

REPORT

Landscape of Science Communication Fellowship Programs in North America

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EXECUTIVE SUMMARY

Science communication fellowship programs play an essential role in providing in-depth and authentic communication training experiences for scientists. While calls for scientists to increase engagement with the public are abundant, gaps may remain between a scientist's interest in communication and their skills to effectively do so. In this context, science communication fellowships give scientists supported, real-life experiences communicating scientific research to bridge these gaps. These programs also provide the societal benefit of embedding scientific experts in key science-society intersections, such as government, media, festivals, and museums. However, minimal research has investigated these programs.

To better understand the unique offerings and barriers faced by science communication fellowship programs in North America, the Rita Allen Foundation commissioned this landscape research to increase understanding of science communication fellowship programs. The aim is to unearth insights from key personnel associated with these programs that will help clarify current program structures and practices; enable useful comparisons across programs; and identify opportunities for research, growth, and maximized impact. This project extends the research team's recent body of research on how scientists, communication trainers, professional scientific societies, and science philanthropies approach communication.

The landscape analysis is based on phone interviews with 25 key professionals working at 23 North American-based science communication fellowship programs, over a three-month period (June-August 2019). Semi-structured interviews were designed to produce qualitative insights and the foundation for further research, while providing science communication fellowship programs with actionable steps they can take to advance their own programs.

KEY FINDINGS

- ▶ Science communication fellowships provide intensive on-the-job training and opportunities to scientists interested in either pivoting careers or in meaningfully weaving communication into their existing research careers.
- ▶ Program curricula emphasize experiences that can both build a scientist's science communication portfolio and self-efficacy in communicating science in particular contexts (e.g. media, politics, museums, festivals).
- ▶ These fellowship experiences are coupled with ongoing support from mentors and peers as well as growing alumni networks that provide access to feedback and to outreach or career opportunities.
- ▶ Fellowship staff consistently identify financial and staffing limitations as barriers to reaching their ideal vision of their programs.
- ▶ There is a need to increase shared learning among fellowship programs. Interviewees were generally unaware of the proliferation of science communication fellowships but expressed interest in opportunities to learn and collaborate and to share best practices with their colleagues from other institutions.
- ▶ There is a desire to improve evaluation efforts. Many respondents lamented the lack of evaluation and expressed interest in collecting meaningful assessment data on their programs.
- ▶ Careful thought is needed to improve accessibility and inclusivity of programs. Every interviewee said they see value in increasing diversity within their staffing and within fellowship cohorts but most efforts at improving diversity are primarily through recruitment and outreach.

INTRODUCTION

Science communication training organizations and programs have grown in both scope and number. Of these training efforts, science communication fellowships provide some of the most intensive communication training experiences to scientists. With the erosion of traditional media and the concurrent call for scientists to interface more directly with the public, this type of experiential training may become more and more important to the science communication landscape. However, to date, little research has been done on understanding the science communication fellowship landscape.

Therefore, we conducted a landscaping study to better understand the unique offerings and needs of science communication fellowship programs with support from the Rita Allen Foundation. The goals of this project are to identify current best practices, and understand current barriers, challenges and appropriate next steps to increase the impact of science communication fellowship programs. This research extends the research team's recent National Science Foundation- and philanthropy-funded work that examined how scientists, communication trainers, professional scientific societies, and science philanthropies approach communication.

We conducted semi-structured interviews with 25 science communication fellowship program directors representing 23 distinct programs over a three-month period (June-August 2019). The appendix includes further details about the respondents (e.g. background, demographics). Interviews were designed to obtain qualitative insights and lay the groundwork for future research on science communication fellowship programs. These questions focused on:

- 1.** The core goals and learning objectives of each science communication fellowship, and how program leaders perceive their programs as unique;
- 2.** What types of ongoing support are provided to fellows both throughout and after the program;
- 3.** The extent of and interest in interacting with other fellowship programs to increase shared learning;
- 4.** The current state of and perceived barriers to inclusivity, equity, and diversity among fellow membership and staff membership; and
- 5.** Information about fellowship program staff, including details about their training and degrees, job responsibilities for staff positions, desired experiences/skills for communication staff positions, etc.

