The University of Texas at Austin
Center for Media Engagement
Moody College of Communication

STEM GRADUATE STUDENTS' PERSPECTIVES ON SCIENCE COMMUNICATION AND THEIR SENSE OF BELONGING IN THESE SPACES

Nichole Bennett, Anthony Dudo, and John Besley

SUMMARY

The Center for Media Engagement conducted in-depth interviews with 24 Science, Technology, Engineering, and Mathematics (STEM) graduate students from the United States and Canada to examine how they make meaning of their science communication activities and their sense of belonging in these spaces. We identified nine key findings from the interviews that suggest the following recommendations for those working in the science communication ecosystem:

- Science communication organizations (e.g., science communication training organizations, science organizations with communication infrastructure) should put more priority on supporting early-career scientists.
- Science communication organizations should make *sense of purpose* and *well-being* — both of which may be provided by science communication activities — central to efforts to support early-career scientists' resilience.
- Science communication organizations should seek to ensure communication spaces have the potential to be healing-centered spaces that can counterbalance the hostile culture of other academic spaces.

These findings provide a foundation for future research focused on early-career scientists' perspectives on science communication and diversity, equity, and inclusion efforts in these spaces.

SUGGESTED CITATION:

Bennett, N., Dudo, A., and Besley, J. (November, 2022). STEM graduate students' perspectives on science communication and their sense of belonging in these spaces. Center for Media Engagement. https://mediaengagement.org/research/stem-graduate-students-perspectives-on-science-communication

BACKGROUND

Academic institutions often fail to reward scientists for public engagement,[1,2] yet many scientists enthusiastically engage with publics about their research.[3,4] Furthermore, there is some evidence that Science, Technology, Engineering, and Mathematics (STEM) graduate students often approach social media channels and controversial topics with more eagerness than their Ph.D.-holding colleagues.[5]

Past scholarship suggests that science communication activities may be opportunities where marginalized students form alternative identities and places of belonging.[6] STEM academic spaces, however, often remain exclusionary spaces, especially for students with one or more marginalized identities.[7,8] Overall, not much is known about how STEM graduate students make sense of their science communication activities and their sense of belonging in these spaces.

To investigate this issue, the Center for Media Engagement conducted semi-structured interviews with STEM graduate students currently enrolled at U.S. or Canadian universities to assess their public engagement and how they are thinking about engagement in light of COVID-19. This work, funded by a grant from The Rita Allen Foundation, aims to build the research base and generate new knowledge and insights about public engagement attitudes and behaviors by the next generation of STEM graduate students in North America. While this work is exploratory in scope, we placed particular emphasis on assessing both the extent to which COVID-19 is influencing how scientists-in-training are thinking, feeling, and behaving about public engagement and the perspectives of junior scientists about diversity, equity, and inclusion in science communication.

Definitions

We describe all the people interviewed for this project as **STEM graduate students or interviewees**. Our sample is restricted to graduate-level (either doctoral- or master's-degree seeking) students currently attending a university in either the United States or Canada. We use the National Science Foundation (NSF) definitions of **STEM fields**, which include mathematics, natural sciences, engineering, computer and information sciences, and the social and behavioral sciences – psychology, economics, sociology, and political science.[9] We do not claim to be able to generalize to all U.S.- and Canada-based STEM graduate students with this work; rather we are interested in the experiences and perspectives of these participants.

Throughout the report, we refer to **public engagement with science** and **science communication**. We use these terms relatively interchangeably to refer to any information exchange intended to engage a targeted audience in the context of STEM topics.[10] We adopt this broad definition as a starting point but privilege participants' sensemaking about the terms wherever possible.

KEY FINDINGS

1. **STEM academia has a straightforward path, while science communication has a more nebulous path**

   STEM graduate students described being driven by early intrinsic motivation (e.g., interest, competence) to pursue their studies. Interviewees often contrasted these more straightforward pathways into academia with more meandering pathways into science communication.

2. **STEM graduate students primarily discovered public engagement through existing opportunities and organizations**

   While STEM graduate students reported many pathways for science communication activities, they often found these activities through existing organizations and training workshops. A few reported that their advisors or peers had urged them to begin these activities.

3. **STEM graduate students participated in a wide variety of science communication activities**

   Most STEM graduate students traced their involvement in science communication activities through existing organizations, and they were involved in a wide variety of science communication activities. Preferences for particular science communication activities seemed mainly related to personal preference — likely from enjoyment and feelings of competence — rather than other reasons, such as trying to achieve a specific goal.

4. **A Variety of Goals Motivated STEM Graduate Students' Science Communication Activities**

   Desired outcomes for STEM graduate students' science communication included (1) sharing information and combatting misinformation; (2) improving science's public image; (3) increasing diversity, equity, and inclusion in STEM; (4) changing audience attitudes and behaviors; (5) building trust and relationships; and (6) self-improvement. Our interviews suggest that early-career scientists may hold a wide range of immediate science communication objectives, as well as long-term goals.

5. **STEM graduate students recognize that social context may shape the amount and nature of their communication roles and opportunities**

   The COVID-19 crisis meant STEM graduate students with medical or medical-adjacent expertise were called upon to communicate more and to do so in targeted, urgent ways that they did not always enjoy. Pivots from face-to-face to online communication channels due to social distancing meant that many other STEM graduate students communicated less often due to their dislike of online communication.

6. **STEM graduate students described intrinsic motivations for participating in public engagement with science activities**

   STEM graduate students primarily described their favorite part of public engagement with science as intrinsic — specifically, enjoying the way it makes them feel. They explained how they experienced pleasure in helping others learn, sharing their enthusiasm for their research, and in the afterglow of a successful performance. They reported that their motivations for public engagement often shifted — from more instrumental motivations to more intrinsic (i.e., values-based) motivations — as they gained experience. This finding suggests that intrinsic motivations — as opposed to extrinsic ones — may be particularly important when it comes to public engagement for STEM graduate students.

