AMERICAN ACADEMY OF ARTS & SCIENCES

THE PUBLIC FACE OF SCIENCE IN AMERICA

Priorities for the Future

A REPORT FROM THE PUBLIC FACE OF SCIENCE INITIATIVE

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AMERICAN ACADEMY OF ARTS & SCIENCES
Cambridge, Massachusetts

ISBN: 0-87724-129-5

This publication is available online at http://www.publicfaceofscience.org.

Suggested citation: American Academy of Arts and Sciences, *The Public Face of Science in America: Priorities for the Future* (Cambridge, Mass.: American Academy of Arts and Sciences, 2020).

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From the President

Since its inception, the American Academy of Arts and Sciences' Public Face of Science Initiative has sought to understand and strengthen the relationship between science and society. The COVID-19 pandemic has stressed the critical role science plays in ensuring the well-being—indeed, the very survival—of both individuals and society as a whole. As we face this crisis, we can take some encouragement from the findings of the Public Face of Science Initiative, which show that confidence in scientific leaders has remained relatively stable over the last thirty years. It is worth noting, however, that this confidence varies based on age, race, educational attainment, region, political ideology, and other characteristics.

The current crisis has underscored the importance of a society in which everyone has equal opportunity to learn from, engage with, and participate in science. However, revenue losses and budget cuts are having an enormous, and still-evolving, impact on the professional writers, educators, museum curators, outreach organizers, and researchers who are dedicated to building the connections between science and society. While the goals and suggested actions identified throughout this report are more important than ever, they are even further from being realized due to diminished resources and field-wide layoffs. For those with the power and capacity to support the institutions and organizations that provide access to science, now is the time to act. The priorities and goals in this report highlight important means for local science engagement efforts, science journalists, and the scientific community more generally to communicate and engage more effectively.

This is the third and final report from the Academy's Public Face of Science Initiative, a multiyear endeavor to learn more about the complex and evolving relationship between scientists and the public. The first report, *Perceptions of Science in America*, was released in February 2018 and examined the current state of trust in science and scientists. The second report, *Encountering Science in America*, was released in February 2019 and highlighted the numerous ways that individuals encounter science in their everyday lives.

The Academy is grateful to the Gordon and Betty Moore Foundation, the Rita Allen Foundation, the Alfred P. Sloan Foundation, and the Hellman Fellows Fund for their generous support of the Public Face of Science Initiative. The Academy also thanks the participants at workshops held in June 2016 and June 2017, as well as the many project advisors whose thoughtfulness and insights contributed to the development of this initiative and final report. A special acknowledgement to the project staff who stewarded the initiative over the years: Erica Palma Kimmerling, John Randell, Rebecca Tiernan, Alison Leaf, Keerthi Shetty, and Shalin Jyotishi.

Sincerely,
David W. Oxtoby
President, American Academy of Arts and Sciences

Introduction

Science shapes American society in many ways, from the scientific information that guides fundamental personal choices—like which foods we eat and what products we buy—to the technologies that lead to entirely new industries. Every day, Americans enjoy the benefits of science, including job growth, economic prosperity, cutting-edge disease treatments, and faster communication than ever before. Scientific information also bears on important societal decisions, such as responses to climate change, the opioid epidemic, and environmental contamination.

The American Academy of Arts and Sciences' Public Face of Science Initiative began in spring 2016 to address the complex and evolving relationship between science and society. In this capacity, the initiative has aimed to: 1) raise awareness in the scientific and science communication communities on how the public currently views and encounters science; 2) encourage scholars, polling organizations, and funders to address unanswered questions pertaining to public attitudes and encounters with science; and 3) improve the science communication and engagement landscape.[1] To achieve these goals, the initiative has engaged experts in communications, law, humanities, the arts, journalism, public affairs, and the physical, social, and life sciences.

The analysis of public opinion polling in *Perceptions of Science in America* (2018), the first report of the Public Face of Science Initiative, paints a picture of a heterogeneous public whose attitudes toward science are dependent on context and values (see Top Three Takeaways of *Perceptions of Science in America* on page 4). The data within the report highlight how trust in and support of science have remained strong relative to other professions. Although attitudes toward science are generally positive, the variation among demographic groups represents an area for concern and additional study. Further, the report shows how perceptions of specific controversial science issues, such as climate change and vaccine safety, are not uniformly associated with any particular demographic group. *Perceptions of Science in America* reiterated the need for science communicators, engagement programs, and scientists to understand the inherent multiplicity of attitudes toward science and the need for additional research on the subject.

The second report from the Public Face of Science Initiative, *Encountering Science in America* (2019), built on the findings of *Perceptions* to explore the complex landscape by which people experience science outside the classroom (see Top Three Takeaways of *Encountering Science in America* on page 5). In addition to presenting a broad conceptual framework for approaching science communication and engagement, the publication highlights the diverse and expanding range of opportunities for people to encounter science. These opportunities include visiting science centers, attending science events, engaging with science online, and participating in scientific research. In addition, the report includes a data-driven discussion section on science in the media. *Encountering Science in America* also explores how science communication and engagement activities can be designed for specific societal benefits, such as increasing community engagement with science, providing trusted information on controversial topics, or broadening participation in STEM.

The heterogeneity of current attitudes toward science, the great breadth of experiences with the potential to influence those attitudes, and the broad range of desired outcomes from science communication and engagement suggest that a multifaceted approach to shaping the public face of science is needed. This approach is based on insights from a series of nationwide expert roundtable discussions and two major workshops in June 2016 and June 2017. Additionally, outreach to key stakeholders following the release of the first two project reports has informed the recommendations for action outlined here.

This final report from the Public Face of Science Initiative identifies three high-level areas for change that can, over the long term, shape attitudes toward science and people's experiences with it. **PRIORITY 1: BUILDING CAPACITY FOR EFFECTIVE SCIENCE COMMUNICATION AND ENGAGEMENT IN THE SCIENTIFIC COMMUNITY** focuses on improving the foundation for these activities within the scientific community, with recommendations for universities (administrators to department heads), scientists, and scientific societies. **PRIORITY 2: SHAPING THE NARRATIVE AROUND SCIENCE** reflects the importance of scientific narratives in guiding the public image of science and presents recommendations for science journalists, science communicators more broadly, scientific societies, and funders. **PRIORITY 3: DEVELOPING SYSTEMIC SUPPORT FOR SCIENCE ENGAGEMENT EFFORTS** addresses the support structures for science engagement and the diverse group of stakeholders with recommendations for funders, scientific societies, science communication and engagement programs or participants, and universities.

Each priority has an accompanying set of goals and recommendations for action. **GOALS** specify where actionable change needs to occur and a metric of what positive progress would look like. **ACTIONS** are specific recommendations for how to make progress on each goal based on project findings, ongoing efforts, case studies, and current research. The goals and actions presented in this report do not reflect the only avenues for addressing the three priorities for the public face of science, but they provide a starting point for progress.

In addition to these recommendations, this report is a call to action for all organizations with an interest in the public face of science to use the resources at their disposal to support effective science communication and engagement.

Recommended actions for particular stakeholders are identified throughout this report using the following icons:

- Funders
- Science Engagement Institutions
- Scientific Societies
- Higher Education Institutions
- Science Communicators

TOP THREE TAKEAWAYS from *Perceptions of Science in America* (2018)

1 **Confidence in scientific leaders has remained relatively stable over the last thirty years.**

- Americans express strong support for public investment in research.
- A majority of Americans views scientific research as beneficial.
- Americans support an active role for science and scientists in public life.
- Americans have varying interpretations of the word "science" and the scientific process; additional research is necessary to understand how these differing interpretations influence perceptions of—and support for—science.

2 **Confidence in science varies based on age, race, educational attainment, region, political ideology, and other characteristics.**

- Although attitudes toward science are generally positive, the degree of confidence in science varies among demographic groups.
- For example, U.S. adults without a high school diploma are less likely than those with a college degree to view science as beneficial.

3 **There is no single anti-science population, but more research is needed to understand what drives skepticism about specific science issues.**

- Attitudes toward science are not uniformly associated with one particular demographic group but instead vary based on the specific science issue.
- Recent research suggests that underlying factors, such as group identity, can strongly influence perceptions about science.
- A person's knowledge of science facts and research is not necessarily predictive of acceptance of the scientific consensus on a particular question. Indeed, for certain subgroups and for certain topics such as climate change, higher levels of science knowledge may even be associated with more-polarized views.
- More research is needed to determine how cultural experience and group identities shape trust in scientific research, and how to address skepticism of well-established scientific findings.
- Future studies should include an expanded definition of science literacy that incorporates the understanding of the scientific process and the capacity to evaluate conflicting scientific evidence.

SOURCE: American Academy of Arts and Sciences, *Perceptions of Science in America* (Cambridge, Mass.: American Academy of Arts and Sciences, 2018), https://www.amacad.org/publication/perceptions-science-america.

TOP THREE TAKEAWAYS from *Encountering Science in America* (2019)

1 **There is a diverse and expanding range of opportunities for people to encounter science, from visiting science centers and attending science events to participating in scientific research or engaging online.**

- Most Americans regularly encounter science content through general news sources, social media, and entertainment.
- The rapid evolution of online platforms is providing new opportunities for science storytelling and extended dialogue. More research is needed to understand fully how online engagement can be effectively used to build a sense of shared understanding and trust.
- Despite the growth of online platforms, attendance at science museums, zoos, aquariums, and other venues and institutions remains strong and these institutions are among the most trusted sources of scientific information.