KEY INSIGHTS

Topical Differences, Pedagogical Similarities

Science communication fellowship programs come in all shapes and sizes. Based on the database we created as part of this project, fellowship programs can be broadly grouped into three main areas: programs that focus on policy, media, and museum/science festivals. Their target audiences differ accordingly. They also differ in their disciplinary focus—some fellowship programs focus on one scientific field (e.g. nutrition policy, entomology and agricultural policy), while others work with scientists from across multiple fields (usually in the natural sciences). Fellowships that are more narrowly focused on a specific field tend to have strong goals associated with that field, such as seeking its prioritization in policy making and government funding decisions. Some programs actively seek fellows regardless of their scientific career stage, but the majority seek newly minted Ph.Ds. Fellowships also differ in geographic scale (e.g., statewide, regional, national) and the duration of the program (e.g. three months to two years).

Despite these differences, fellowships have similar core pedagogical priorities. For example, most programs focus on developing fellows' tangible communication skills and providing a foundational understanding of the program ecosystem (e.g. media landscape, policy process, etc.). They also commonly prioritize mentor-mentee relationships and foster connections across current and past fellows. Programs also commonly place a high value on being reflexive and adapting based on fellows' interests and feedback. Of note, many interviewees highlighted the aforementioned priorities as indication of program uniqueness, when, according to our interviews, these priorities appear to be widely embraced across the fellowship landscape.

Goals of Science Communication Fellowships

Based on our interviews, the primary goals of science communication fellowships are to embed more science in society and expose scientists to authentic experiences in the science communication landscape in order to help science more positively impact society, regardless of whether a fellowship is focused on policy, media, museums/festivals, etc.

- ▶ *We really feel like the voice of science is essential to a functioning democracy. Therefore, having scientists who are willing and able to communicate the importance of what they do and why they do it to a variety of audiences is key to meeting that mission. (Interview 19)*

For policy- and media-based fellowships, the goal of embedding science in society seems to focus primarily on informing individuals about science knowledge or defending science. Museum- and festival-based fellowships articulate this same broad goal (embedding science in society), but often in a more audience-centered way that also seeks to humanize scientists through various dialogic goals.



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- ▶ *If you don't want to have anything to do with science in your career or your schooling, fine, but next time you're swiping through news articles and there's a science one, say, "You know what? I can look at this. I should care." That's great, too. We just want a community that cares about science and feels that it's in their life wherever they are and whoever they are. (Interview 6)*
- ▶ *What we know is that a lot of times when people talk to scientists, especially teens and adults, they feel more defeated than when they started. Our long-term goal with this fellowship program is to really start a trend in the next generation of scientists that can talk to people and communicate effectively. It's a lofty goal. (Interview 4)*

Another significant goal of these fellowships is to increase confidence in communication. The scientists that apply for these fellowship programs tend to already be passionate about science communication, and the primary goal of many of these programs is to help them feel more confident and comfortable in their communication with non-science audiences (i.e., increase self-efficacy). A hoped-for result of this confidence is that scientists will feel more willing to speak with different publics and will continue to engage in public outreach.

- ▶ *A lot of these people have what it takes already. A lot of it is confidence growth. I really try to build their confidence. I hope by the end they're confident enough that when they do the couple of programs with us that are required, that they are able to have fun and not be dreading it or scared. If they have fun at that point and they get that high of public presentation, they'll want to do it again. (Interview 22)*

A secondary goal of many of these fellowships programs is to help change academic scientists' perspectives on science communication. One way they seek to accomplish this is by empowering young academic scientists to take their next career steps in science communications. Fellows are typically recently graduated Ph.D.s (although there is some program variation), and fellowships aim to help these scientists understand the landscape and opportunities related to science communication. Fellows somewhat commonly switch from academic career paths to science communication career paths (e.g., policy, media, etc.). Two of the fellowship directors reported that about half of their fellows went on to non-academic science communication careers afterwards. This suggests that these fellowships may serve as a key pivot for career changes. Some of these fellowship programs are prestigious and frequently provide professional opportunities for the fellows. Conversely, interviewees discussed how fellows that choose to stay in academia gain deeper understanding of why they want to remain on that professional path. Either way, our interviews suggest that the authentic field experiences commonly facilitated by these fellowships can empower scientists to make more confident career decisions.

Fellowship directors also frequently suggest that fellows gain a better understanding of the needs and expectations of the science communicators with whom they may work (e.g., public information officers, journalists, policymakers, museum staff, etc.). More broadly, these programs seek to normalize science outreach as a part of a scientist's career, expanding their ideas about what it means to be a scientist. Interviewees often noted that fellows who stay in academia seem more likely to become community-responsive, as they realize the importance of and find more opportunities to weave communication into their professional lives.