7. **STEM graduate students described barriers to their science communication activities, which suggest ways that science communication organizations might support them more effectively**

   When asked about the worst parts of public engagement with science, STEM graduate student participants' responses reflected their (1) concerns about skill and efficacy, (2) concerns about the impact of their communication, (3) concerns about the adequacy of support infrastructures, and (4) concerns about how science communication is devalued relative to research. These themes suggest ways that science communication organizations (e.g., science communication training organizations, science organizations with communication infrastructure) can better support early-career scientists in their public engagement activities.

8. **STEM graduate students feel conditional support and approval from advisors and peers, as long as they also prioritize research**

   STEM graduate student interviewees reported that their advisors approved of their science communication activities, but often with the caveat that it does not interfere with prioritizing research progress. Interviewees also reported they perceived that their peers approve of and participate in science communication activities. Many STEM graduate students were concerned that their academic advisors were not well equipped to mentor them in their science communication activities, and this may be a key role for science communication organizations to fill.

9. **STEM graduate students experience academia as othering and exclusionary, but science communication spaces have the potential to be "pockets of belonging"**

   STEM graduate student interviewees described how their science communication activities often serve as an antidote to hostile academic cultures and as "pockets of belonging" by encouraging slowing down and reflecting (mattering to self), cultivating relationships and validation (mattering to others), and making space to zoom out and see the impact of their research (mattering to the world). Conceptualizing science communication spaces as potential "pockets of belonging" for STEM graduate students may suggest ways to intentionally cultivate belonging in both science communication *and* STEM spaces.

RECOMMENDATIONS

- Science communication organizations (e.g., science communication training organizations, science organizations with communication infrastructure) should place more priority on supporting early-career scientists.
- Science communication organizations should make *sense of purpose* and *well-being* — both of which may be provided by science communication activities — central to efforts to support early-career scientists' resilience.
- Science communication organizations should seek to ensure communication spaces have the potential to be healing-centered spaces that can counterbalance the hostile culture of other academic spaces.

DETAILED FINDINGS

Finding 1: STEM Academia Has a Straightforward Path, While Science Communication Has a More Nebulous Path

When asked to describe their pathways to becoming a graduate student in STEM, most interviewees recalled how early interest or competence in science, technology, mathematics, and engineering started them on their journey. In comparison to the career path of academic STEM, many felt the path to science communication activities or careers was more nebulous.

The academic pathway may have been easier for interviewees to describe because of the institutionalization of the apprenticeship model of academia in contrast to the more amorphous, extracurricular nature of science communication activities. When asked how they came to be graduate students, a few described their STEM graduate student story as "just what happened" as they kept following the path set ahead for them by other tenure-track faculty.

Almost all interviewees described intrinsic motivation, rather than instrumental reasons, for their involvement in STEM graduate school; many of these early interest or competence experiences with STEM occurred in early grade school. Most of these early STEM experiences were relational, occurring either through teachers that sparked their interest, family members that held STEM careers, or a community that valued STEM. A couple of interviewees also described early negative experiences with STEM teachers that initially discouraged them from this career pathway, but then shared how subsequent positive relationships with teachers changed their minds.

Some interviewees described pressure from their parents to go into secure career paths that were known to make money (e.g., medicine). While some described how they ignored this advice from the outset, others initially followed this advice to go into a "practical" major that would get them a job but then later switched to something they were more passionate about.

This early interest or competence in STEM led many of the interviewees to pursue classes in the field, read more about the field, and participate in research experiences. These experiences helped them narrow down their interests to their current, more specific, field. Often, classroom experiences or research internships showed them there were career pathways aligned with their interests.

Many interviewees also chose their STEM field of study because they wanted to make an impact or to be of service to society. A few interviewees described switching to more applied majors for this reason:

> *"But then I think at a certain point, something didn't really sit right, and I was, like, trying to figure out what it was because I did like what I was doing, and my mentor was great. But then I realized it's because I was having trouble seeing the impact of my work. Like, yeah, studying proteins is cool and all, but where's the connection to the real world? What am I helping?"*

Similarly, other interviewees were inspired to study their particular STEM fields due to personal or family connections with disability or disease. This desire to be more applicable to society also led many of these STEM graduate students to pursue public engagement with science (see Key Finding 2).

In contrast to pathways to STEM academia, interviewees consistently described their experiences with science communication as being more haphazard. Many found these experiences through existing organizations they were able to plug into (see Key Finding 2) and found that their advisors were often ill-equipped to mentor them in science communication (see Key Finding 8). A few described how they had to find out about existing opportunities through peers or listservs. For instance, one interviewee described the difficulty of finding science communication mentors:

> *"And it's a lot more like kind of nebulous, right? Because the mentor-mentee relationship is very strict and defined for your science stuff. But for scicomm, it's kind of like these people I had for a little while, and I can continue to use them, but like, it's up to them to say whether they are available or not."*

Finding 2: STEM Graduate Students Primarily Discovered Public Engagement Through Existing Opportunities and Organizations

Interviewees named multiple pathways through which they became involved with science communication, but a common theme throughout most of the interviews was that they found these activities through existing organizations. Many described how they started their science communication activities after participating in a science communication organization, previous job, or training workshop. These existing opportunities often came in the form of a science communication training program that offered real-world practice as a part of the training. Often these first experiences were science communication experiences with young people at local schools. Interviewees expressed that they did not feel they had time or expertise to do a lot of the behind-the-scenes organizing and relationship work that was required to keep a science communication organization going. Instead, many preferred to plug into existing organizations:

> *"I would say, personally, the hardest thing for me is it's not the in-the-moment. It's not like the talking to people. It's the planning. I'm not very good at that. And sort of how to do that again, it's just not something setting that up, organizing that planning. It is something that I've always struggled with. So that would probably be the hardest thing. The thing that makes me feel the worst about it."*

Interestingly, a couple of the interviewees said they were not interested in science communication training/opportunities that did not offer specific platforms for meaningful participation (i.e., all theory and no practical activities). For example, one interviewee did not continue participating in a science communication club because it did not have opportunities to practice:

> *"So, there's a scicomm club here … they're really big. So, I first I went to a meeting and I was like 'Oh, like, I'm trying to find ways to express things that I think people should know." … I didn't feel a connection to what they're doing or like anything that I could actively participate in."*

A few interviewees also named public engagement as part of a job they had before starting graduate school. Often, this previous job involved teaching or tutoring.

