* https://lternet.edu/engaging-communities/lter-arts-sciences/
5. Guerilla Science. (2024). *Lab rats.* https://guerillascience.org/events/lab-rats/
6. Risien, J., & Storksdieck, M. (2018). Unveiling impact identities: A path for connecting science and society. *Integrative and Comparative Biology, 58*(1), 58–66. https://doi.org/10.1093/icb/icy011

More questions than answers

1. SciPEP. (2023, July 25). *9: A SciComm research agenda - What do we include? New insights for communicating basic science virtual conference* [Video]. YouTube. https://youtu.be/s4_9HZMRoRM
2. Borchelt, R., Sawyer, K., & Smith, B. (2022). *Charting a path for public engagement in basic science: A prospectus.* Report for the Department of Energy Office of Science and The Kavli Foundation as part of the Science Public Engagement Partnership. https://doi.org/10.17605/OSF.IO/PYJAX
3. Cialdini, R. B., Reno, R. R., & Kallgren, C. A. (1990). A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places. *Journal of Personality and Social Psychology, 58*(6), 1015–1026. https://doi.org/10.1037/0022-3514.58.6.1015



Lithium nanowires seen with a scanning electron microscope. (Credit: Rui Xu, Argonne National Laboratory)

PORTRAIT PHOTO CREDITS

- **Olivia Ambrogio** photo courtesy of Olivia Ambrogio, American Geophysical Union
- **John Besley** photo courtesy of John Besley, Michigan State University
- **Carmen Drahl** photo credit: Rosa Carrasco
- **Xinnan Du** photo courtesy of Xinnan Du, Kavli Institute for Particle Astrophysics and Cosmology
- **Anthony Dudo** photo credit: Marc Speir, Moody College of Communication, University of Texas at Austin
- **Mónica Feliú Mójer** photo credit: Ramdwin González Otero
- **Cary Funk** photo courtesy of Pew Research Center
- **Rose Hendricks** photo courtesy of Rose Hendricks, Association of Science and Technology Centers
- **Bruce V. Lewenstein** photo credit: Dave Burbank
- **Laura Lindenfeld** photo courtesy of the Alan Alda Center for Communicating Science
- **Beronda L. Montgomery** photo courtesy of Beronda L. Montgomery
- **Todd P. Newman** photo courtesy of Todd P. Newman, University of Wisconsin-Madison
- **Ben Shouse** photo courtesy of Ben Shouse, U.S. Government Accountability Office
- **Christopher Volpe** photo courtesy of Christopher Volpe, Science Counts
- **Michelle Warren** photo courtesy of Michelle Warren
- **Sara K. Yeo** photo courtesy of Sara K. Yeo