An important potential impact of these fellowship programs is the connectivity they can foster. Interviewees frequently said their programs create networks of people interested in science outreach, both among the

fellows they train as well as the agencies with whom they partner. Our interviews suggest that fellows often return to their home institutions motivated to share their newly-acquired skills and perspectives with their own local scientific networks.

Overall, when it comes to core program goals, fellowship directors seem primarily focused on helping individual fellows and boosting their ability to effectively engage with society. It was sometimes difficult for our interviewees to answer questions about the impacts their programs seek to have on their fellows' home institutions. This suggests programs more commonly focus on macro- (i.e., society) and micro-level (i.e., individual scientists) goals, then they do on meso-level outcomes (i.e., helping fellows to change their home organizations). However, interviewees often recounted that alumni fellows help their programs improve thanks to their continued enthusiasm, sharing new ideas, and contributing models or examples of projects that stem from their own science communication efforts.

- ▶ *[Alumni] often help us innovate. We have limited resources. We innovate to solve problems when we're trying to figure out how to make something look cool on some sort of website or whatever. They help us innovate and try new things. (Interview 14)*
- ▶ *[Alumni] leave behind a trail of content, of blog posts that we often then repurpose and use across multiple platforms. (Interview 14)*

Small Staff Sizes, Variety of Backgrounds

Most fellowship program staffs are small, usually comprised of one or two people and they are entrusted with running the program. Staff possess a wide array of background experiences. Some fellowship directors have science training (and many indicated this training is something they would look for in a new hire). Other interviewees have media training (also mentioned as an important quality when bringing on a new person). And other key program staff report coming from a variety of other professional backgrounds, including literature, sales, and policy. When hiring, staff commonly report they would value candidates who are detail-oriented, highly organized, and prepared to juggle the multiple roles that frequently characterize fellowship program management. They also often expressed prioritizing new hires who are empathetic and able to allay scientists' communication anxieties. Conversations with fellowship directors also suggest that staff experience influence the type of training that is offered, especially for programs not able to hire extra staff for trainings. For example, programs that have staff with some theater training often feature improv or storytelling in their curricula.

Small staff, as well as constraints related to time and funding, can sometimes limit what fellowships are able to accomplish. Staff members wear many hats and report wanting more time to read science communication scholarship, expand their program curricula, and develop more rigorous approaches to evaluation. However, smaller staff sizes may also mean some programs are more agile and positioned to respond quickly to feedback they receive from fellows and partnering agencies. This flexibility seems to be a strong component of many programs and so it may be worth considering how to preserve it in the face of efforts to scale.

Lack of Interaction

Our interviews suggest that the majority of science communication fellowship programs do not interact with one another. The overwhelming perception expressed by interviewees is that there are not many other fellowship programs, though that is not the case. Lack of time and staffing may contribute to this skewed perception. Fellowships embedded within larger organizations that host multiple fellowship programs often have some interactions with one another because their goals and trainings commonly overlap. Two fellowship directors also report attending the biannual Fellowship Roundtable hosted by the National Academies of Sciences, Engineering, and Medicine to share best practices.

- ▶ *Honestly, knowing other programs that exist in my space would be very helpful. I don't know of other associations that are doing what we're doing. We started by talking about ongoing collaborations. If you hear about stuff, I'd love to hear about it. (Interview 20)*
- ▶ *My sense is that it is -- I'm guessing that you know the answer to this. This may not be true. My sense is that it is not super common. I'm sure that if you tell me the number of outreach fellowship programs that exist, I will be shocked. I didn't really think there were that many. (Interview 4)*

Despite the current lack of interaction, the majority of fellowship directors would welcome more opportunities to engage with their contemporaries. They report especially wanting interactions through which they can share and develop best practices. Although fellowship directors were often reluctant to share funding contacts or resources, they expressed little sense of competition and more of a sense of collaboration with other programs in terms of sharing lessons learned and working toward common goals.