> *"When I was in undergrad, I was a teaching assistant for my microbiology courses and a couple of my animal science courses, and I was a teacher for biochemistry. And I just always really enjoyed the kind of feeling that you get when you are teaching. And when you're teaching people who are taking intro courses, you're usually kind of trying to distill what's really difficult down into what's slightly simpler. And so I always really enjoyed that during my teaching opportunities. … Unfortunately, my Ph.D. program doesn't have teaching opportunities. I tried hard to create a class that we could be teaching assistants for, but there was some pushback due to money. So, I was like, okay, what can I do instead? And I saw that there was this outbreak exhibit at the National Museum of Natural History, the Smithsonian."*

Like the interviewee in the quote above, many others named education as an important entry point for their interest in science communication. One person traced their interest in science communication back to their experience mentoring younger scientists in their lab. Others had jobs in nature education before graduate school that introduced them to science communication.

Some interviewees reported that they started their science communication for instrumental reasons, either to gain skills in communicating or to meet people outside of their lab. One person stated that they started public engagement with science to improve their English skills, as prompted by their advisor. Others also named their advisors as the ones who prompted them to get into public engagement with science, either to gain skills or because the advisor valued science communication. In addition to advisors, peers were also an important influence in getting started with science communication, and a few interviewees noted that their peers had urged them to get involved.

A final group of interviewees reported that they were drawn to public engagement because of their values. For some, this was because they were in a STEM field that directly impacts society and they wanted to be able to communicate about their work with their stakeholders.

> *"I don't know if it is or not, but for me, it is exciting to talk about this, so all the time, I try to be more engaged with people from a broader audience about the importance of water management, water resources. And as you can imagine, especially in [names specific place], we had the problem of various long droughts and shortage of water resources. So, I try to … engage with people, talking about this crisis with a broader audience."*

Enthusiasm for research also drove many interviewees toward public communication. Others started science communication to address misperceptions or misunderstandings that they felt publics have about scientific issues. For some, this involved speaking with stakeholders about misunderstandings or misperceptions they might have about their research.

Others found that doing community-engaged research projects that had communication integrated into them made them more willing to prioritize creating participatory communication activities that allowed them to better hear others' perspectives and insights. Some interviewees shared that science communication came to have a more personal meaning as they were able to share about diseases or disabilities that impacted them. For others, the context of COVID-19 and the relevance of their research meant that science communication took on a new sense of purpose for them during an otherwise trying time. Some interviewees, however, shared the perspective that the urgency of the COVID-19 crisis sometimes displaced their departments' or institutions' ability to deal with other issues (e.g., diversity, equity, and inclusion initiatives).

Finding 3: STEM Graduate Students' Participated in a Wide Variety of Science Communication Activities

Interviewees participated in a wide range of activities that they considered to "count" as science communication:

> *"There are so many different forms [of science communication]; you can find the one that fits to you. And so many people say stuff like, 'Oh, I don't have time for this, or I don't have the resources for this.' And I'm like, well, there's like a billion ways to do it."*

Some interviewees considered their STEM teaching experiences to be science communication. Others participated in programs with local K-12 educational institutions.

Many of these were traditional, one-way presentation formats whereas others, like the Skype-a-Scientist program or science pen pal programs, were more interactive. Some interviewees perceived that their peers were primarily involved in interactions with K-12 programming, and that those efforts likely served as important gateways into science communication activities.

Likewise, presentations — which scientists do in other contexts for their peers — may also serve as entry points into science communication. Presentations occurred in a variety of venues, including conferences, community events, Three Minute Thesis competitions, bar nights, and outdoor lecture series. Other interviewees participated as nature guides or in museum exhibits. While most presentations seemed to encourage the one-way dissemination of science information, some interviewees described how they made their events more interactive. For example, rather than have science bar night presentations, they included an "Ask a Scientist" format to encourage conversation on topics both scientific and personal.

Many STEM graduate students participated in social media for science communication. These channels usually included Instagram or Twitter and became more central during the COVID-19 pandemic. Some interviewees wrote for online news sources or personal blogs, while others made videos for YouTube. Regardless, most social media science communication seemed to center on sharing scientific information or allowing a peek into the life of a scientist.

A few interviewees participated in policy-based science communication, usually to advocate for science-based decision-making or funding for science research. However, a couple of the interviewees saw their policy-based science communication as an opportunity to hear their community's voices through listening sessions or consensus conferences.

Some interviewees participated in science communication activities as a communication intern for an organization, doing public relations tasks, mentoring other volunteers, or evaluating community science programs. Interviewees also found science communication or affinity-based clubs as a platform for their activities.

While many interviewees conceptualized their science communication activities as journalistic, others regarded simple, ad hoc conversations they had about scientific topics as their science communication activities. These conversations happened with family and friends, in places of religious worship, COVID-19 testing sites, and community gardens.

A few STEM graduate students engaged in creative and artistic forms of science communication, including short fiction stories, poetry, and role-playing games.

Some STEM graduate student interviewees conceptualized their communication activities as integrated into their research, especially those that engaged in community-centered

research that was co-created with local people. These interviewees, rather than seeing science communication as a final step and separate from their research, saw it as an integral part of their science.

When it came to preferences for science communication channels, there was not a lot of broad agreement among participants for favorite channels. Rather, choices related to specific science communication activities seemed to derive from personal and contextual factors. Contextually, the shift from face-to-face to online channels during the COVID-19 pandemic affected all participants (see Finding 5). One interviewee also mentioned switching to online science communication due to experiences of racism.

