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Broadening Perspectives on Broadening Participation: Professional Learning Tools for More Expansive and Equitable Science Communication

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Many professionals in the field of science communication have argued that our work too often tends to be designed for people like ourselves—those already interested in, comfortable with, and engaged with science. Thus, our work, ostensibly intended to broaden who engages with STEM, may in fact be exacerbating rather than reducing disparities with regard to who has access to and makes use of designed (vs. everyday) opportunities for science engagement. In this conceptual analysis, we posit that inclusive science communication must be conceptualized as a process of cultural exchange, rather than as a process of translation. Thus, the goal is not to speak more simply or more loudly, but rather with more understanding and mutualism. We share the results of an exploratory project that developed a suite of research briefs designed to support science communication professionals in reflecting on key structural barriers that operate to institutionalize science as an non-inclusive domain of activity. We conclude that more dialogic ways of professional learning among science communicators can reveal biases, gaps between goals and reality, and other underlying practices that must be addressed if we are to advance inclusive forms of science communication.

Keywords: equity, inclusion, professional learning, boundary object, boundary crossing, science communication, broadening participation

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INTRODUCTION

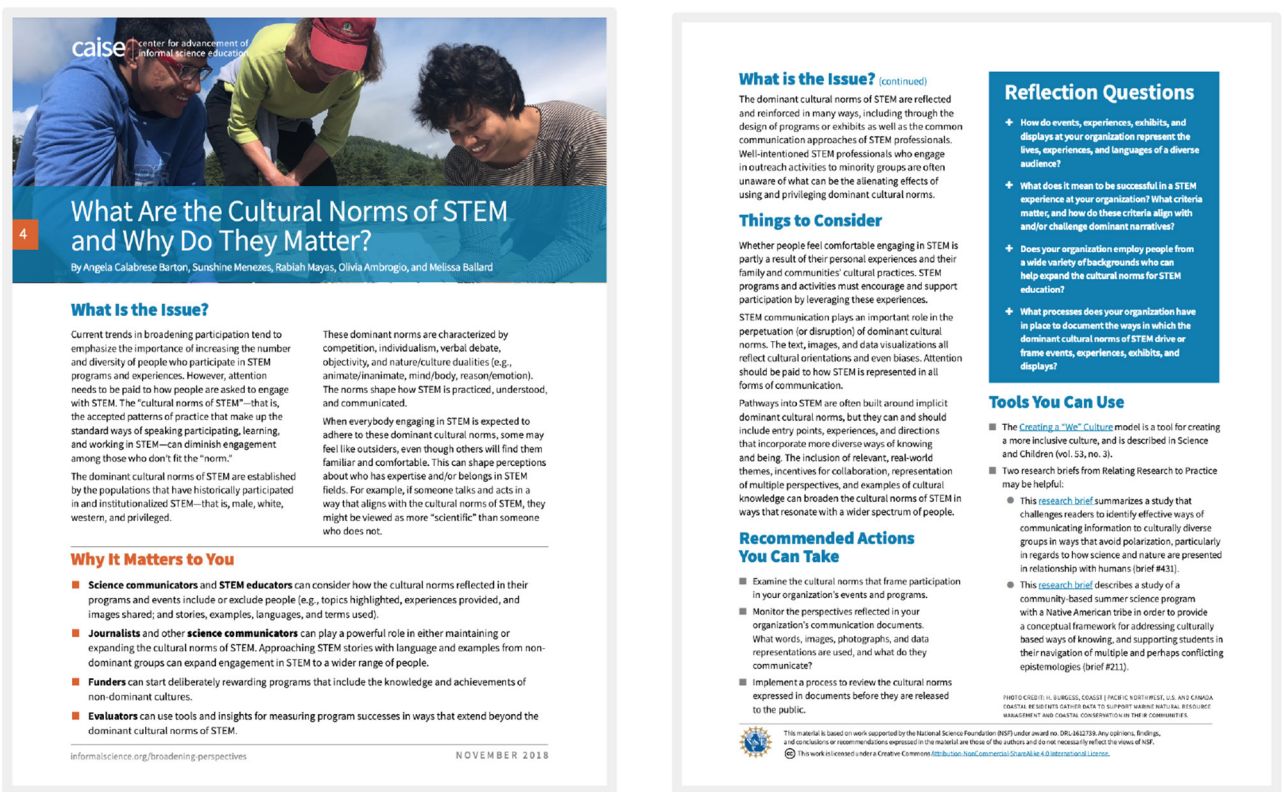
The Matthew Effect describes the phenomenon whereby systems of reward and recognition lead to the rich getting richer while the poor get poorer (Merton, 1968). For example, in science the more well-established you are, the more often your studies are cited, even if they are not much different than the work of newer scientists or scholars. Fame attracts fame, wealth attracts wealth. Feinstein and Meshoulam (2014) have argued that the work of science communication often triggers the Matthew Effect: We primarily engage those who seek engagement on our terms, on our turfs, in our language, and in ways that we ourselves find appealing or salient. Thus, the already science-engaged become even more science engaged. Through such approaches, the authors note, we may, in fact, be exacerbating rather than ameliorating disparities with regard to who has access to and makes use of designed (vs. everyday) opportunities for science engagement.