- ▶ *Yes, we could all be very segregated and, "No, this is ours. You can't have it." If we can all come together and share resources and share the things that we've learned, the more we can encourage the science community to prioritize that, the better. Right now, some universities support it. Some don't. It's not like there's ten scientists in the world and we're fighting over them. There's a constant supply of new people coming into STEM. It's more about getting people to realize the importance of it than it is about, we need to be the number one. I don't feel like I'm communicating that very well. What I'm saying is that I do think that it could be really useful to learn about other people's programs as long as there's that openness and established that it's not like I'm going to steal your idea and we're going to become competitors, but that it's like we'll all share everything because we want everyone to succeed. (Interview 6)*
- ▶ *I am always looking to interact more with people. Reinventing the wheel seems always silly to me. We have so much to learn from other people and their experiences. Particularly because we are just starting out, we have much to learn and much to refine. I always feel like I can learn from getting together with other people who do this work. (Interview 18)*

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- ▶ *The other thing I've always wanted to do [...] is have a conference of science communications programs. We can all come together for three days or something and learn from each other. (Interview 19)*

A few fellowship directors mentioned wanting to bolster or form new collaborations with science communication researchers to ground their curricula in theory. These few interviewees discussed frustrations with the inaccessibility of peer-reviewed communication scholarship and expressed a desire for more tailored, streamlined delivery of actionable insights from scholarship. One respondent mentioned that a barrier to collaborating with academics centers on their different goals and metrics for success.

Lack of Diversity

Although many fellowship directors view diversity in both fellows and audiences as a core value of their organization as well as partner organizations, there seem to be gaps in how this concern manifests in reality. Diversity among fellowship program workforce is minimal, perhaps partially due to staff size being low in the first place. Many fellowship programs seem to have grown organically and the recruitment of new staff members is often ad hoc and through established networks. Many respondents also lamented their program's lack of diversity in the makeup of their fellows. Interviewees often connected the lack of diversity in STEM fields as a whole to the lack of diversity—especially ethnic diversity—seen in their applicant pools.

- ▶ *It is generally a struggle for us. In the earth and space scientific [indiscernible] are certainly not as diverse as they should be. The applicant pool generally reflects that. (Interview 21)*

However, fellowship participants did skew female, which may reflect higher relative interest from this gender in science communication careers. While many directors mentioned issues of socioeconomic, gender, or ethnic diversity, none of the respondents mentioned other forms of diversity (e.g. physical or neurological differences).

Diversification efforts on the part of the fellowship programs primarily involve outreach, recruitment, and the selection of fellows. This often includes targeting recruitment at universities that historically contain underrepresented groups or revising advertising and communications materials to widen applicant pools. A few fellowship directors also mentioned that it can be a struggle to balance efforts between building and maintaining current relationships and recruiting outside of these established networks.

- ▶ *The whole recruitment and selection process can be tricky. The big thing that we're struggling with right now is that we have a lot of good connections in the local community and a lot of people who have had really great experiences with us, and we want people who are not all just like them. We're not sure how to get out of that loop. (Interview 13)*

Most of the fellowships' curricula did not explicitly address diversity, equity, and inclusivity. For the few that did, it was mentioned in relation to how they interact with their audiences, not in other areas (e.g. creating inclusive spaces in the fellowship itself). These curricula emphasized the need for fellows to learn to take on new perspectives as they go through their training so that scientists can communicate with audiences that differ from them; however, few directors mentioned measures they take to ensure fellows themselves feel that they belong.

Goals for Science Communication

Fellows often set their own goals regarding their career path, skill acquisition, and project selection. Several fellowship directors emphasized allowing fellows to choose goals they are motivated by, not restricting themselves to what they think their audience will most prioritize. A few programs have fellows set these goals in a document that they can refer to later in their one-on-one meetings. Most of the conversations with fellows about their goals seem to occur during these meetings. Goals are updated throughout the fellowship program and serve as a touchstone for fellows.

Many fellowship directors recognize that fellows are setting goals in unfamiliar areas, so long-term goal-setting may not be a feasible or even productive. Instead they find that conversations about interests are often more helpful.

- ▶ *It starts off, getting the fellowship, there are some essays that we have people do. Why are you interested? Why are you wanting to move out of the lab? Why is it science policy that you want to focus your efforts and energies on? What sort of previous experience in science policy have you had? It used to be that my scientist advisors would want to have someone sit down and say, "What's your five- or ten-year goal? Where do you want to be in one year, five years, ten years?" I find that to be not particularly helpful or a fruitful discussion for someone who is beginning a complete total career change. (Interview 12)*

Upfront Fellowship Training

Upfront training for science communication fellowship programs ranges vastly in terms of time, from nothing, to a few hours, to a few months. Traditional workshop training is not a substantial component of the curriculum because fellowships are more focused on giving scientists on-the-job experiences. But some fellowships include upfront training to introduce fellows to the field and to give them some skills they will use in their projects.