2 **More social science research is needed to understand the impacts of science communication and engagement, including on public interest in, understanding of, and support for science.**

- The diverse backgrounds, expertise, and attitudes of individual participants affect short-term outcomes in measurable ways.
- The long-term, cumulative impacts are challenging to assess because of the complex landscape of experiences and a limited understanding of how people move among activities.
- A common language among scholars and practitioners, along with shared metrics and methodologies, is needed to address this knowledge gap and allow for comparative evaluations.

3 **Understanding participant motivations is a critical component of effective science communication and engagement.**

- Individuals do not necessarily engage in science-centered activities with the sole intention of learning about science. For many people, the desire for social experiences and entertainment may be the primary reason for participating.
- Despite the broad range of individual motivations and outcomes, activities can be designed for specific societal benefits, such as increasing community engagement, providing trusted information on controversial topics, or broadening participation in STEM.

SOURCE: American Academy of Arts and Sciences, *Encountering Science in America* (Cambridge, Mass.: American Academy of Arts and Sciences, 2019), https://www.amacad.org/publication/encountering-science.

Priorities, Goals, and Actions for Shaping the Public Face of Science

PRIORITY 1

Building capacity for effective science communication and engagement in the scientific community.

GOAL 1: Increase appreciation, awareness, and understanding of the skills required for effective science communication and engagement among the scientific community.

ACTION 1: STEM undergraduate and graduate programs should integrate core science communication and engagement competencies into their curricula.

ACTION 2: Scientific societies should establish or further develop their resources on science communication and engagement.

GOAL 2: Increase the capacity for science communication and engagement at higher education institutions.

ACTION 1: Higher education institutions should designate centralized staff to connect and support on-campus science communication and engagement activities. Designated staff could support bridge-building between local efforts and the broader field and serve as a central resource for the dissemination of best practices.

ACTION 2: Higher education institutions should encourage on-campus interdisciplinary research and programming partnerships to support science communication and engagement.

ACTION 3: The promotion and tenure system should reward—not discount—participation in science communication and engagement activities.

PRIORITY 2

Shaping the narrative around science.

GOAL 1: Decrease mischaracterizations of science in science communication.

ACTION 1: Whenever possible, science communicators should emphasize the scientific process, highlight unanswered questions, note previous advances within the field, and avoid sensationalism when discussing science.

ACTION 2: Scientific societies should develop action plans to enable rapid responses to significant mischaracterizations of scientific discoveries or misinformation on scientific topics.

GOAL 2: Increase fundamental resources for science journalism.

ACTION 1: With support from external funders, higher education institutions should develop workshops and experiences to provide journalists with insights into the scientific process and research enterprise.

ACTION 2: Funders should support initiatives that provide journalists and editors with sources, fact sheets, and resources on controversial or topical scientific subjects. Science journalists and editors should seek out existing resources.

PRIORITY 3

Developing systemic support for science engagement efforts.

GOAL 1: Increase opportunities among researchers, practitioners, science centers, and communication and engagement organizations and networks to collaborate and share resources and best practices.

ACTION 1: Funders should support the development of centers, databases, and practical approaches that connect researchers and practitioners, such as through travel support for conferences and meetings.
ACTION 2: The leaders of science communication and engagement organizations and networks should collaborate on areas of shared interest.
ACTION 3: Science engagement networks and programs should dedicate resources to support efforts to increase diversity, equity, and inclusion and share these resources with the broader community.

GOAL 2: Strengthen local science engagement ecosystems, especially where access may be limited, and increase cooperative science engagement efforts.

ACTION 1: Local scientific institutions, schools, science centers, and libraries should (continue to) form strategic partnerships and collaborations on local science issues and engagement outcomes. Local stakeholders (government, university, industry) should invest resources in these ecosystems.

GOAL 3: Standardize and increase the number of resources for assessing outcomes and long-term impacts of science communication and engagement.

ACTION 1: Funders should support professional organizations in establishing shared databases and metrics.

Priority 1: Building Capacity for Effective Science Communication and Engagement in the Scientific Community

The public is both a benefactor and beneficiary of science. In 2015, the federal government supported 44 percent of basic research in the United States.[2] The outcomes of this scientific exploration can lead to direct impacts on society, from technologies that enable human gene editing to autonomous vehicles. The intrinsic links between the scientific community and the broader public necessitate that scientists actively pursue opportunities for engagement and education, from discussing findings with policy-makers to engaging directly with local communities.

Progress toward this priority will require developing institutional support, instituting structural reform, and connecting the scientific community with fields and professions that specialize in science communication and engagement. Capacity-building will also need to reflect an understanding that the skills and approaches required for these activities will vary based on the content, audiences, and objectives (see Top Three Takeaways from *Perceptions of Science in America* on page 4). Exemplifying this dynamic approach to science communication and engagement, the American Association for the Advancement of Science (AAAS) offers a variety of programs that provide scientists with the skills and opportunities to work with journalists, policy-makers, and communities. Such AAAS programming also demonstrates the established interest in the scientific community to connect with new partners and communities.

As discussed in *Encountering Science in America*, scientists have a variety of individual professional motivations for participating in science communication and engagement, including the desire to improve science literacy, to strengthen the perception of science, and for personal enjoyment. Science communication and engagement support programs designed for scientists can foster these motivations. For example, scientists who participated in the nationwide "Portal to the Public" training program were more likely to cite objectives such as "getting people excited about science" and "describing scientific findings in ways that make them relevant to people" than university-level scientists who did not participate.[3]

AAAS Programming for Scientists

The American Association for the Advancement of Science offers a suite of science communication and engagement fellowships and professional development opportunities, including:

- **AAAS Science and Technology Policy Fellowship** (established in 1973). This fellowship offers Ph.D.-level scientists the opportunity to work in the executive or legislative branches of government in order to learn about government and policy-making. Fellows serve in government for one year, sometimes extended to two. Approximately 275 fellows are now spread across all three branches of the federal government. Since its founding, there have been more than three thousand AAAS Science Policy Fellows, about half of whom continue working in government following their fellowship, while others return to the bench or enter other boundary-crossing careers.[4]
- **Leshner Leadership Institute for Public Engagement with Science** (established in 2016). Every year, each Leshner Fellow cohort specializes in a different scientific domain that broadly impacts society, such as human augmentation or water security. Leshner Fellows continue to work at their home institutions while receiving training in science engagement best practices and support for broader engagement activities, including plan development.
- **AAAS Mass Media Fellowship** (established in 1973). The Mass Media Fellowship is a ten-week experiential learning program that places scientists who are already active science communicators with major media outlets such as NPR, *WIRED* magazine, and NOVA/PBS. Some scientists have continued to work within the field after their fellowship.
- **Communicating Science Seminar and Workshops**. A recurring part of the AAAS Annual Meeting, the Communicating Science Seminar attracted five hundred participants in 2019. The full-day schedule of plenary talks and breakout sessions provides a forum that brings together aspiring science communicators and experts. In addition to the seminar, AAAS hosts Communicating Science Workshops tailored to provide scientists with tools to engage effectively with a range of audiences.

GOAL 1: Increase appreciation, awareness, and understanding of the skills required for effective science communication and engagement among the scientific community.

A recent survey of scientists found that a greater expectation of enjoyment and ability to make a difference were associated with a higher willingness to engage with the public.[5] Similarly, during Public Face of Science Initiative activities and research efforts, a lack of appreciation for the skills and activities associated with science communication and engagement was cited as a recurring barrier to building systemic capacity. A collective recognition of the expertise required for—and the benefit of—these activities will be necessary to assess accurately and reward scientists for their contributions.[6] This recognition should occur within all levels of the established structures of the scientific community, including academic departments, organizational leadership, and scientific societies.

To build capacity for science communication and engagement, there also needs to be a stable and responsive pipeline for the scientific community to learn and master continually evolving and developing best practices. Science communication and engagement rely on expertise from a range of fields outside of the technical and field-specific knowledge and experience of scientists and engineers, including but not limited to communication, education, public relations, and the cognitive, social, and behavioral sciences (see page 25).

Currently, the burden to learn and understand best practices typically falls on individual scientists and engineers to seek out resources or training. Science communication trainers have recently identified the foundational skills necessary for effective science communication. A table of these skills has been included as part of Appendix A in this report. The actions for this goal utilize current frameworks within the scientific community and would shift the burden from the individual scientist to the broader scientific community. Systemic and institutional changes that build capacity for science communication and engagement will understandably require a significant dedication of resources, including time, funding, and personnel from the scientific community.

[GOAL 1] ACTION 1: STEM undergraduate and graduate programs should integrate core science communication and engagement competencies into their curricula.

Long-term capacity-building requires educating the next generation of scientists on best practices in science communication and engagement. Integrating science communication and engagement into the core competencies for scientific training will have a greater systemic reach than one-time workshops and training experiences. Understandably, this action will present challenges due to the lack of expertise of department faculty and the need to devote time and resources to the task. However, institutions that adopt this approach will be acknowledging how fundamental these skills are to becoming a scientist, as explored in-depth in two 2018 reports from the National Academies of Sciences, Engineering, and Medicine (NASEM). The NASEM report *Graduate STEM Education for the 21st Century* presents recommendations for improving the graduate STEM education system to meet twenty-first century demands on the scientific workforce, including "expansions in the scope of occupations needing STEM expertise." The report suggests core educational elements for master's and doctoral degrees, specifically suggesting the development of foundational and transferrable skills in "leadership, communication, and professional competencies," including "the capacity to communicate, both orally and in written form, the significance and impact of a study or a body of work to all STEM professionals, other sectors that may utilize the results, and the public at large."[7] Published by NASEM the same year, *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education* examines the evidence for integrating curricula from the arts and humanities into scientific disciplines, including a 2015 study of MIT mechanical engineering undergraduate alumni showing that communication was among the top skills used and expected by employers. The report concludes that "certain approaches that integrate the humanities and arts with STEM have been associated with positive learning outcomes," including communication skills.[8] Recent efforts to identify specific learning outcomes for science communication training further support the ability to integrate core competencies into curricula.