> *"Being outdoors in North Carolina started freaking me out unless I was in nature, because I just had a lot of racist experiences, just, like, walking downtown and sheerly existing [...] And so I started doing a lot more engagement online. And I started finding these communities of scientists doing a lot of work on social media."*

As for personal preferences, these varied across interviewees. Some preferred writing or presenting to what they felt were more extemporaneous forms of communication because they wanted the chance to get their thoughts in order. Sometimes this preference was because English was their second language and they wanted to handle their science communication in formats with which they felt most comfortable. Sometimes these preferences came from not feeling like they were good at something when they first tried it (e.g., social media). Some also mentioned preferring longer writing or presentations to shorter forms, so they can draw from lived experience. One interviewee preferred extemporaneous activities over written science communication because they felt they are more engaging, personal, and far-reaching:

> *"Improv in front of 200 people is really hard and kind of scary. But written science communication is so boring, both from reading the material boring but also from an approach boring, because the only person who's going to read that article in [names high-profile science magazine] is somebody who was already looking for science content."*

Finding 4: A Variety of Goals Motivated STEM Graduate Students' Science Communication Activities

STEM graduate student interviewees held a wide variety of goals which motivated their choices in communicating about their research. Although past research has suggested that Ph.D.-holding scientists mainly prioritize knowledge-sharing objectives,[11] STEM graduate students seemed to hold a wider variety of long-term goals and shorter-term cognitive and affective objectives for science communication. Near-term objectives included: (1) providing information and attempting to correct misinformation, (2) improving science's public image (i.e., fostering trustworthiness perceptions), and (3) changing audience and attitudes. Goal behaviors included (4) encouraging choices that advance diversity, equity, and inclusion in STEM (i.e., career choice, retention, hiring), (5) fostering trust/relationships, and (6) self-improvement. Although many interviewees expressed that their science communication channels narrowed during the COVID-19 pandemic, they did not express that their goals, objectives, and tactics also narrowed during this time.

Some STEM graduate student interviewees reported their science communication objectives included sharing knowledge or attempting to correct misinformation because they viewed STEM knowledge as a valuable form of capital; wished to draw attention and awareness to a particular issue or problem; or wanted to increase scientific literacy in general. Sharing expertise on a topic of social concern became especially salient for STEM graduate students with medical expertise during the COVID-19 pandemic.

STEM graduate students also participated in science communication to improve scientists' public image. This typically meant trying to help people see scientists in a trustworthy way by making them more relatable. For some, this meant explaining the positive motivations behind STEM professions and research activities. For others, this meant breaking stereotypes around science and scientists by challenging notions of what a scientist looks like or by humanizing scientists, often by increasing contact between the local community and scientists.

Overall, most STEM graduate student participants seemed to think of themselves as representing science as a whole rather than representing their institutions, but there were exceptions. For example, one interviewee felt they represented their institution when they communicated about emerging research related to COVID-19.

Another science communication objective of STEM graduate students was changing audience attitude with the overall goal of changing behavior. Attitude changes that interviewees hoped their audiences experienced included (1) having a more positive attitude toward science, (2) seeing science as more accessible, or (3) seeing a particular topic in a new or more complex way.

In this same vein, some focused on making science less scary. Many expressed a wish to help their audience build an interest in STEM topics or careers. Others aimed to spark specific positive emotions, like awe or excitement, in their audience.

Building interest in STEM topics often involved the overall goal of encouraging young people to pursue studying for careers in STEM, often with a focus on encouraging those from marginalized groups. However, one participant rejected that goal for herself because she rejects the hierarchy of STEM jobs as "better."

> *"I'm not particularly interested in getting people to become scientists. I think that's, like, a cool goal for some people. And I get that there's like, you know, this issue with retention and blah, blah, blah. But I also think it's really important to acknowledge that artists are just as important. People who are interested in styling hair are just as important. And you can't like, look down at these people just for choosing to not do STEM."*

Other behavior changes that interviewees hoped to see in their audiences included (1) science-based decisions or policy choices, (2) becoming more active citizens, or, generally, (3) thinking like a scientist. STEM graduate students also often said their long-term goal was building behavioral trust in the form of strong relationships with their audiences. Such trust involves a degree of being willing to make oneself vulnerable. Interviewees explained that building trust with an audience required (1) empathizing with the audience, (2) authentic listening, and (3) investing time.

> *"The relationship aspect of it I do enjoy because, like, anti-vaxxers usually all that's coming from somewhere. Like, it's a lived experience to lead you to this point. …It's a lot of work to break down somebody's things and get them to a point where they see you as a person and they want to communicate with you, and now you just bring a different perspective to them and you'll be the face they think about when they're like, oh, I know someone who is okay with vaccines."*

One interviewee pointed out her ability to build trust with other Puerto Ricans during the COVID-19 crisis because of shared cultural identity and language. Another shared how she changed her appearance to be "more professional" during her public appearances during COVID-19 as a way to build trust. For many, two-way communication was seen as trust-building form of communication, regardless of whether they were able to do it or not.

STEM graduate students also shared science communication goals around increasing diversity, equity, and inclusion in STEM. Some viewed this as diversifying and broadening the audiences of science communication beyond the usual audiences served, or as cultivating a sense of belonging in their audience. Others viewed this as recruiting or retaining more people with marginalized identities in the STEM field. Increasing representation in science communication of people with one or more marginalized identities was also valued. Others saw science communication as a way to shift or to interrogate the current power dynamics. For example, some interviewees shared how they used participatory research and communication rather than subscribing to traditional, top-down methods in their university.

Finally, STEM graduate student interviewees also shared that they participated in science communication activities with a goal of self-improvement. This typically meant changes to one's own skills, understanding, or behavior. For some, science communication was seen as an instrumental way to gain skills, either in the English language or in communication generally. One interviewee shared that they got ideas for their research from their science communication. Others saw it as giving them a sense of purpose (see Finding 9) or a sense if enjoyment (see Finding 6). Some saw science communication as a way to share their enthusiasm for their research. To some, science communication represented a space where they could be their whole self and escape the harsh culture of academia (see Finding 9). A few saw science communication as a way to leave a legacy.

> *"I feel like in the end, it's kind of a waste of time because you're not gonna be doing science forever you're gonna get old and you need to retire. So you better get more people interested in what you're doing so they can keep your work alive."*

Finding 5: STEM Graduate Students Recognize That Social Context May Shape the Amount and Nature of the Communication Roles and Opportunities

The social distancing required to slow the spread of the COVID-19 virus meant switching science communication activities from face-to-face to online, which many STEM graduate students disliked. Interviewees described communicating less since the start of the pandemic. However, for STEM graduate students with medical expertise, the COVID-19 crisis meant they felt an urgency to communicate their expertise. As these interviewees noticed themselves becoming trusted sources for family, friends, and community, they often perceived communication as more fully integrated into the scientific process.