Many of the fellowships use this kickoff training to help scientists gain an understanding of the landscape of their particular science communication context (e.g., policy, media, museum, or festival). Many respondents report this training aims to give scientists their first taste of what life is like outside of academia and introduces them to the norms and expectations of these careers. Many interviewees also mentioned that this initial training period serves as time for creating cohort cohesion, as these relationships between fellows form an important component of these fellowships.

Some fellowship staff said this kickoff training period also serves as a time to engage in low-stakes practice before placing scientists in real-world science communication experiences. For example, scientists might practice journalistic interviews or build prototypes of interactive museum activities before they reach the "real public." The goal here is to build self-efficacy through initial experiences and to begin to allay scientists' lingering communication apprehensions. They receive coaching and feedback throughout the process and can take this iterative rehearsal with them into the next steps of the fellowship experience.

- ▶ *Then the thing that's generally described as most useful is right out of the gate where they're, on day two, sitting down across the table from a Pulitzer Prize-winning reporter having to do an interview and walk out of that immediately feeling like, "I think I might be able to get there with that. I might be able to do this." They look at their body, and there's nothing bleeding. [laughter] (Interview 19)*

One respondent mentioned that even when fellows transition to real-world communication experiences, they can also rely on the support of the fellowship staff, suggesting that one of the strengths of these fellowship programs lies in the scaffolding of initial science communication experiences.

- ▶ *They have to work one day on the weekend for about a four-hour shift. They are out on the floor with our general public. That's the first time that I unleash them to the wolves. I'm there the whole time checking on them, answering, "Someone came up and asked this. I didn't know how to answer it," and giving them that real-life experience but in a safe place, more controlled environment. (Interview 22)*

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The biggest thing, you're not a scientist unless you do some science. ... You're not really a science communicator unless you do it. The biggest thing is really doing it. (Interview 9)

Practical, Tangible Training Curricula

Fellowship staff reported that, for the most part, fellows learn by doing. The programs, therefore, emphasize project-based learning and authentic engagement experiences (rather than lecturing or theorizing). Many of the programs offer very little formal training other than occasional upfront training for fellows. These experiences appear to emphasize practice, repetition, and hands-on experimentation for scientists to both master skills and to gain confidence in communicating.

- ▶ *The biggest thing, you're not a scientist unless you do some science. You can take biology classes, but unless you go in the lab and they put a [indiscernible] in your hand or whatever type of science it is, you're not a scientist unless you do it. You're not really a science communicator unless you do it. The biggest thing is really doing it. (Interview 9)*

For example, fellows in some programs serve year-long assignments in the branches of the federal government. Another program has fellows plan events for a science festival. Science communication fellowships associated with museums have scientists develop a hands-on interactive science activity that can be used in multiple settings. Another program has scientists serve on the staff of media organizations. Still other programs are more like communication internships where fellows integrate into host organizations and are involved in blogging, social media management, event planning, writing policy statements, and more.

When concrete skills are taught to fellows in workshops, most interviewees report that they identify the end product the fellow will produce and work backwards from there to identify skills for fellows to practice (rather than teaching a list of techniques).

Fellowship staff reported that, for the most part, fellows learn by doing.

Additionally, respondents reported that they incorporate professional development topics into training because the focus of many of these fellowships is to introduce scientists to the world outside of academia. Training is usually both context-specific (e.g. learning to pitch a story for a media fellowship) and customized to the individual fellow.

- ▶ *There's no formula here. In the communications world, you can read about it. "Here's what you do. Here's this very important [indiscernible/laughter]." Why don't we just get scientists to do improv? That is great, but it's not a formula. People aren't robots. Each of our people are very individual, of course. We feel that they will be most successful as communicators when they are deeply comfortable and very much in touch with why they are doing what they do, why it's important to them. That's different for each one of them." (Interview 19)*

Support During and After Fellowship

Most staff at science communication fellowships indicated that fellows receive support primarily in the form of one-on-one meetings with staff or a mentor in the field. During these meetings, fellows get and give feedback on how it is going and evaluate their personal goals. They can also bring up specific challenges. This feedback is often addressed on-the-fly by fellowship staff. Fellows also receive professional development and career choice advice. This is also an opportunity that many fellowship staff say they use to reassure scientists about feelings of imposter syndrome they may be grappling with in their new positions. Interviewees reported that fellows often rate this ongoing support as one of the most useful parts of the fellowship.