RESEARCH HIGHLIGHT

"Science Communication Training: What Are We Trying to Teach?"

Curricula with integrated core science communication and engagement competencies will need to be developed and evaluated based on specific learning goals and objectives. In a 2017 publication, science literacy and communication scholars Ayelet Baram-Tsabari and Bruce Lewenstein outlined a preliminary, high-level list of learning goals to "provoke conversation about the contours of the overall field of science communication training."[9] They envision science communicators who:

"
1. Experience excitement, interest, and motivation about science communication activities and develop attitudes supportive of effective science communication.
2. Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science communication.
3. Use science communication methods, including written, oral, and visual communication skills and tools, for fostering fruitful dialogues with diverse audiences.
4. Can reflect on science and science communication's role within society; on processes, concepts, and institutions of science communication; and on their own process of learning about and doing science communication.
5. Participate in scientific communication activities in authentic settings, creating written, oral, and visual science messages suitable for various non-technical audiences and engaging in fruitful dialogues with those audiences.
6. Think of themselves as science communicators and develop an identity as someone who is able to contribute to science communication. "

[GOAL 1] ACTION 2: Scientific societies should establish or further develop their resources on science communication and engagement.

Scientific societies are a common resource for professional development, research dissemination, and network-building. Moreover, scientific societies already have a vested interest in communication and engagement activities as a means of increasing awareness of current research in their fields. Time and monetary constraints typically limit the number of conferences and workshops individual scientists can attend, which creates inequitable access to best practices in science communication and engagement. Scientific societies are uniquely positioned to provide discipline-relevant resources for their members.

Science communication and engagement resources and training should be developed with clear objectives and, to avoid a duplication of effort, be informed by current research and practices in science communication fields. Understanding and implementing these standards will present a challenge to smaller scientific societies with fewer resources and personnel. Successful development of resources will likely require strategic partnerships with established programs or experts from the social, behavioral, and cognitive sciences.

RESEARCH HIGHLIGHT

"Scientific Societies' Support for Public Engagement: An Interview Study"

A 2019 study by communication and media scholars Shupei Yuan, Anthony Dudo, and John C. Besley of twenty-one scientific societies in the United States found that "society leaders recognize the value of public engagement and the critical role of societies in supporting public engagement activities."[10] Unique aspects of scientific society support for public engagement that surfaced in the study include:

- Impact of societies as a credible messenger;
- Lifelong support for their members; and
- Programming and content tailored to the differing needs of individual disciplines.

Of the interviewed societies, a majority already offered some form of science communication training, although this may not reflect the realities of smaller societies with scarce resources. However, the authors determined that few of the interviewed societies "have a clear objective when it comes to the design and development of their engagement activities," and evaluation of these activities was limited.

The American Geophysical Union's Science Communication and Engagement Resources

In 2010, the American Geophysical Union (AGU) released a new strategic plan with the mission to "promote discovery in Earth and space science for the benefit of humanity"[11] and vision to "[galvanize] a community of Earth and space scientists that collaboratively [advances] and [communicates] science and its power to ensure a sustainable future."[12] To align with this newly stated mission and vision, AGU launched Sharing Science, a network made up of AGU members and led by a team of AGU's staff from different departments across the society, including education, public affairs, strategic communications, and public information. This dedicated staff support allows for sustained and strategic development of Sharing Science programming.

Goals of the Sharing Science network include:

- "Helping scientists powerfully convey the value of their work to the public and build important relationships with journalists, policy makers, educators, and community groups.
- Making scientists visible, authoritative, and accessible voices in their community and the world.
- Breaking down barriers by promoting scientific literacy and helping scientists to be compelling communicators and receptive participants in important conversations.[13]"

Sharing Science makes resources available on a website accessible to members and nonmembers alike and provides tools and exercises for scientists engaged in science communication. For example, to encourage scientists to rethink their use of scientific lingo in communication efforts, AGU provides a list of geophysical science jargon with dual meanings to avoid, such as "model" and "cycling."[14]

Sharing Science has also added programming to AGU's annual conference, with the 2018 conference attracting nearly thirty thousand people. As part of the formal conference, Sharing Science hosts a week of sessions and workshops devoted to science communication aimed at targeting a range of audiences through a variety of platforms and multimedia. Sharing Science also partnered with established science communication platforms and professionals, including the podcasts Story Collider and Third Pod from the Sun, filmmaker James Balog, and other artists, poets, bloggers, and social media and science communication experts active in this space. AGU's dedicated programming demonstrates the organization's recognition that science communication requires a sustained effort over time and is an important priority for its membership.

GOAL 2: Increase the capacity for science communication and engagement at higher education institutions.

Academic institutions conduct slightly less than half of all basic research in the United States, while also educating and training the next generation of scientists.[15] As a result, building capacity within the scientific community for science communication and engagement requires building capacity at higher education institutions. Science communication and engagement efforts should, whenever possible, be built on a current understanding of the research and evaluation of previous activities. Efforts to systemically change higher education institutions will require a multifaceted approach. For example, the Association of American Universities' (AAU) effort to reform undergraduate STEM education was developed around a framework that included pedagogy, support structures, and cultural change.

A 2018 landscape of university support systems and people supporting scientists in public engagement identified possible levers of change based on a review of twenty-six recent reports and seven focus groups with individuals from twenty-two institutions.[16] These levers of change included 1) exposing the time investment required for effective engagement; 2) supporting brokers to magnify existing programs; 3) developing sophisticated metrics; and 4) conducting promotion and tenure reform.

CASE STUDY

AAU Undergraduate STEM Education Initiative[17]

When: Launched in 2011.

AAU member participation in undergraduate reform activities (as of 2017): 55 out of 62 member universities and 275 faculty members/leaders.

Focus of the initiative: "To influence the culture of STEM departments at AAU universities so that faculty members are encouraged to use teaching practices proven by research to be effective in engaging students in STEM education and helping them learn."

Infrastructure: Dedicated AAU staff member who engages with dedicated campus liaisons, workshops/in-person forums, and collaborations with national associations, funders, and industry partners.

Recommendations for successful institutionalization of undergraduate STEM education reforms:

1. Shift from individual to collective responsibility for courses and curricula;
2. Consider hiring nontraditional positions to bolster education reforms;
3. Reorganize support services to augment departmental reform efforts;
4. Employ and adequately support evidence-based educational best practices as an institutional responsibility; and
5. Better manage the simultaneous pursuit of high-quality teaching and research.[18]

[GOAL 2] ACTION 1: Higher education institutions should designate centralized staff to connect and support on-campus science communication and engagement activities. Designated staff could support bridge-building between local efforts and the broader field and serve as a central resource for the dissemination of best practices.

A centralized, permanent support structure for on-campus science communication and engagement activities will support the development of institutional memory, encourage on- and off-campus partnerships, and provide a unifying resource. A significant obstacle to building capacity is the inefficiency of information-sharing on campuses and with local and national efforts. At the same time, common obstacles to building institutional knowledge are the single-effort nature of engagement activities, disjointed efforts across campuses, the reliance on soft funding for supporting professional facilitators and organizers, and the lack of funding for travel to relevant conferences and meetings. Efforts to generate support within an institution for capacity should also consider using established tools for understanding an institution's current commitment to engagement.

Dedicated institutional resources can also help support aligned research and community-building efforts. The Association of Public and Land-grant Universities' (APLU) Public Impact-Focused Research (PIR) initiative has sought to design a common framework capable of empowering more institutions to undertake societally responsive research. The PIR report released in November 2019 identifies efforts to build communications capacity through investing in communications and weaving communications training into the fabric of academic institutions as critical components of successful PIR programs.[19]

HIGHLIGHTS FROM THE FIELD

The National Coordinating Centre for Public Engagement: EDGE Tool

The National Coordinating Centre for Public Engagement (NCCPE) was founded in 2008 as part of an initiative to "create a culture within UK higher education where public engagement is formalised and embedded as a valued and recognised activity for staff at all levels, and for students."[20] The NCCPE's EDGE tool is an example of a framework for self-assessing an institution's support for public engagement in terms of "Embryonic, Developing, Gripping and Embedded levels of support."[21] The tool uses purpose, process, and people as focal points for assessing public engagement. For example, institutional missions with "little or no reference to public engagement in the organisational mission" would be at an embryonic level of support compared with institutions with an embedded level of support where engagement is "prioritised in the institution's official mission and in other key strategies, with success indicators identified."[22]

[GOAL 2] ACTION 2: Higher education institutions should encourage on-campus interdisciplinary research and programming partnerships to support science communication and engagement.