There are notable exceptions to this scenario in the many promising efforts that deeply engage socially, racially, and economically diverse communities [see Dawson (2014), Canfield et al. (2020), Polk and Diver (2020)]. These communication efforts move beyond the walls of universities and museums to adopt culturally relevant and responsive "asset-based" modes of interaction or pedagogy, and they seek to co-design and collaborate with communities. But such programs remain the exception to the rule; they are often led by particular and passionate individuals, or supported by specific, often short-term, funding streams. Their celebrity status, as distinct from the pack, suggests the existence of more deep-seated structural, institutional, and cultural factors that limit such notable programs from becoming more widespread and sustainable.

It is that challenge—to identify structural issues that seem to hold back the field in its efforts to expand diversity, equity, inclusion, and access—that the Center for the Advancement of Informal Science Education (CAISE) sought to address in the fall of 2017 by forming a task force to review current practices in the field and make recommendations for how we might move the field forward. The task force consisted of 15 professionals from a wide range of science communication organizations, including community-based organizations, science museums and universities, and representing both research and practice. In this paper we describe how we theorize the process of changing attitudes, commitments, and strategies for broadening participation in science communication as work at the boundaries of multiple professional perspectives—of scientists, science communicators, informal science practitioners, and others. As such we explore how "boundary objects" co-developed by professionals from across a range of perspectives, can be used to foster productive conversations about equity and inclusion in science communication, and to negotiate tensions that will inevitably arise as individuals, teams, and organizations seek to make change (see **Figure 1** for example). The case that this project describes is intended to lay the groundwork for further research and development, including future empirical studies related to the efficacy of adopting "boundary-crossing" approaches to inclusive science communication.

A TASK FORCE ON BROADENING PARTICIPATION

Broadening participation in STEM has generally referred to increasing participation of people from historically underrepresented communities in the pursuit of STEM studies, professions, and civic decision-making (Fealing et al., 2015). These communities include people of color, people with disabilities, women and girls, people living in poverty, people who were formerly incarcerated, others, and include the ways in


caise center for advancement of informal science education

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What Are the Cultural Norms of STEM and Why Do They Matter?

By Angela Calabrese Barton, Sunshine Menezes, Rabiah Mayas, Olivia Ambrogio, and Melissa Ballard

What Is the Issue?

Current trends in broadening participation tend to emphasize the importance of increasing the number and diversity of people who participate in STEM programs and experiences. However, attention needs to be paid to how people are asked to engage with STEM. The "cultural norms of STEM"—that is, the accepted patterns of practice that make up the standard ways of speaking participating, learning, and working in STEM—can diminish engagement among those who don't fit the "norm."