Another source of support for fellows is their involvement in a network of fellows and alumni. Many fellowship staff connect fellows with mentors in their area of science communication who can talk about their career journeys. Interviewees describe access to these networks via kickoff trainings, peer mentoring groups, listservs and Slack channels, and informal social events (e.g., happy hours, mixers, etc.).

In addition to support throughout the fellowship, most staff shared that fellows continue to receive support after the end of the program through multiple channels. This support may take the form of continued mentor-fellow meetings, of newsletters or listservs, or of alumni support networks. These sources of support aim to connect fellows with outreach or workshop opportunities, to provide references, or to give feedback. A few of the fellowship staff mentioned that they do not sunset their fellowships; in these instances, fellows are kept on staff until they find a job so that fellowship staff can assist them with connections and applications. Many of the museum-based fellowships also welcomed fellows to continue participating in their programming even after their fellowship tenure was complete.

Lack of Evaluation

Many fellowship staff report not being able to conduct effective evaluation. Often staff link this challenge to financial and staff constraints. Most program staff indicated that they primarily rely on exit surveys or exit interviews of fellows to evaluate their programs. Some of these programs indicated they have added in a mid-program or pre-program survey or interview to their evaluation protocol. Interviewees explained that most of the questions in these evaluations center on how the fellowship experience was for the scientist and on whether or not the scientist feels more confidence

in communicating after the program. These surveys or interviews are often conducted by fellowship staff, who do not usually have expertise in evaluation.

A subset of fellowship staff described what they view as being innovative (or unique) evaluation tactics. One program, for example, performs an emotional intelligence assessment of its fellows and incorporates this into related training exercises throughout the program. Another fellowship collects cross-sectional data on their alumni's eventual career placement. They find, thus far, that about half of their fellows stay in academia and half go into a science communication career. Another fellowship collects data on perspective changes in their fellows; they are interested in whether their fellows view their community differently, and whether or they feel more deeply connected to their community.

Most fellowship staff remarked that if they had more capacity (e.g. time, staffing), they would want to collect more quantitative and longitudinal data on their programs. Some want data on the fellowship's impact on scientists' career trajectories, others want data on scientists' awareness of science communication career opportunities. A few staff members want to know about fellowship attrition and why some fellows leave the program. One fellowship director wants evaluation to examine whether or not scientists' mental models of communication shift from deficit model to dialogue models, and from advocacy models to inquiry models. Only a few fellowship staff described wanting data that captures the perspectives of the organizations with whom their fellows partner or the audiences with whom their fellows engage.

Most fellowship staff remarked that if they had more capacity (e.g. time, staffing), they would want to collect more quantitative and longitudinal data on their programs.

Fellowship staff situated in programs that have existed longer and/or grown quickly reported that they are beginning to bring in external evaluators to assess their programs. One program is using external evaluators to gather data on alumni career placement and advancement. Another fellowship is currently conducting social network analyses to help maximize alumni's ability to support one another.

Fellowship staff report a need for more and better evaluation measures and, while some are making strides to do so, most of the reports of fellowship impact (e.g. career placement, internal hiring, shifts in self-efficacy) remain anecdotal or, at best, through post-program cross-sectional surveying or interviewing.

RECOMMENDATIONS

- ▶ **Build a connective infrastructure for fellowship programs.** Growing the connective tissue between fellowship programs will likely help promote two other key areas for improvement: (1) developing more rigorous evaluation and (2) improving program and staff diversity. Fellowships are facilitators of engagement and communication—they connect scientists to audiences with whom they would like to communicate (e.g., policymakers, media outlets, museum-goers, festival-goers). While fellowships seem to have highly connected internal infrastructures focused on mentorship and networking for their fellows, interaction between fellowship programs is almost nonexistent.
 - All scientists should have access to a broader fellowship infrastructure. This infrastructure should be constructed by a diverse set of people so that it invites change and is accessible to all.
 - There is an opportunity and an appetite among fellowship directors to build this infrastructure intentionally and inclusively.
 - Many fellowships seem to have formed through local availability (e.g. housed in a museum, connections with policy offices), not out of strategic planning. A larger infrastructure would help fellowships become more intentional and community-oriented.