Most higher education institutions already possess expertise in the education, communication, social, behavioral, and cognitive sciences on campus. Transdisciplinary partnerships have the potential to address emerging research questions such as those surrounding public engagement with gene editing and can serve as a resource for best practices in communication and engagement (see page 25).[23] This action also reflects the recent growth of interdisciplinary research as a means of addressing the grand challenges facing society.[24]

The need for on-campus partnerships will only continue to grow considering the increased emphasis on evaluation and program impact of science communication and engagement activities. In addition to one-on-one partnerships between faculty, dedicated departments or initiatives can also support formal, interdisciplinary campus activity. Examples include:

- **The Department of Life Sciences Communication** in the college of Agricultural and Life Sciences at the University of Wisconsin–Madison has been a source of cutting-edge research on science communication, working with life scientists on topical issues such as gene drives and genetically modified organisms (GMOs).[25] In addition to research, the Department of Life Sciences Communication offers undergraduate, master's, and Ph.D. programs, including a Ph.D. minor in science communication.
- Duke University's **Initiative for Science & Society** seeks "to maximize social benefit from scientific progress by making science more accessible, just, and better integrated into society."[26] The initiative has core and affiliated faculty from across disciplines, provides resources and programming on areas such as research impact and science communication, and supports interdisciplinary research.
- Iowa State University's **Science Communication Project** emphasizes research, education, and dissemination. In addition to interdisciplinary research on "communicating science in controversial settings and of appropriate methods for addressing these challenges," the project develops educational materials and trainings for early-career scientists.[27]

[GOAL 2] ACTION 3: The promotion and tenure system should reward—not discount—participation in science communication and engagement activities.

Although science communication and engagement should not be limited to tenure track faculty at research universities, the lack of formal incentives for these activities has a ripple effect throughout the broader scientific community. Changes to the promotion and tenure structure that acknowledge science communication and engagement will likely need to come alongside additional STEM reform efforts currently under discussion. These efforts include recognizing and rewarding progress in undergraduate education, transdisciplinary research partnerships, and effective mentorship. Ongoing efforts attempting to identify case studies of successful promotion and tenure reforms should be supported alongside national efforts to address this issue.

Priority 2: Shaping the Narrative around Science

Scientific narratives encompass everything from the discussion of specific scientific topics, such as vaccine safety, to assessments of the efficacy of the scientific enterprise. Discussion of science in news media and on digital platforms impacts public perceptions of science. Media coverage of scientific topics has been found not only to raise awareness of a particular subject, but also to shape trust in the relevant science bearing on that topic.[28]

Efforts to shape the narrative around science should be based on a rigorous understanding of how these narratives are transmitted and interpreted by audiences. The science of science communication is the study of scientific messaging, including how those messages are interpreted and how they influence behaviors and attitudes. The 2017 *Oxford Handbook on the Science of Science Communication* provides insights from this field, including case studies of failures and successes in communication, that should inform efforts to shape the narrative around science (see research highlight on page 20 for a specific example).[29]

Ideally, scientific narratives should accurately reflect scientific consensus and the contributions of current scientific research. Narratives also have the potential to influence perceptions about who can contribute to science and use scientific thinking. Despite recent strides to bring more diversity into STEM fields, there is still pervasive underrepresentation of women and minorities in the workforce, with women accounting for just 30 percent of STEM professionals.[30] When this disparity is compounded by a lack of representation of women scientists in the media, the public receives the message that only people who comply with a particular image can participate and inform science.

In addition to encouraging approaches to science communication that reduce misconceptions, shaping the narrative around science will require the creation and utilization of resources that both support accurate coverage of scientific topics and respond to misinformation.

ONGOING EFFORTS: 500 WOMEN SCIENTISTS

"Request a Woman Scientist: A Database For Diversifying the Public Face of Science"

Founded in November 2016 by four graduates of the University of Colorado Boulder, 500 Women Scientists is an ongoing effort to address the narrative that science is informed and shaped solely by men and to highlight the vibrant and diverse voices and perspectives that exist within the science community. 500 Women Scientists first launched with the release of an open letter "re-affirming [their] commitment to speak up for science and for women, minorities, immigrants, people with disabilities, and LGBTQIA."[31] With an initial goal of five hundred signees, the pledge would obtain nearly twenty thousand signatures from women in STEM and supporters of women in STEM from more than one hundred countries.

In January 2018, the organization launched Request a Woman Scientist, an extensive database of self-identifying women scientists across the world to be used by conference organizers, journalists and the media, and students and scientists seeking partners and collaborators. The database addresses the claim of "not being able to find women experts" working in the field and aims to be a platform for highlighting voices from underrepresented backgrounds across the world.[32] As of November 2018, a total of 7,500 women from 133 countries have voluntarily signed up as a resource and the database has been accessed more than one hundred thousand times by journalists, conference organizers, schoolteachers, and others. *The Atlantic*, *Grist*, and *National Geographic* are among the media platforms that have used Request a Woman Scientist to find women scientists as sources for articles.

GOAL 1: Decrease mischaracterizations of science in science communication.

Reducing mischaracterizations and instead accurately representing science in accessible ways will help to preserve trust and inform decision-making. There are also unintended consequences on perceptions of science when narratives surrounding science misrepresent the status quo (see research highlight on page 20). Of particular concern are mischaracterizations of scientific consensus, the impact of new scientific results, and the pace of scientific discovery. Progress on this goal will require efforts from all science communicators, including but not limited to journalists, public relations officers, and scientists. A challenge to achieving this goal is the conflict that can arise between acquiring and maintaining audience interest in a news article, press release, or social media post and the nuance and details required to represent accurately scientific content. Further, the public information officers and public relations staff who write press releases are often incentivized to sensationalize new scientific studies in a manner that may misrepresent the data in order to increase their perceived newsworthiness.

RESEARCH HIGHLIGHT: WHY CONTEXTUALIZATION MATTERS

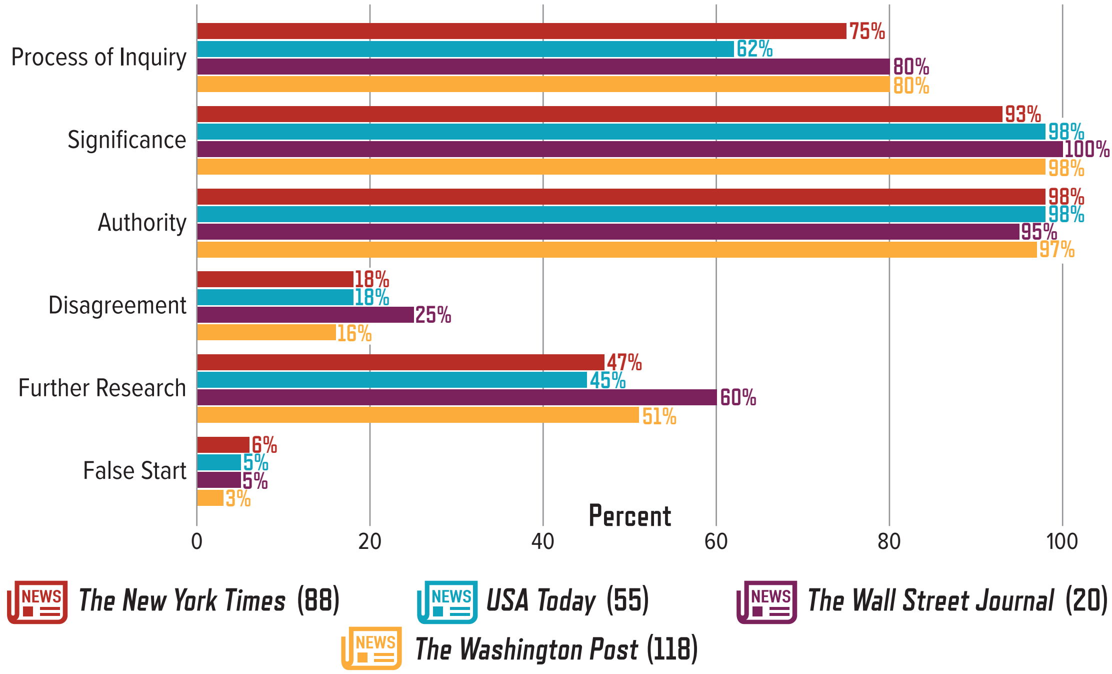
"Science as 'Broken' versus Science as 'Self-Correcting': How Retractions and Peer-Review Problems Are Exploited to Attack Science"

In this chapter from the 2017 *Oxford Handbook on the Science of Science Communication*, authors Joseph Hilgard and Kathleen Hall Jamieson explore examples of widely reported scientific retractions to understand the framing of these retractions in the media.[33] One of the retractions explored in-depth is that of a study published in *Science* that claimed that opinions of same-sex marriage could be changed through short conversations. The study was retracted after an attempt to repeat the experiment revealed that the original research was misrepresented and included "statistical irregularities."[34] In one hundred articles about the retraction, only four noted that retractions are rare, and only ten addressed the retraction as a form of scientific self-correction. Due to the political nature of the subject, the retraction was attributed to liberal confirmation bias in some media outlets and used to justify cuts to public funding of the social and behavioral sciences. As Hilgard and Jamieson discuss in the chapter, partisans have interpreted issues with peer review and retractions to advance a message that science is corrupt. They also suggest that science communicators should test alternative approaches that highlight the self-correcting nature of science and the rarity of retractions as a means of blunting overgeneralization.

[GOAL 1] ACTION 1: Whenever possible, science communicators should emphasize the scientific process, highlight unanswered questions, note previous advances within the field, and avoid sensationalism when discussing science.

Contextualization of science can encompass everything from the need for further research to the failures and barriers that produced dead ends along the way. The Annenberg Science Media Monitor "analyzes the news coverage of widely reported scientific findings and disseminates its findings to science journalists," including a study of nearly two years of news reports in *The New York Times*, *USA Today*, *The Wall Street Journal*, and *The Washington Post* on 165 widely covered scholarly studies.[35] Although major news outlets regularly highlight the significance of a scientific finding and identify those responsible for it, it is less common for these stories to discuss disagreement within the scientific community, false starts, or the need for further research. It is unclear, however, whether these rates of coverage apply to news outlets with fewer resources. In addition to contextualization in news articles, science communicators can provide additional context on social media and online platforms. For example, the Twitter account @justsaysinmice retweets headlines that overhype preliminary results by neglecting to mention that the findings were only "IN MICE," as James Heathers, the research scientist who runs the account, emphatically comments. The account has succeeded in pressuring science writers to add more context to their stories.[36]

Rate of Coverage in Articles on Scientific Studies (by Newspaper)



NOTE: Authority designates "whether authorities such as scientists or institutions involved were mentioned in the finding." Numbers of articles on scholarly studies appear in parenthesis. **SOURCE:** Modified from The Annenberg Public Policy Center, "Annenberg Science Media Monitor–Report 1" (Philadelphia: The Annenberg Public Policy Center, University of Pennsylvania, 2018), https://cdn.annenbergpublicpolicycenter.org/wp-content/uploads/2018/08/science-media-monitor-report-1.pdf.