For some interviewees, COVID-19 meant lower participation in science communication activities. Social distancing meant many people that had been participating in face-to-face

activities had to quickly pivot to online. Many described how this switch was less of an intentional pivot and more of a narrowing of options — where activities once done in a face-to-face context were quickly adapted to Zoom. This switch was universally disliked, which meant that many participated less or stopped altogether. Interviewees described numerous challenges of online communication, primary among them (1) the difficulty of ascertaining engagement, (2) lost access to the spaces of STEM, and (3) a lack of gatherings for activism or affinity groups:

> *"I do feel like you lose out on engaging with people … For part of our high school program this year, we tried to implement [an online] program where every week we would just meet and talk about different topics and [the student participants] wouldn't show up. And then when they were there, they weren't really there. I think, whereas in person, that's not an issue because they're there. They're physically there. Where else [are they] going to be? So, that's something I think is a real loss."*

However, for STEM graduate students who held medical expertise, the COVID-19 crisis often meant more demand for their science communication activities. These interviewees described how travel restrictions and laboratory shutdowns meant more time for communicating about the COVID-19 virus with the public, which they did through blog posts, social media, COVID-19 testing sites, and national news programs. They expressed that they had become trusted sources for their friends, families, and communities about the pandemic and felt this trust emerged not only from their expertise (especially early in the pandemic), but also from sharing a linguistic and cultural background with their chosen audience.

But this increased demand for urgent communication about their expertise during the COVID-19 pandemic was not without its challenges. Many of the interviewees who increased their science communication activities during this time complained about the urgency, lack of autonomy, and politicization of the topic. One person expressed how she had come to dislike her COVID communication and research throughout the process:

> *"It makes me feel very one-dimensional. I'm a COVID researcher and I am the person in which, like, at the dinner party you should talk to about your COVID questions. And I'm like, I literally only talk about COVID for work and that's all I am talked to about here and it's just like pretty much all I freaking do anymore. I don't have any of my other hobbies because I just stay inside and work. And so, it definitely makes me feel like the COVID robot."*

Overall, it seems that although the COVID-19 pandemic made science communication more fundamental to certain STEM graduate students than it was previously, it often did so in ways that were compulsory and presented serious drawbacks.

Finding 6: STEM Graduate Students Described Intrinsic Motivations for Participating in Public Engagement with Science Activities

Interviewees commonly described science communication activities as intrinsically rewarding rather than being "another line on their CV." Most described their favorite part of public engagement with science as how it feels, especially the (1) pleasure in experiencing their audience learn, (2) pleasure in sharing their enthusiasm for STEM topics, or (3) pleasure in the afterglow of a well-done performance.

> *"Yeah, I think it's just like helping people understand something new and, like, making things that seemed inaccessible, accessible. … And I find it very emotionally rewarding to help people understand something because that's like a huge part of being a human and being a part of a community and a society."*

Some described their favorite part of public engagement with science as the pleasure of sharing their passion for STEM topics or being able to creatively express oneself. Others expressed their favorite part as being the afterglow they experience after a communication effort goes well:

> *"I like how I feel at the end of the show. … It's so selfish because I always feel sometimes it's a little stressful getting set up and everything, but always by the end of the show I feel, like, a glow because I have established this camaraderie with the audience."*

Notably, many of the interviewees who emphasized feelings of pleasure as being the favorite part of their science communication efforts also expressed sometimes feeling selfish about their enjoyment of that pleasure.

Some interviewees emphasized that they found public engagement satisfying, rather than enjoyable or fun. Aspects of this included (1) working to solve societal problems, (2) helping their mentees evolve and succeed, and (3) being able to authentically engage with and give back to their communities. A few interviewees also described their favorite part of public engagement as being able to connect with like-minded others.

Finding 7: STEM Graduate Students Described Barriers to Their Science Communication Activities, Which Suggest Ways That Science Communication Organizations Might Support Them More Effectively

These barriers centered around four themes: concerns about (1) skill/self-efficacy, (2) effectiveness/response efficacy, (3) available infrastructure, and (4) how science communication is devalued relative to research.

Many interviewees reported that they felt they lacked some form of skill or efficacy in communicating. Skills that they felt they lacked included distilling a message and framing it for a particular audience, overcoming communication anxiety, and improvisation. Regarding concerns about efficacy, lack of time was a common theme shared by many of the STEM graduate student participants. This theme of lack of time was often related to Key Finding 2 because many STEM graduate students feel time is scarce. That is, they feel compelled to plug into existing science communication organizations because they don't believe they have sufficient time to design and implement science communication activities.

Other responses seemed to relate to participants' perceptions of response efficacy — their belief that their communication will be effective. Two main themes that emerged around these concerns were (1) worries about "preaching to the choir" and (2) dialogue across difference. Worries about "preaching to the choir" often involved concerns about audience makeup and, related to Key Finding 2, in that STEM graduate students often felt they were not able to choose the audiences they worked with because they were plugging into an existing science communication organization:

> *"I would say I don't have that much freedom in terms of choice of where we go per se. I think there's established relationships with certain places that we continue just to build on. So, there isn't too much of brainstorming as to why we're at certain places."*

Interviewees also described the challenge of dialogue across difference. Some participants seemed to hold deficit views of these audiences, framing them as disinterested or as being "anti" science. However, others did not frame their audiences as deficient and instead described their audiences in ways that acknowledged them as being complex.

Interviewees were also commonly concerned about how infrastructure limits their science communication efforts. These concerns include how their desires to foment interdisciplinary science communication are stymied by the increased specialization of STEM disciplines. Interviewees also reported feeling that their preferences for science communication (e.g., the goals, objectives, tactics, and audiences they want to prioritize)

are often constrained by the organizations they can plug into (see Key Finding 2). They also noted how infrastructure constrains their desire to evaluate their science communication activities. Some interviewees connected these struggles to evaluate with institutional norms and power imbalances.