The dominant cultural norms of STEM are established by the populations that have historically participated in and institutionalized STEM—that is, male, white, western, and privileged.

These dominant norms are characterized by competition, individualism, verbal debate, objectivity, and nature/culture dualities (e.g., animate/inanimate, mind/body, reason/emotion). The norms shape how STEM is practiced, understood, and communicated.

When everybody engaging in STEM is expected to adhere to these dominant cultural norms, some may feel like outsiders, even though others will find them familiar and comfortable. This can shape perceptions about who has expertise and/or belongs in STEM fields. For example, if someone talks and acts in a way that aligns with the cultural norms of STEM, they might be viewed as more "scientific" than someone who does not.

Why It Matters to You

- **Science communicators** and **STEM educators** can consider how the cultural norms reflected in their programs and events include or exclude people (e.g., topics highlighted, experiences provided, and images shared; and stories, examples, languages, and terms used).
- **Journalists** and other **science communicators** can play a powerful role in either maintaining or expanding the cultural norms of STEM. Approaching STEM stories with language and examples from non-dominant groups can expand engagement in STEM to a wider range of people.
- **Funders** can start deliberately rewarding programs that include the knowledge and achievements of non-dominant cultures.
- **Evaluators** can use tools and insights for measuring program successes in ways that extend beyond the dominant cultural norms of STEM.

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What is the Issue? (continued)

The dominant cultural norms of STEM are reflected and reinforced in many ways, including through the design of programs or exhibits as well as the common communication approaches of STEM professionals. Well-intentioned STEM professionals who engage in outreach activities to minority groups are often unaware of what can be the alienating effects of using and privileging dominant cultural norms.

Things to Consider

Whether people feel comfortable engaging in STEM is partly a result of their personal experiences and their family and communities' cultural practices. STEM programs and activities must encourage and support participation by leveraging these experiences.

STEM communication plays an important role in the perpetuation (or disruption) of dominant cultural norms. The text, images, and data visualizations all reflect cultural orientations and even biases. Attention should be paid to how STEM is represented in all forms of communication.

Pathways into STEM are often built around implicit dominant cultural norms, but they can and should include entry points, experiences, and directions that incorporate more diverse ways of knowing and being. The inclusion of relevant, real-world themes, incentives for collaboration, representation of multiple perspectives, and examples of cultural knowledge can broaden the cultural norms of STEM in ways that resonate with a wider spectrum of people.

Recommended Actions You Can Take

- Examine the cultural norms that frame participation in your organization's events and programs.
- Monitor the perspectives reflected in your organization's communication documents. What words, images, photographs, and data representations are used, and what do they communicate?
- Implement a process to review the cultural norms expressed in documents before they are released to the public.

Reflection Questions

- How do events, experiences, exhibits, and displays at your organization represent the lives, experiences, and languages of a diverse audience?
- What does it mean to be successful in a STEM experience at your organization? What criteria matter, and how do these criteria align with and/or challenge dominant narratives?
- Does your organization employ people from a wide variety of backgrounds who can help expand the cultural norms for STEM education?
- What processes does your organization have in place to document the ways in which the dominant cultural norms of STEM drive or frame events, experiences, exhibits, and displays?

Tools You Can Use

- The Creating a "We" Culture model is a tool for creating a more inclusive culture, and is described in Science and Children (vol. 53, no. 3).
- Two research briefs from Relating Research to Practice may be helpful:
  - This research brief summarizes a study that challenges readers to identify effective ways of communicating information to culturally diverse groups in ways that avoid polarization, particularly in regards to how science and nature are presented in relationship with humans (brief #431).
  - This research brief describes a study of a community-based summer science program with a Native American tribe in order to provide a conceptual framework for addressing culturally based ways of knowing, and supporting students in their navigation of multiple and perhaps conflicting epistemologies (brief #211).