[GOAL 1] ACTION 2: Scientific societies should develop action plans to enable rapid responses to significant mischaracterizations of scientific discoveries or misinformation on scientific topics.

Scientific societies have an inherent interest in preserving perceptions around the efficacy of their research or scientific consensus in their field. Misconceptions can undermine public trust in their findings and support of their use in decision-making. Research suggests that corrections of misinformation are less effective when there is a time delay between misinformation and its correction, or when misinformation has been repeated.[37] Expert voices and messages around the scientific consensus have been shown to be ineffective on issues on which people hold established perspectives, such as GMOs (see research highlight on page 22). For rapid response approaches to be effective, corrections to misinformation or false narratives should use techniques that are based on current research in the cognitive and behavioral sciences.[38] A mechanism for monitoring and addressing misrepresentations does not currently exist; it is up to the leadership of individual scientific societies, in consultation with relevant experts, to build it.

RESEARCH HIGHLIGHT

"Examining the Impact of Expert Voices: Communicating the Scientific Consensus on Genetically Modified Organisms"

Forty-nine percent of U.S. adults believe GMO foods are worse for one's health than non-GMO foods.[39] Recent research on messaging about the scientific consensus of GMO safety has found that approaches that emphasize the scientific consensus are not linked to changes in attitudes about GMO foods. Results also suggest that previously held attitudes toward GMOs were the strongest predictor of outcomes compared with other study variables. These findings fit with additional research on the role of motivated reasoning in shaping a person's response to scientific information, as well as evidence that people are more likely to reject information that disagrees with previously held beliefs.[40]

GOAL 2: Increase fundamental resources for science journalism.

Science journalism is responsible for providing an independent assessment of scientific progress and its implications for society. This role is distinct from other forms of science communication and engagement, which may have a goal of generating support for science or building trust in scientific information. A recent Pew Research Center study on *Science News and Information Today* showed that Americans blame reporters, not science researchers, for how science news is covered, and that 54 percent of people regularly get their science news from outlets that cover a variety of topics, as opposed to specialty news outlets.[41] Considering the pivotal role of science journalism in shaping the narrative around science, it is essential that resources for science journalism increase.

Because the news media is currently in a state of flux, recommendations will be challenging to implement. Within the last decade, as the number of full-time science journalists in media organizations has declined, opportunities for stories to reach new audiences on social media, video platforms, and podcasts have increased. Further, as a result of philanthropic support for science journalism, there has been a growth in high-quality, science-focused digital magazines.[42] Philanthropic support can also be used to reinforce and recognize excellence in science journalism, such as the AAAS Kavli Science Journalism Awards. The turbulence within the media landscape suggests the need for approaches to strengthen science journalism that are scalable and support journalists—from diverse backgrounds and experiences—reporting on science topics.

Percentage of U.S. Adults Who Say . . .

54% They get their science news from general news outlets.

They believe general news sources get their science facts right most of the time. **28%**

SOURCE: American Academy of Arts and Sciences, *Encountering Science in America* (Cambridge, Mass.: American Academy of Arts and Sciences, 2019).

[GOAL 2] ACTION 1: With support from external funders, higher education institutions should develop workshops and experiences to provide journalists with insights into the scientific process and research enterprise.

To account for the decline in knowledge-based journalism, professional development opportunities that provide journalists with insight into the scientific process need to expand. Providing journalists with a deeper understanding of the scientific process, data collection, and scientific uncertainty can help protect against mischaracterizations in science journalism. Programs that offer this form of training, such as Metcalf Institute's Annual Science Immersion Workshop for Journalists, report being unable to meet demand.[43] For this action to impact regional and freelance journalists, the burden for financing these opportunities should be shifted from individual journalists to nonprofits and other interested stakeholders.

HIGHLIGHTS FROM THE FIELD

Metcalf Institute Annual Science Immersion Workshop

The mission of the Metcalf Institute at the University of Rhode Island is to expand accurate environmental news coverage. In addition to occasional science seminars and webinars on specific environmental topics, the Institute offers its Annual Science Immersion Workshop, where journalists get direct access to scientists in and out of the field. The trainings seek to:

1. Increase journalists' understanding of the process of scientific research through off-deadline interactions with scientists;
2. Familiarize journalists with the concept of scientific uncertainty;
3. Increase journalists' ability to interpret scientific information; and
4. Prepare journalists to provide scientific context in their reporting on environmental stories.[44]

A study of Science Immersion Workshop participants revealed that journalists' post-training stories offered "broader scientific context and more frequent references to scientific uncertainty."[45] Since the study, the workshop has iterated to offer more of a focus on fundamental skills such as understanding and interpreting probabilities and statistics.

[GOAL 2] ACTION 2: Funders should support initiatives that provide journalists and editors with sources, fact sheets, and resources on controversial or topical scientific subjects. Science journalists and editors should seek out existing resources.

Freely available online resources such as fact sheets and briefings tailored for journalists have been used to improve coverage in other fields of journalism. The growth of new programs such as SciLine also suggests a demand for these types of scientific resources. SciLine launched in October 2017 with the mission to "provide context and research-based evidence to journalists working on deadline and in-depth stories."[46] Since its founding, SciLine has curated a database of nearly ten thousand scientists and recommended more than one thousand scientists to reporters with approximately 80 percent of related stories quoting a recommended expert.[47] These types of resources should be appropriately funded to support outreach to local journalists.

HIGHLIGHTS FROM THE FIELD

Dart Center for Journalism and Trauma[48]

The Dart Center for Journalism and Trauma is a resource center "dedicated to improving media coverage of trauma, conflict and tragedy," from natural disasters to mass shootings. Now a project of the Columbia University Graduate School of Journalism, the original programming began at Michigan State University in 1991 and included curricula on newsroom ethics for covering issues such as sexual assault. In addition to offering tip sheets (summaries of the latest information on a particular subject), trainings, and curricula, the Dart Center offers fellowships for journalists looking to improve their reporting on conflict. One of the missions of the center is to "create and sustain interdisciplinary collaboration and communication among news professionals, clinicians, academic researchers and others concerned with violence, conflict and tragedy." The Dart Center and its programming are supported by funding from major donors and foundations.

SPECIAL SECTION:

THE CRUCIAL ROLE OF THE SOCIAL AND BEHAVIORAL SCIENCES

The Public Face of Science Initiative has examined attitudes toward science and the contexts and experiences that shape those attitudes. This effort has required substantial contributions by the social and behavioral sciences. As the fields of science communication and engagement continue to develop and the available data on perceptions and encounters with science become more complex, these sciences will continue to be critical. Explicit recognition of the importance of the behavioral and social sciences is necessary, as is proper citation of their findings. Too often social and behavioral science concepts are treated as common sense: that is, "well, we always knew that." This misrepresents such scientific contributions as:

1. **Polling data.** Nationally representative polling data on trust in science, such as from the General Social Survey (a half-century of trend lines) and Pew Research Center, is depicted throughout *Perceptions of Science in America*. Social science underlies everything from survey question development to data collection methodology and data analysis. The 2019 American Academy report *The Public Face of Science Across the World* analyzes polling data from the World Values Survey for insights into how cultural and economic contexts are associated with attitudes with science across fifty-four countries.[49]

2. **Understanding the underlying factors.** *Perceptions of Science in America* emphasizes how context and values may influence public attitudes. For instance, some recent research suggests that although conservative Republicans are less likely to believe in the scientific consensus on climate change, those with a higher curiosity about science are more likely to agree with the consensus.[50] However, other studies suggest alternative patterns and influences.[51] Exactly when, and how, the source of information influences the response to that information is not settled science and requires continued research in this domain.

3. **Correcting misinformation.** Responding to misinformation without reinforcing falsehoods is of critical importance to the scientific community. Research considering how information is processed and spreads through society is fundamental to this goal. *Encountering Science in America* highlights approaches for correcting misinformation based on insights from the cognitive sciences: for example, providing correct factual information in a manner that does not restate the falsehood.[52]

4. **Measuring impact.** *Encountering Science in America* describes the measurement and evaluation data of science festivals and science communication training programs. Here the focus is on motivations for and consequences of such initiatives. Social science concepts, methods, and analytic tools are foundational to understanding public engagement.

These examples are but a few of the many ways in which research probing attitudes toward and engagement with science, of all kinds, is necessary to the science of communicating science. Developing this expertise results in both practical applications relevant to the complex ways in which the public face of science is presented and interpreted, and is necessary as a standalone research domain. That is, this fairly recent social science initiative needs resources to mature into a major research field in its own terms. This point is stressed in the 2017 NASEM report on *The Value of Social, Behavioral, and Economic Sciences to National Priorities: A Report for the National Science Foundation*: "Nearly every major challenge the United States faces . . . requires understanding the causes and consequences of people's behavior."[53]

Call to Action

Despite the essential nature of the social and behavioral sciences, funding for these fields is frequently threatened. In addition to recognizing and highlighting the contributions of these fields, the following actions are necessary for advancing the goals of the Public Face of Science Initiative:

1. **Increasing research on effective communication of the social sciences.** Social sciences such as the science of science communication typically focus on topics like biotechnology or climate change, but more research is needed on how to communicate effectively the value and contributions of the social sciences themselves.[54]

2. **Connecting research and practice.** There continues to be a need to link more effectively research and practice through partnerships, codevelopment, and boundary-spanners. An example of current attempts to strengthen this connection is the NASEM Standing Committee on Science Communication Research and Practice, which, in addition to colloquiums, has issued Partnership Awards to support the development of collaborative projects.