> *"[Because it is challenging to effectively assess science communication] it's very difficult for people [e.g., primary investigators, department chairs] to take it seriously or to value it or prioritize it. So, that's what's frustrating."*

Interviewees also commonly described how science communication is systematically devalued relative to research in academic contexts. For many, this manifests in the lack of compensation — monetary or otherwise — for their participation in science communication activities. Interviewees often expressed feelings of frustration related to their institution not understanding what it takes to prepare and execute effective science communication. Some lamented how their science communication efforts are not valued in academia as much as peer-reviewed papers, despite their potentially greater impacts on society.

Finding 8: STEM Graduate Students Feel Conditional Support and Approval From Advisors and Peers, As Long As They Prioritize Research

Overall, most STEM graduate students felt approval and support for their science communication activities from both advisors and peers. However, approval from advisors and departments often felt conditional on research progress, and interviewees often felt their advisors were not well equipped to mentor them in science communication.

The few that did not feel support or approval from advisors described it more as prioritizing research alone rather than outright disapproval or preventing them from participating in science communication activities. Sometimes this was simply because the advisor was not aware of their graduate students' science communication activities or because there was a general lack of communication between advisor and graduate student.

Most interviewees, however, felt that they had conditional approval from their current advisor as long as it did not interfere with their research progress. Many STEM graduate students perceived that their advisors viewed science communication instrumentally (e.g., as a line on the CV), at least at first. A few interviewees believed their advisors also valued science communication more intrinsically. For some, these values seemed to stem from the advisor also participating in science communication activities. A few received encouragement from their advisors to begin their science communication activities (see Key Finding 2).

Many STEM graduate students described themselves as “lucky” to have an advisor that approves of their science communication efforts or described their advisor’s approval in contrast to their department’s disapproval. A few interviewees contrasted previous advisors’ disapproval with their current advisors’ approval. There was a clear sense that advisor approval of science communication activities by STEM graduate students may not be widespread. Furthermore, many of the interviewees who described conditional support for the science communication activities also complained about the vagaries of this support, namely how there is no clear sense of exactly what “too much” science communication versus research looks like:

> *"I’ve had meetings like committee meetings or things like that where they’re like, what are the other things you’re doing? What’s taking up your time? Because you’re never making enough progress."*

Other interviewees agreed and mentioned that if advisee-mentee relationships were strained, science communication activities were often blamed first.

> *"It’s like if you are having a difficult time with this advisor, you need to be going through the process even faster. The solution isn’t to improve the relationship. The solution is to graduate faster. And so, anything that you do that is outside of actual research is you choosing to put yourself in this situation for longer. And so, it is like a time thing. You are wasting your time by doing this outreach kind of work. "*

The few STEM graduate students who had been asked by advisors or committees to cut down on science communication activities reported that they did not change their level of involvement, but rather made sure to show that they were prioritizing their research over science communication in more intentional ways.

> *"I think even after having that conversation with her [about quitting non-research activities], I didn’t end up letting go of anything. I just kind of showed her that I was very interested in the research, even just showed her more interest in that regard. And I just kept what she said in mind but didn’t actively quit anything."*

Some interviewees worried that even though their advisor approved of their science communication activities, they would eventually be penalized when pursuing tenure-track academic careers for not solely focusing on publishing.

Although many interviewees felt conditional approval for their science communication activities, many also described that their advisors were ill-equipped to mentor them in careers or opportunities in science communication. For many, academic careers appear to be a more straightforward path, and science communication pathways are more nebulous:

> *"And so, I think [my advisor] was a little worried, like, 'Oh, no, I don't know how to deal with you. I don't know how I'm going to effectively mentor you for a career because I don't know anything about it and none of my friends do this' ... And he pushed me to get a shadow advisor in the policy department, which I did, and it was great. I actually got two of them."*

Most of the interviewees perceived that a fair amount of their peers also participated in science communication activities. Only one perceived that their peers do more science communication than they do, and a subset of others felt they were in the middle of their peers in terms of participation. Some interviewees noted that they got their start in science communication activities because peers encouraged them to do so (see Key Finding 2).

A subset of the interviewees shared that they felt there was a trend for younger scientists to be more interested in and to value science communication more. One person shared that their department was placing more emphasis on hiring faculty that valued science communication and was creating a departmental committee to support science communication. A few interviewees also shared their perception that peers in more applied fields, such as biologists, seem more likely to communicate because their field more directly impacts society.

Regardless of their perceptions of general approval from peers or advisors, some interviewees shared that the approval of their advisor or peers matters less to them than being in alignment with their values, approval from their family, or approval from their communities.

Some interviewees shared that becoming more of a public figure in science communication comes with drawbacks, including discrimination (see Key Findings 7 and 9) or worries about being a "Twitter scientist" who is known more for outreach than research productivity. A few people also shared their perceptions that certain forms of science communication that they valued were not sanctioned by their departments, including activism or entrepreneurship.

While lack of time was named as a barrier by many interviewees (see Key Finding 7), many of them explained that they did not see their science communication activities as a "waste of time" because of the benefits they received for both their research and their well-being. They felt that science communication activities were often devalued relative to their research activities by others, but to them had intrinsic value (See Key Finding 7).

Finding 9: STEM Graduate Students Experience Academia as Othering and Exclusionary, But Science Communication Spaces Have the Potential to Be "Pockets of Belonging"

STEM graduate student interviewees described academia as a space where they experience low psychological safety, intense competition, and isolation. Many also described academic culture as dehumanizing. Interviewees with one or more marginalized identities described experiences with discrimination and how these spaces required them to assimilate to the white, cis, straight, male, able-bodied, affluent, somatic norm:

> *"I don't know anyone who's gotten out of academia unscathed that's not a white male with [already established] competence and privileges."*

Science communication spaces were also sometimes perceived as othering and exclusionary by STEM graduate student interviewees, especially with concern to fitting their image to the stereotypical image of a scientist (e.g., white, cis, male, able-bodied). Many, however, expressed that science communication serves as an antidote to academia, either by providing a place to escape hostile academic cultures or by helping to build resilience and developing a "backup plan."