- ▶ **Define desirable learning goals and outcomes before training takes place and use a mixed evaluation approach.** To be able to effectively evaluate science communication fellowships, these programs first need to embrace a more diverse set of explicit, strategic goals for science communication. There is no “one-size-fits-all” approach to evaluating science communication fellowship programs, nor would that be ideal.
 - Fellowships should formulate their core learning goals and incorporate evaluation protocols from the outset.
 - Fellowships should expand beyond training that seeks to increase communication micro-competencies or filling knowledge deficits.
 - Fellowships should integrate training that helps fellows achieve audience-centered communication goals that promote more meaningful science-public engagement (e.g. fostering authentic interactions, building interest/excitement around science, motivating audiences to act, establishing trust in science).
 - Some fellowship programs are touching on these audience-centered goals, but it would be helpful to examine which audiences are currently being overlooked. For example, fellowships could be a key conduit through which to receive feedback from local communities on scientific topics that affect them.

- ▶ **Pursue more rigorous program evaluation using more methods and data.** The risk of weak evaluation is that policies and practices are based on intuition, personal context, or implicit biases. While most interviewees acknowledged the importance of evaluation, few had the capacity—time, money, staffing—to make it a focus. Most programs rely on self-reports from scientists that occurred shortly after they completed the program (some also had pre- and mid- self-reports).

While fellowships seem to have highly connected internal infrastructures focused on mentorship and networking for their fellows, interaction between fellowship programs is almost nonexistent.

- Current best practices imply that fellowship programs expand their evaluation practices by using a broader mix of data sources (e.g. fellow perceptions and performance, facilitator perceptions, external perceptions) and methods (e.g. surveys, in-depth interviews, cohort analysis).
- Fellowship programs should consider using/adapting established evaluation procedures (e.g., Kirkpatrick's Four-Levels of Training Evaluation Model) and forming partnerships with social scientists (explored more below).
- It may also be helpful for fellowships to hire external program evaluators, when financially possible.

▶ **Build meaningful interactions between fellowship programs, especially those with shared goals.**

While there are strong networks within fellowships, between-fellowship networks are weak or absent. The science communication fellowship ecosystem is fragmented and disparate efforts are largely uncoordinated. Multiple inputs (e.g. scientific societies, funding agencies, universities, government agencies) often contribute to a single scientist's communication training and efforts. Does each input add value, or are there redundant or conflicting efforts? Fellowship staff believe more fluid connections between programs could create greater value for the fellowship ecosystem through joint identification and sharing of best practices.

- A central organizing mechanism for all of these institutions would likely improve coordination of disparate efforts.
- Building infrastructure will increase shared learning of best practices and help reduce redundant or ineffective programming.
- Fellowship staff expressed interest in a conference or other coordinating mechanism where they can share best practices that they can customize to fit their programs.

▶ **Build mutually-beneficial partnerships with social scientists.** Fellowship staff reported being unable to utilize relevant insights from social science due to their limited bandwidth and perceptions that the research is inaccessible.

- Fellowship staff often express hope that scholars will disseminate and streamline social science research in more user-friendly formats, but these hopes are unlikely to be met in the absence of structural and culture changes. An established infrastructure for fellowship programs could, as one of its key functions, help connect fellowship staff to germane social science and expertise.
- Fellowship-social scientist partnerships should be leveraged to improve evaluation of fellowship program impacts.
- Fellowship-social scientist partnerships should seek to understand how best to maximize potential partnerships between fellowship programs and other training programs with different business models (i.e., those that focus on serving more scientists via shorter coursework).

▶ **Rethink and expand recruitment networks to improve the accessibility of fellowship programs.**

While the current study is limited to the perspectives of fellowship staff, we are able to begin to understand the current state of, and possible barriers to, diversity and inclusion in fellowship spaces. Staff report that they have lower diversity in both their staff and fellow makeup than they would like. Although this situation was commonly attributed to the lack of diversity in STEM fields, it is worth examining possible cultural, structural, and systemic factors that may be constraining diversification in the fellowship community. For example, many fellowship staff rely on their staff and alumni networks for recruitment. While the fellowship alumni and staff networks that these programs create are valuable, they are also in danger of becoming closed networks that exclude new voices from joining the conversation.