3. **Funding.** Continued support for research in the social sciences is critical to realizing the societal goals described throughout this report. Funding is particularly critical for maintaining publicly accessible polling data, understanding impact, and exploring how shifts in the communication and engagement landscape influence behavior.

Priority 3: Developing Systemic Support for Science Engagement Efforts

As highlighted in *Encountering Science in America*, there is a diverse and expanding range of opportunities for people to encounter science, including visiting informal science institutions, participating in citizen science activities, or attending science events. These activities can be designed to achieve societal benefits, from broadening participation in STEM to expanding community engagement with research and building trust in information on controversial topics.[55] These science-based experiences are the result of efforts in the fields of science communication, public engagement with science, and informal science education. For each of these fields, there are a broad range of institutions and practitioners that contribute to science engagement efforts. A systems-level approach to supporting science engagement reflects the complexity of the landscape by which people come to experience science.

In the context of this priority, providing systemic support for science engagement refers to resource-sharing and bridge-building efforts among institutions or practitioners with shared engagement goals. In addition to improving outcomes of engagement, greater interconnectivity within science engagement landscapes also has the potential to raise awareness of current efforts and increase the number of new activities that build on prior research and experience.

Insights from *Encountering Science in America*: The Participants

Supporting Institutions

Institutions can provide access to critical resources, from financial and logistical support to the personnel or infrastructure that make science communication and engagement possible. These participants have a significant role in **DEFINING THE OUTCOMES AND POTENTIAL IMPACT**. Supporting institutions include but are not limited to:

- NONPROFITS
- GOVERNMENTS
- PRIVATE SECTOR
- UNIVERSITIES
- INFORMAL SCIENCE ORGANIZATIONS

Professional Practitioners

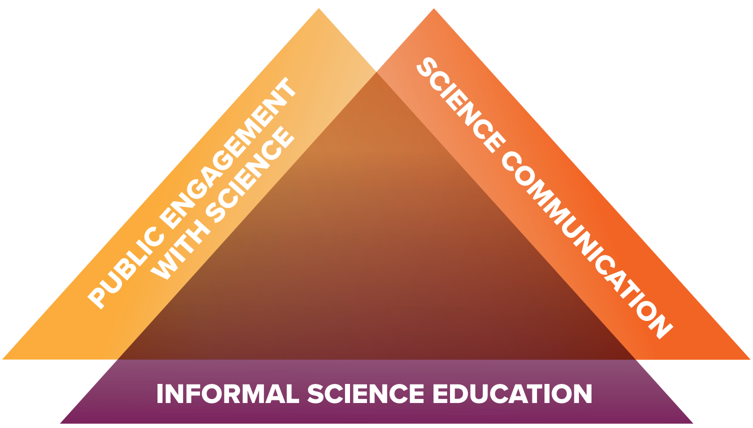
Each of the following categories of professionals may possess **EXPERTISE** in science communication, engagement, pedagogy, or, in the case of scientists, a specific subject matter. Moreover, scientists who gain experience and training in science communication and engagement techniques may assume dual roles, becoming facilitators, writers, or producers in addition to content experts. Professional practitioners can include:

- SCIENCE WRITERS/ CONTENT PRODUCERS
- FACILITATORS
- TRAINERS
- EDUCATORS
- SCIENTISTS

GOAL 1: Increase opportunities among researchers, practitioners, science centers, and communication and engagement organizations and networks to collaborate and share resources and best practices.

The science communication and engagement space includes at least three distinct but overlapping fields (see figure for description). Resources and expertise typically exist within these individual fields and are less likely to be shared more broadly. A recent workshop series convened by the Kavli, Rita Allen, David and Lucile Packard, and Gordon and Betty Moore Foundations highlighted the need to strengthen the bridge between research and practice, including in the areas of science communication training and engagement facilitation.[56]

With a finite amount of funding available to support science communication and engagement activities, it is critical that programs and activities use and build on the current understanding within this space (see Appendix B: Resources on Science Engagement). Shared resources are particularly important when there are shared communication and engagement objectives, such as an increase in informed decision-making, participation in research, or interest in science.



PUBLIC ENGAGEMENT WITH SCIENCE The American Association for the Advancement of Science defines "public engagement with science" as "intentional, meaningful interactions that provide opportunities for mutual learning between scientists and members of the public."[57]

SCIENCE COMMUNICATION A National Academies of Sciences, Engineering, and Medicine report on communicating science effectively defines science communication as "the exchange of information and viewpoints about science to achieve a goal or objective such as fostering greater understanding of science and scientific methods or gaining greater insight into diverse public views and concerns about the science related to a contentious issue."[58]

INFORMAL SCIENCE EDUCATION The Center for Advancement of Informal Science Education describes the field of informal science education as pursuing opportunities for "lifelong learning in science, technology, engineering, and math (STEM) that takes place across a multitude of designed settings and experiences outside of the formal classroom."[59]

Where Informal STEM Education (ISE) and Science Communication (SciComm) Meet

In January 2019, the Center for Advancement of Informal Science Education (CAISE) released the results of a series of studies on the overlap between informal science education and science communication. The studies were part of CAISE's efforts to build capacity for these fields. A survey on the professional connections and resources within both fields revealed that the two professional communities are siloed, but indicated that there is a "larger research-practice divide in SciComm than in ISE." ISE was found to emphasize youth, learning, and the STEM education pipeline, whereas the science communication community focused on adults, general audiences, and decision-making. The report presented three conclusions and opportunities as a result of their studies:

> 1. ISE's experience and expertise in broadening participation of underrepresented audiences can inform issues of growing interest in SciComm, such as the desire to engage with new, diverse publics. SciComm's growing knowledge about decision-making can inform ISE efforts to design for changing behavior.
> 2. In a landscape where ISE and SciComm researchers and practitioners are mostly siloed within their own domains, there [is] a small number of people whose activities span the two communities. These dual ISE/SciComm citizens could serve as ambassadors to enhance knowledge exchange between the fields.
> 3. Bridging research and practice requires more efforts to highlight the work of practitioners as relevant and salient to researchers across the fields. It is also crucial to represent research findings in formats that practitioners can use, ideally with guidance for translating research into practice.[60]

[GOAL 1] ACTION 1: Funders should support the development of centers, databases, and practical approaches that connect researchers and practitioners, such as through travel support for conferences and meetings.

Funders with interest in a particular goal or outcome of science communication and engagement can support resource-sharing around that goal. For example, the National Science Foundation (NSF) recently funded a new Center for Advancing Research Impact in Society (ARIS), building on the success of the National Alliance for Broader Impacts (NABI). To ensure that new centers or databases reach broad populations of practitioners, researchers, facilitators, and trainers, the designers of these resources should intentionally engage members from across the science communication and engagement landscape to identify interested users.

In addition to investing significant resources into infrastructure for information-sharing, increased funding for researcher-practitioner interactions, such as through travel support, will be important for creating a bridge between the two spheres. A recent example of this type of support is the National Academy of Sciences (NAS) Standing Committee on Advancing Science Communication Research to Practice Partnership Awards, which are "catalyst awards" of up to $12,000 to support new collaborative partnerships.[61]

CASE STUDY

Center for Advancing Research Impact in Society and the National Alliance for Broader Impacts

Founded in 2014, the National Alliance for Broader Impacts is an NSF-funded international network of almost eight hundred members working to "build institutional capacity, advance BI [broader impacts], and demonstrate the societal benefits of research." In addition to hosting an annual national summit, NABI has produced resources such as their "Broader Impacts Guiding Principles and Questions for National Science Foundation Proposals," a guiding document for improving consistency in BI proposal evaluation.[62] In 2018, NABI released its report *The Current State of Broader Impacts*.[63]

Building on the reach and insights from NABI, the Center for Advancing Research Impact in Society was created in 2018. Also funded by the NSF, ARIS is an emerging network of funders, researchers, and practitioners working together to move the needle on the societal impacts of research. ARIS seeks to build capacity within individuals—researchers and practitioners—as well as institutions for broadening the impact of research through partnerships, scholarship, and professional development. More specific, ARIS seeks to narrow the gap between research and practice through evidence-based resources and training.

[GOAL 1] ACTION 2: The leaders of science communication and engagement organizations and networks should collaborate on areas of shared interest.

Science communication and engagement networks are typically based around either a specific field or topic (such as public health, climate change), target audience (such as families, young adults, policy-makers), or venue or profession (science festivals, science museums, science writing). There are also networks dedicated to specific goals, such as graduate student science communication training or increasing diversity, equity, and inclusivity. Breaking down barriers among existing networks and organizations will allow for increased sharing of best practices and expertise and will encourage collaboration where networks share a common societal mission. For example, at an October 2018 convening, thirty science communication and engagement network leaders identified areas on which shared action was possible, including connecting research to practice and practice to research, as well as increasing diversity, equity, and inclusivity in science communication and engagement.