> *"So, then you come to this sort of point where you think, 'okay, do I continue to fight in academia or do I bail?' And bail isn't necessarily a negative thing, but it's perceived [that] way. So, that's frustrating. But I've always done outreach as a way to have some sort of contact with the world outside of academia."*

Beyond science communication activities as an escape or a backup plan, STEM graduate student interviewees described how these activities enhance their sense of belonging by helping them (1) matter to themselves, (2) matter to others, and (3) matter to the world. STEM graduate students, for example, described science communication activities as allowing them to matter to themselves through mindfulness. Slowing down and reflecting

through communicating scientific research may play a key role in meaning-making about the self. For example, one interviewee described that she realized she was unhappy in her research program because she enjoyed talking about research that was not her project. The self-knowledge gained from slowing down and reflecting also provided a way to resist assimilation. For example, interviewees with invisible disabilities had to learn about themselves and advocate for themselves, which they described as helping them to better understand their boundaries.

In addition to helping people matter to themselves, science communication may also be a way that STEM graduate students come to matter to others. Interviewees often described the relational belonging that occurred in science communication spaces. For some, affinity spaces where they could be around others that shared their — often marginalized — identities contributed to a sense of belonging. For others, meaningful relationships helped them feel free to be fully themselves, rather than fitting into academic norms.

> *"I think [science communication] spaces ... have given me self-confidence and awareness that I belong, that I don't have to fit in."*

While some STEM graduate students described academic spaces as having low psychological safety, many described science communication spaces as places they were more comfortable making mistakes:

> *"I wouldn't say anything at all [in academic spaces] because I thought people would make fun of me or whatever. But doing this public outreach has made me kind of feel less scared about talking about things."*

Interviewees also described how science communication allows them to share their struggles and feelings of shame. For example, some expressed that they were better able to talk about invisible and/or stigmatized mental health issues or disabilities in science communication spaces than in academic ones.

In addition to mattering to themselves and others, STEM graduate students also described how science communication spaces allowed them to feel they mattered to the world by offering them a sense of purpose and meaning. For many, research activities alone failed to help them feel they impacted society, whereas science communication activities did.

> *"Most humans want to contribute in a positive manner to society in a way that they feel capable and where they are able to make positive impact. And for me, the realm that works is through science communication and outreach."*

The context of the COVID-19 pandemic made this sense of purpose especially salient during a global crisis, especially for STEM graduate students in the medical or medical-adjacent fields.

> *"COVID happened. The lab was closed for many months. Everything got delayed. So, I think [names various communication activities related to COVID-19] gave me a sense of purpose during those months that we were in lockdown. It felt like I was helping in some sort of way, sharing my knowledge of immunology, whatever was COVID-related, that I felt comfortable with. So, yeah, [those communication activities] definitely gave me a purpose."*

Interviewees described how their science communication activities brought them back in contact with the bigger picture and the stakeholders of their research, which reminded them why they loved science. They often described that talking to others about their research helped them connect their day-to-day research activities — which could often be mundane or rife with failures — to a greater sense of purpose.

> *"And [names science communication activity] was really cool because it was a time that my reactions were all going wrong in the lab and blah, blah, blah. And you feel like your world is ending. But it was also really an eye-opener for me because I was like, okay, this is the importance of what I'm doing."*

DETAILED RECOMMENDATIONS

Science Communication Organizations Should Place More Priority on Supporting Early-Career Scientists

Because most STEM graduate students plug into existing organizations to start and guide their science communication activities, these organizations have the potential to play key roles in not only building communication skills, but also in offering real-world opportunities to enact these skills. For example, many STEM graduate student participants reported that they plugged into existing communication infrastructures of science organizations. These organizations are positioned to help scientists-in-training develop a more sophisticated sense of communication, including considerations of evidence-based strategy and inclusiveness, that can further enrich the practice of engagement and its impact. Many STEM graduate students explained that science communication pathways seem much more nebulous than academic ones, and that their academic advisors are often ill-equipped to mentor them in science communication activities. Many STEM graduate students, for example, expressed a desire to do science communication designed to foster long-term relationships with stakeholders or to reach audiences beyond dominant groups. Science communication organizations, unlike their academic advisors, are better positioned to provide junior scientists with support and direction related to these communication goals. Overall, science communication programs and organizations may be able to play a key role in supporting early-career scientists in their science communication activities. Although this recommendation should not be interpreted to suggest that science communication organizations reduce their support for more senior-level scientist communicators, it does highlight the opportunity for these organizations to think strategically about the extent to which their support is connecting with and designed for early-career scientists.

Science Communication Organizations Should Make Sense of Purpose and Well-Being – Both of Which May Be Provided By Science Communication Activities – Central to Efforts to Support Early-Career Scientists' Resilience

These findings suggest that external rewards may be less effective than tapping into and supporting the intrinsic motivation already available to early-career scientists in their science communication activities. This finding is consistent with theories as broad-ranging as Self-Determination theory[12] and Black Feminist theory.[13] Research about marginalized students in STEM fields suggests that many of these students seek out community- or social justice-oriented goals for their science and that focusing on these goals — rather than on external rewards — may be a key pathway to recruiting and retaining more scientists from marginalized groups.[14] Likewise, frameworks of science identity suggest that persistence in STEM fields derives from an individual being able to connect their STEM

experiences with their lives and with their personal goals, rather than from their professional success and abilities.[15] The purpose and meaning that STEM graduate students derive from their science communication activities may play a key role in resisting burnout and encouraging well-being, especially in the context of the COVID-19 pandemic.

Science Communication Organizations Should Seek To Ensure Communication Spaces Have the Potential to Be Healing-Centered Spaces That Can Counterbalance the Hostile Culture of Other Academic Spaces

STEM graduate students described how science communication activities often allow them to be their full selves. More specifically, science communication spaces have the potential to provide "pockets of belonging" for many STEM graduate students wherein they can more readily matter to themselves, matter to others, and matter to the world.[16,17] These positive experiences appear uncommon within the often-hostile culture of academia, and many interviewees lamented that science communication activities are often undervalued and under-resourced within their institutions. Cultivating these "pockets of belonging" in science communication spaces may help early-career researchers develop more resilient, healthy, and sustainable scientific identities. They may also represent a way to more intentionally and meaningfully cultivate inclusion, belonging, and well-being into science communication spaces *and* the culture of science itself. Fulfilling this recommendation will require making structural and logistical decisions that maximize these pockets of belonging.