- Infrastructure between fellowship organizations and a central organizing mechanism may help these networks spread more equitably and intentionally throughout the scientific community. Building recruitment networks with HBCUs and partnering with already-established networks of underrepresented groups could be a first step.
- Assessing which audiences these programs are currently reaching (and overlooking) may also improve these networks. If programs are only speaking to privileged and powerful groups (e.g. policy, media), how can they make their efforts also reach groups that often feel ignored by science communication efforts?

▶ **Diversify types of fellowship opportunities offered to increase accessibility.** Most programs prioritize onboarding scientists with previous experience in science communication because this demonstrates passion and interest, thereby focusing on giving scientists additional communication opportunities. This emphasis likely privileges scientists with access to and time for outreach opportunities. Some of the shorter-term program staff mentioned that they specifically seek to be stepping stones for the longer-term (and often more prestigious) fellowships. Could expanded infrastructure in this space help these “stepping stone” programs increase inclusivity in the fellowship ecosystem?

- There may be a need to diversify fellowship models to improve accessibility to more scientists. Programs often require fellows to move somewhere for an extended amount of time, pause their research projects, and take lower pay, often in cities with high costs of living, like Washington D.C.
- Interviewees suggested using scientist-in-residence programs where fellows can stay working in their home labs while partnering with local science communication outlets, as well as shorter-term programs that do not require fellows to pause their research for a full year.
- A potentially important tradeoff here is that the prestige of fellowship programs is often associated with its length (e.g., longer equals more prestigious) and location (e.g., a larger city equals more prestigious). When creating new fellowship models, it will be important to consider how to avoid having them be labeled as “less prestigious”.

▶ **Plan for long-term fellowship sustainability.** Many programs struggled with obtaining and adjusting to new funding after their initial sources expired. Fellowship staff commonly noted how establishing successful new programs hinges on the presence of clear, long-term financial planning. Fellowships are high-quality but rare opportunities for scientists to gain access to communication training and opportunities. While some interviewees mentioned there were ample opportunities (e.g., twice the amount of positions than they could fill), staffing and financial constraints limit the total amount of fellows that each program can serve each year.

- Evaluation demonstrating fellowship impact on the fellow, the agency they are placed in, and the audiences they interact with can help convey the program’s value to current and potential funders.
- Fellowship programs may benefit from being more intentional about scaling and growth. Larger staff sizes and bigger budgets may mean more capacity, but smaller staff sizes may be more agile and responsive.

Most fellowship staff remarked that if they had more capacity (e.g. time, staffing), they would want to collect more quantitative and longitudinal data on their programs.

APPENDIX

Interviewee background information

Prior to the interviews, we obtained informed consent and background information through an online questionnaire. Twenty-three science communication fellowship interviews were conducted with twenty-five individuals. All twenty-five respondents provided demographic information.

- ▶ A majority of the respondents identified as female ($n=21/25$). The age range was between about thirty and about seventy. The age median and mean were around forty years of age. Almost all identified as White, Non-Hispanic or Latinx ($n=22/25$). One identified as Black or African American and one identified as White and Native American or Alaskan Native. Two identified as Hispanic, Latino, or Spanish in origin (both Mexican-American or Chicano).
- ▶ Almost half ($n=10/25$) said they spent some of their time on the fellowship but also had substantial other responsibilities. The other half said they either spent a good portion of their time ($n=5/25$) or almost all of their time ($n=7/25$) focused on the science communication fellowship. The remainder said they spent most of their time ($n=1/25$), very little of their time ($n=1/25$), or none of their time ($n=1/25$) on the science communication fellowship.
- ▶ In terms of educational background, almost half said they identified with biological or medical sciences ($n=11/25$). Almost half said they identified with social sciences, policy, or communication ($n=11/25$). The next highest proportion (one-fourth) was geosciences ($n=5/25$). This was followed by chemistry and/or history/philosophy/humanities (both $n=3/25$) with one or two respondents choosing physics or astronomy or engineering. No respondents chose computer science or math. Most respondents chose more than one field. Most had a Master's degree ($n=10/25$) or a doctoral degree ($n=8/25$, including professional doctorates).
- ▶ When asked to briefly describe their background in an open-ended question, most ($n=18/25$) mentioned professional experience in some aspect of communication or policy. Many ($n=11/25$) mentioned having a decade or more of experience in professional science communication or policy.