ONGOING EFFORTS

Outcomes: Support Systems for Scientists' Communication and Engagement

Between December 2017 and May 2018, the Kavli, Rita Allen, David and Lucile Packard, and Gordon and Betty Moore Foundations hosted a workshop series on "Support Systems for Scientists' Communication and Engagement: An Exploration of the People and Institutions Empowering Effective Impact." This series convened scientists, academic leaders, engagement professionals, researchers, communication trainers, and foundation leaders in order to identify how to make the field more "effective and sustainable."[64] This discussion series identified a need to connect better the work, people, and ideas across different—and often disparate—science communication and engagement networks. In January 2020, a network for Leaders in Science and Technology Engagement Networks (LISTEN) hosted their inaugural summit. Shared priorities include:

- Building new capacity and models for putting communities first in science engagement;
- Creating more diverse, equitable, and inclusive environments for science engagement;
- Connecting research and practice in science engagement;
- Contributing to shifting the incentives and disincentives for how science engagement is encouraged, recognized, and rewarded;
- Advancing measurement and evaluation of engagement practices;
- Fostering systems for connecting scientists and engagement opportunities; and
- Connecting and supporting current and emerging science engagement networks.

[GOAL 1] ACTION 3: Science engagement networks and programs should dedicate resources to support efforts to increase diversity, equity, and inclusion and share these resources with the broader community.

Principles of diversity, equity, and inclusion (DEI) should be embedded in all aspects of science communication and engagement. The federal government prioritizes DEI through its support for programs that help to broaden participation in the STEM workforce. However, DEI in science communication and engagement is also important for enabling people to engage with science. Science communication and engagement networks or programs that seek to integrate DEI into their activities should build on existing resources and seek to learn from established networks within this space, such as the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) and Ciencia Puerto Rico, or participate in emerging online communities, such as #InclusiveSciComm on Twitter.

REPORT

CAISE Broadening Participation Task Force

In February 2019, the Center for the Advancement of Informal Science Education Task Force for Broadening Participation in STEM released a toolkit to support science engagement professionals in these efforts. The toolkit included:

- The report *Broadening Perspectives on Broadening Participation in STEM*.[65]
- A summary for stakeholders, such as supervisors and board chairs, of the benefits of increasing support for DEI initiatives.
- A conversation guide to help facilitate DEI discussions with staff.
- Practice briefs with discussion ideas that include recommendations and resources.

The taskforce also stressed that "broadening participation, equity, and inclusion work needs to be positioned as core to the organization's mission and success, and not tacked on or siloed within an organization or program." Providing the necessary staffing and support required to execute effective DEI efforts was fundamental to this goal. The task force also raised the need for engagement professionals to make an effort to demonstrate how "STEM relates to and can be advanced by other cultural ways of knowing and being."[66]

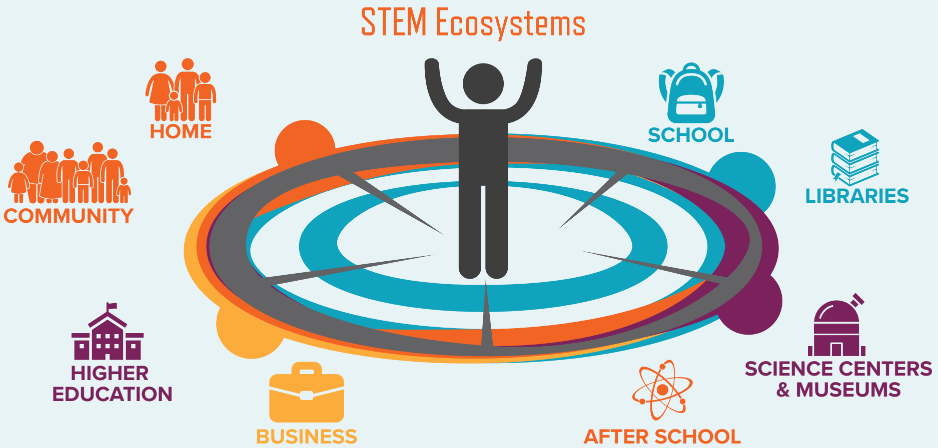
GOAL 2: **Strengthen local science engagement ecosystems, especially where access may be limited, and increase cooperative science engagement efforts.**

The National Science and Technology Council has described STEM ecosystems as being able to "bridge, integrate, and strengthen the learning opportunities offered by organizations across sectors compared with isolated, independent entities."[67] STEM ecosystems, consisting of informal science education, formal science education, universities, industry, government, libraries, festivals, community centers, and other mission-aligned organizations, have traditionally been organized around learning outcomes of science engagement for pre-K–16 students. In addition to these knowledge and skills-based outcomes, local science engagement ecosystems have the potential to address additional outcomes of science communication and engagement associated with lifelong interest, motivation, and behavior change. Moreover, local engagement ecosystems can address community-specific science needs and support programming that accounts for any history of exclusion.

ONGOING EFFORTS

The STEM Funders Network's STEM Learning Ecosystems Initiative

The STEM Learning Ecosystems Initiative is a global community of practice with eighty-four communities supporting "cross-sector collaborations to deliver rigorous, effective pre-K–16 instruction in STEM learning."[68] Although individual local ecosystems self-organize, the initiative supports resource-sharing and collaboration between ecosystems. The framework for the STEM Learning Ecosystems community of practice is built around four strategies: 1) cultivating cross-sector partnerships; 2) creating and connecting STEM-rich learning environments; 3) equipping educators; and 4) supporting youth pathways.[69]



SOURCE: Figure by STEM Ecosystems, modified with permission.

[GOAL 2] ACTION 1: Local scientific institutions, schools, science centers, and libraries should (continue to) form strategic partnerships and collaborations on local science issues and engagement outcomes. Local stakeholders (government, university, industry) should invest resources in these ecosystems.

Comprehensive frameworks such as the Science Capital Model developed in the United Kingdom, highlighted in *Encountering Science in America*, considers the multiple dimensions that can shape the perception that science is "for me."[70] These dimensions include talking about science in everyday life, science literacy, and participation in out-of-school learning. Partnerships between local institutions with shared engagement goals will allow for experiences that "enrich and reinforce" each other in order to build long-term impact.[71] These collaborations are particularly of interest for addressing scientific topics that have become controversial in the public discourse.

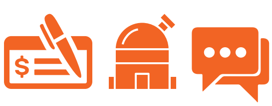
CASE STUDY

The Potential of Local Efforts to Address Controversial Scientific Topics

As discussed in *Perceptions of Science in America,* the leaders of the scientific community are among the most-trusted groups compared with bankers, congresspeople, and media representatives. However, there are areas for concern around a minority of specific science topics such as vaccines, climate change, and GMOs. These topics require evidence-based methods, dialogue, and trusted messengers. Local science engagement ecosystems have the potential to engage effectively on these topics. As highlighted in *Encountering Science in America*, meteorologists have been identified as effective climate change messengers because of their access to sizeable audiences for whom they are trusted sources of information.[72] Additionally, informal science educators at zoos, aquariums, museums, and national parks can act as authentic person-to-person messengers when discussing climate change in the context of local impact.[73] There are also national networks available to support these types of local efforts, such as the National Network for Ocean and Climate Change Interpretation, which provides informal science centers with training on evidence-based climate change communication approaches.[74]

GOAL 3: Standardize and increase the number of resources for assessing outcomes and long-term impacts of science communication and engagement.

One takeaway from *Encountering Science in America* is the need for additional social science research to understand the impacts of science communication and engagement, including on public interest in, understanding of, and support for science. An individual's underlying attitudes toward science are the product of cultural influences, fundamental belief structures, experiences with science, and prior knowledge about science. The long-term, cumulative impacts of experiences and engagement with science are challenging to assess because these experiences do not occur as isolated events and there is limited data on an individual's movement between activities. Further, differences in metrics and methodologies limit researchers' ability to compare existing evaluation data.



[GOAL 3] ACTION 1: Funders should support professional organizations in establishing shared databases and metrics.

Shared databases and metrics are necessary for comparing engagement activities and assessing long-term impact. Recent investments in shared metrics highlight the potential for this data to be used to identify national trends. Evalfest was founded in 2014 as an NSF-funded community of practice that developed resources for collecting data from science festival stakeholders. To date, Evalfest has created nine methods and worked with twenty-five partner festivals to complete forty thousand attendee surveys. As a result of these efforts, they are able to identify national trends in the audiences for science festivals.[75] The funding also supports the development of evaluation scales that are applicable to other science communication and engagement domains.

Conclusion

In the twenty-first century, science will continue to have a profound influence on people's daily lives and well-being. People's attitudes toward science and the ways in which they engage with scientific content will impact everything from their curiosity about scientific discoveries to evidence-informed decision-making to their desire to participate in science. The three publications from the Public Face of Science Initiative have highlighted a breadth of critical resources, including public opinion polling, academic literature, databases, institutions, professional organizations, programs, and experts that show we are not starting from a deficit in this space. We are at a moment in time when the enthusiasm and support for science communication and engagement can be harnessed for greater impact through widescale efforts to build capacity. The goals and priority areas in this report offer a starting point for long-term action.

APPENDIX A: Foundational Skills for Science Communication

The following abstract and table are part of a manuscript outlining the need for core science communication competencies to advance training efforts around public engagement with science.[76] The authors—Elyse L. Aurbach, Katherine E. Prater, Emily T. Cloyd, and Laura Lindenfeld—outline the disjointed and disconnected nature of practical advice surrounding science communication training efforts and demonstrate how the research and evaluative literatures can expand to better support the utility and application of these communication skills.[77] The table on the following pages is intended to serve as a coherent organizing framework to provide guidance to science communication trainers and trainees as they work to understand and incorporate foundational science communication skills into educational opportunities.