This could involve centering the lived experiences and perspectives of early-career scientists with one or more marginalized identities because these were the individuals in our study that were best able to name and notice how academic culture was hostile and were best equipped to seek out, create, or imagine these "pockets of belonging" in their science communication activities. This finding suggests that long-term change focused on inclusion, belonging, and well-being in these spaces may require a more equitable distribution of resources to these "pockets of belonging." This might look like granting science communication organizations more influence and resources by more fully integrating them into the structure of research departments.

METHODS

We conducted 24 interviews between February and April 2021 using video conferencing software. Interviewees were recruited through emails with existing contacts in the science communication ecosystem.

Seventy-six eligible potential participants (STEM graduate students currently enrolled at a U.S. or Canadian university with previous experience in public engagement) contacted

us with interest in participating in the study. We emailed a pre-survey to all interested people to purposely sample for a variety of intersectional identities, scientific disciplines, and universities. From those that answered the survey (64), we selected 24 to interview. All participants chosen for the study were sent an introductory email that included a video introducing the first author's background and motivations for doing the study. Each participant received a $50 stipend for participating in the study.

Before being interviewed, STEM graduate students completed an online informed consent form and were asked a short set of demographic questions. We used this questionnaire to help maximize the diversity of our sample across ethnicity/race, gender expression, sexuality, scientific field, and university geography.

In terms of racial and ethnic identities, participants reported they were white/non-Hispanic (8/24), white/Iranian (1), white/Asian (1), white/Jewish (1), white/Hispanic/Latinx (1), Black/African (1/24), Ecuadorian (1), Afrodescendent/Puerto Rican (1), Latinx/Puerto Rican (1), Latinx (1), Brazilian (1), Middle-Eastern (1), Chinese (2), Asian (1), and South Asian (1). Participants reported they were cisgender men (7), cisgender women (15), genderfluid (1), and trans man (1). Participants reported their sexualities were heterosexual (15), asexual (2), bisexual/pansexual (3), and gay/queer/lesbian (2).

In terms of scientific field, participants varied widely because of how sample selection was conducted. Participants represented (often-overlapping) fields including physics/astronomy, engineering, biological/medical sciences, geosciences, chemistry, mathematics, computer science, and social sciences. Participants' universities were located in the midwest-US (3), southwest-US (4), southeast-US (1), northeast-US (5), West-US (1), Newfoundland-Canada (1), Ontario-Canada (3), and Québec-Canada (1).

The interviews followed a semi-structured format and addressed the following topics:

- How the participant came to be a STEM graduate student.
- How the STEM graduate student got started in public engagement with science.
- What types of public engagement the STEM graduate student was involved in.
- The best and worst parts of public engagement, from their perspective.
- How public engagement affected other parts of their life.
- Which spaces the STEM graduate student felt they belonged and in which they felt like an outsider.
- The STEM graduate student's plans for the future.

Interviews were designed to obtain qualitative insights and lay the groundwork for future research focused on early-career scientists' perspectives on science communication and their sense of belonging in these spaces.

ENDNOTES

[1] Edwards, M. A., & Roy, S. (2017). Academic research in the 21st century: Maintaining scientific integrity in a climate of perverse incentives and hypercompetition. *Environmental Engineering Science*, *34*(1), 51-61.

[2] Moran, H., Karlin, L., Lauchlan, E., Rappaport, S. J., Bleasdale, B., Wild, L., & Dorr, J. (2020). Understanding Research Culture: What researchers think about the culture they work in. *Wellcome Open Research*, *5*, 201.

[3] Besley, J. C., & Nisbet, M. (2013). How scientists view the public, the media and the political process. *Public Understanding Of Science, 22*(6), 644-659.

[4] Rainie, L., Funk, C., Anderson, M., & Page, D. (2015). How scientists engage the public. *Pew Research Center*.

[5] Howell, E. L., Nepper, J., Brossard, D., Xenos, M. A., & Scheufele, D. A. (2019). Engagement present and future: Graduate student and faculty perceptions of social media and the role of the public in science engagement. *PLoS One*, *14*(5), e0216274.v

[6] Thiry, H., Laursen, S. L., & Liston, C. (2007). Valuing teaching in the academy: Why are underrepresented graduate students overrepresented in teaching and outreach?. *Journal of Women and Minorities in Science and Engineering*, *13*(4).

[7] McGee, E. O. (2021). *Black, brown, bruised: How racialized STEM education stifles innovation.* Harvard Education Press.

[8] Riegle-Crumb, C., King, B., & Irizarry, Y. (2019). Does STEM stand out? Examining racial/ethnic gaps in persistence across postsecondary fields. *Educational Researcher*, *48*(3), 133-144.

[9] Gonzalez, H. B., & Kuenzi, J. J. (2012, August). Science, technology, engineering, and mathematics (STEM) education: A primer. Washington, DC: Congressional Research Service, Library of Congress.

[10] Canfield, K., & Menezes, S. (2020). The state of inclusive science communication: A landscape study.

[11] Dudo, A., & Besley, J. C. (2016). Scientists' prioritization of communication objectives for public engagement. *PloS one,* 11(2), e0148867.

[12] Ryan, R. M, Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist. 55* (1): 68–78.

[13] Lorde, A. (1984). The Uses of the Erotic. In *Sister Outsider.* Crossing Press.

[14] McGee, E. O. (2021). *Black, brown, bruised: How racialized STEM education stifles innovation.* Harvard Education Press.

[15] Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187–1218.

[16] Love, B. L. (2019). We want to do more than survive: Abolitionist teaching and the pursuit of educational freedom. Beacon Press.

[17] Ginwright, S. (2022). The Four Pivots: Reimagining Justice, Reimagining Ourselves. Penguin.