White Paper Abstract

In order to work toward greater coherence across different training approaches supporting science communication and public engagement efforts, we present a preliminary framework that outlines foundational science communication skills. This framework categorizes different skills and their component parts and includes: identifying and aligning engagement goals; adapting to communication landscape and audience; messaging; language; narrative; design; nonverbal communication; writing style; and providing space for dialogue. Through this framework and associated practical, research, and evaluative literatures, we aim to support the training community to explore more concretely opportunities that bridge research and practice and to collectively discuss core competencies in science communication and public engagement.

TABLE: Foundational Science Communication Skills, Their Category Elements, and Example Questions

Foundational Science Communication Skill Category	Category Elements	Example Questions by Element (non-exhaustive)
Goals and Objectives	Visioning success	If the communication or engagement effort was successful, what would happen? What signals or measurement would indicate that the effort was effective?
	Goal identification and audience alignment	Given the communication context, what is a reasonable ultimate goal that the engagement work is intended to achieve? What goals might other stakeholders enter with? Are these appropriate and/or aligned?
	Communication objective segmentation	Can the objective be broken down into more concrete elements which indicate whether the effort is successful? What other goals might come into play for the communication effort? How are these different from the specific objectives and tactics that might be used in the specific communication effort?
Adapting to a Communication Landscape and Audience	Audience choice	Why this audience? Why now? Why this context/space/channel?
	Logistical	How many people? How much time? What format?
	Expertise	What type of background in the content is the audience likely to have? How can you connect to and build on what they know?
	Values and core beliefs	What matters deeply to the audience? What beliefs about norms, oneself, and/or other people might be at play? Are there likely to be charged or controversial topics which challenge audience values that might get raised?
	Understanding historical contexts and inequities	What previous experiences has this audience had with scientists? Are there sensitive issues or contexts which might impact trust or other elements of relationship-building?
	Sources of information	What can be gleaned from event organizers? What must a communicator assume and/or make an educated guess? What can be determined in real time (e.g., using tools like straw polls)?
	Goals and motivations	Why did the audience show up? What are their expectations? How will the audience use the information? Do these factors align with the communicator's goals and objectives?

Foundational Science Communication Skill Category	Category Elements	Example Questions by Element (non-exhaustive)
Messaging	Message prioritization & distillation	What is (are) the core message(s) to communicate for this audience? Must this message be crafted from scratch or are there pre-developed effective messages that I should amplify?
	Grouping like ideas; supporting key messages	What are the key elements or pieces of evidence necessary to support the core idea? How can information be grouped to maximize coherence? What is extraneous information to be eliminated because it's not relevant or useful to audience?
	Goal and audience alignment	Is this message appropriate to my communication goal? Is this message appropriate for my audience? Does this message align with what my audience needs, wants, or expects from this interaction?
Language	Recognizing "science language" including jargon; using plain language	What words and vocabulary should I use to advance my goals? How can I effectively contextualize and define words that may be new to my audience?
	Literary or linguistic tools	Are there analogies, metaphors, descriptive examples, or other tools which I can use to make abstract ideas more concrete?
	Goal and audience alignment	What are the "languages" that my audience speaks? What words or concepts are important or familiar to my audience? How can I reference or incorporate those words or ideas into my discussion?
Narrative	Organizing information	Am I conveying all the information I need to tell the story? Is my information sequenced in a logical way to tell my story? Do I have all the necessary information to tell the story?
	Compelling storytelling elements	How can I make my story meaningful and compelling to them? Does my sequence build and release tension? Are there tools which I can employ (e.g., personal stories/anecdotes, analogies/metaphors/ visual imagery, etc.) to connect? Are the tone and frame in keeping with my goals?
	Goal and audience alignment	Is this narrative appropriate to my communication goal? Is this narrative appropriate for my audience? Does this narrative align with what my audience needs, wants, or expects from this interaction?

TABLE: Foundational Science Communication Skills, Their Category Elements, and Example Questions (continued)

Foundational Science Communication Skill Category	Category Elements	Example Questions by Element (non-exhaustive)
Design	Design principles	What is the color story? How can I use whitespace effectively? Flat/cartoon, hand-drawn, or dimensional design style?
	Graphical storytelling	What is the core message of this design? Where are the focal points & how does information flow in this design?
	Representing data	What kind of visual would best represent my data/ study compellingly and accurately?
	Goal and audience alignment	Are my visuals appropriate for my audience? Do they align with what my audience needs, wants, or expects from this interaction?
Nonverbal Communication	Posture	How can I position my body in space to express confidence, warmth, and openness? How and where should I move through the space?
	Gesture	How can I use my body and hands to add emphasis to my words and visuals?
	Expression	How can I use my face to convey emotion or add emphasis to my words and visuals?
	Vocal dynamics	How might I use different vocal tools, including pitch, pace, volume, and rhythm, to help make my oral communication dynamic and engaging?
	Goal and audience alignment	Are my nonverbals appropriate for my audience? Do they align with what my audience needs, wants, or expects from this interaction?
Writing Style	Grammar	Am I using appropriate and correct grammar for my audience?
	Voice and tense	Am I using active voice and/or descriptive verbs? Am I speaking in the present tense?
	Sentence structure	Am I using declarative sentences? Am I posing questions where appropriate?
	Clarity	Are my sentences compact and clear?
	Tone and formality	Does my personality come across? Is my tone and the relative level of formality appropriate for the audience and communication context?
	Goal and audience alignment	Is my writing style appropriate for my audience? Does it align with what my audience needs, wants, or expects from this interaction?

Foundational Science Communication Skill Category	Category Elements	Example Questions by Element (non-exhaustive)
Creating Space for Dialogue: Listening, Empathy, and Audience Engagement	Recognizing historical inequities that have previously excluded audiences	What audiences have been excluded in the past? How can I acknowledge privilege? How can I integrate equity and inclusion into my communication effort?
	Listening	How can I create space to evoke engagement with my audience? What questions can I ask or discussions can I prompt to promote engagement? How can I convey that I am listening and open to understanding their thoughts (e.g., with active listening or mirroring)? What might I learn from my audience?
	Demonstrating openness and warmth	How can I sincerely embody and communicate the willingness to connect on a human level? How does or might my body language, voice, or writing convey warmth and openness? How might I stay open-hearted/wholehearted to listen and respond to my audience without defensiveness if a discussion becomes tense?
	Cultural relevance and humility	Are my frames and examples appropriately situated in my audience's social, cultural, and environmental contexts? If I do not belong to the same social or cultural groups, how might I express humility and a desire to connect and learn from my audience?
	Promoting dialogue	What questions might I ask of my audience? What can I learn from my audience? How might I incorporate what I learn from the audience into this interaction and future interactions?
	Recognizing audience attention as it ebbs and flows	What nonverbal or verbal signals can I pick up on to determine how my audience is responding to me? How can I change my approach to maintain energy and flow?

APPENDIX B: Resources on Science Engagement

Theory of Change for Public Engagement with Science (2016)

A summary and overview of the American Association for the Advancement of Science vision for engagement that supports long-term, aggregate impact. This theory includes a "logic model for public engagement with science."[78]

CAISE's Year in ISE Review (most recently, 2018)

An annual report of notable publications, events, and trends in the informal STEM education community. It includes resources related to making and tinkering, citizen science, media, cyber learning and gaming, public science events, and more.[79]

Learning Science in Informal Environments: People, Places, and Pursuits (2009)

A consensus report from the National Academies of Sciences, Engineering, and Medicine that presents a comprehensive analysis of learning environments and types of learners.[80]

Many Experts, Many Audiences: Public Engagement with Science and Informal Science Education (2009)

A CAISE inquiry report examining how public engagement with science contributes to science education.[81]

Public Engagement Research and Major Approaches (2015)

An annotated bibliography of science engagement literature, commissioned by the American Association for the Advancement of Science Alan I. Leshner Leadership Institute for Public Engagement with Science.[82]

Public Engagement with Science: A Guide to Creating Conversations among Publics and Scientists for Mutual Learning and Societal Decision-Making (2017)

"A guide to creating conversations among publics and scientists for mutual learning and societal decision-making" from the Museum of Science in Boston. The guide includes key questions for planning, designing, and evaluating engagement activities, with examples and descriptions of concepts throughout.[83]

Typology for Public Engagement with Science: A Conceptual Framework for Public Engagement Involving Scientists (2016)

A conceptual framework for public engagement with science from the Center for Research on Lifelong STEM Learning at Oregon State University. The typology provides an overview of the key elements of science engagement and example opportunities targeted toward scientists and practitioners.[84]

APPENDIX C: Public Face of Science Steering Committee and Staff

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The Public Face of Science

The Public Face of Science Initiative of the American Academy of Arts and Sciences is a three-year project that began in Spring 2016 and involves a broad range of experts in communication, law, the humanities, the arts, journalism, public affairs, and the physical, social, and life sciences. The initiative comprises a series of activities that address various aspects of the complex and evolving relationship between scientists and society and examine how trust in science is shaped by individual experiences, beliefs, and engagement with science.

Publications of The Public Face of Science Initiative

Perceptions of Science in America, American Academy of Arts and Sciences, 2018

"Science & the Legal System," *Dædalus* 147 (4) (Fall 2018)

Science During Crisis: Best Practices, Research Needs, and Policy Priorities, by Rita Colwell and Gary E. Machlis, American Academy of Arts and Sciences, 2019

Encountering Science in America, American Academy of Arts and Sciences, 2019

The Public Face of Science Around the World, by Matthew C. Nisbet and Erik C. Nisbet, American Academy of Arts and Sciences, 2019

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