PHOTO CREDIT: H. BURGESS, COAST | PACIFIC NORTHWEST, U.S. AND CANADA COASTAL RESIDENTS GATHER DATA TO SUPPORT MARINE NATURAL RESOURCE MANAGEMENT AND COASTAL CONSERVATION IN THEIR COMMUNITIES.

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FIGURE 1 | Sample practice brief on cultural norms of STEM. ©Center for the Advancement of Informal Science Education.

which multiple identities may intersect. In this view, both the broadening participation challenge and solution focus primarily on creating access to existing pathways into STEM and on increasing the number of those pathways. The assumption underlying this approach is that when points of access are increased, more diverse and more representative populations will have more opportunities to participate in STEM and will opt to pursue those opportunities.

The CAISE task force began its work by seeking to broaden definitions of what broadening participation means and looks like. Using purposive sampling (Babbie, 2014), we interviewed 30 experts in the field recognized for their work in informal STEM learning and science communication to surface critical issues and challenges regarding broadening participation and needs in the field. We then assembled the task force, and through both virtual and face-to-face monthly meetings, the group challenged definitions that were focused on "access" alone, and shared examples of efforts that adopted inclusive, culturally relevant pedagogies, to change the places, reasons, and strategies for science communication. Over the course of the year, task force members identified many committed individuals, promising practices, and generative ideas in the field. It also identified four underlying systemic factors that appeared to be constraining the field's overall progress in broadening participation:

1. Science communication programs commonly adopt narrow definitions of "what counts as STEM" which constrains our ability to recognize the STEM learning experiences and assets that people bring to science engagement opportunities.
2. Representations and instantiations of science are typically informed by the dominant cultural norms of STEM, which are mostly white, western, and male. Reinforcing these norms can further alienate or marginalize publics from non-dominant communities.
3. Science communication programs seldom are designed with learning ecosystems perspectives in mind, which means that they miss building on existing or prior STEM experiences and linking to future and ongoing experiences beyond the science communication event itself.
4. Science communication programs are often housed in larger organizational or institutional settings that do not place equity on the same footing as science itself in terms of organizational mission and focus. This imbalance often leads to the marginalization of staff heading up equity initiatives and ultimately a lack of budget and staff support, frequently limited by time-constrained grant funding.

More detail on these barriers can be found in the CAISE report: https://www.informalscience.org/sites/default/files/BPreport.pdf.

The task force began to investigate models for supporting individuals committed to change to begin to develop conversations and allies within their programs or organizations. Responding to research that questions the value of traditional "translational" approaches of simply "telling" people what research says (Biesta, 2010; Weiser, 2015), we instead chose to pursue a more dialogic approach that recognized the cultural fields and boundaries that often separate the scientific community from more marginalized communities historically excluded from science. While no one set of tools will definitively move the entire field forward, research suggests that through reflective and critical discussion, science communicators can become aware of ways to work with, in, and/or around such structural barriers, and over time begin to make change in their practices and priorities [e.g., Bevan and Xanthoudaki (2008), Martin et al. (2019)]. This is where change can start: Building movements at the staff level that transition to organizational levels and ultimately to a field level where they can no longer be marginalized.

Boundary Objects

The CAISE task force thus set out to create a set of boundary objects that could support professional groups in developing shared understandings of what broadening participation in science is/could be, the practices that support broadening participation in science, and the challenges institutions may face in working toward broadening participation in science.

A boundary object is any object that facilitates communication across different social worlds (Star and Griesemer, 1989). Boundary objects gain meaning when people from different communities need to collaborate, but do not always bring a shared history of perspective to that collaboration. Yet the objects themselves are familiar to different stakeholders even if their purpose, value and/or meaning may be taken up differentially because of the social worlds they inhabit (Akkerman and Bakker, 2011). Boundary objects are both adaptable to local needs and constraints while stable enough to build a common identity across different worlds (Star, 1989).

For example, in their landmark study of boundary objects in museum contexts, Star and Griesemer (1989) describe how various artifacts of the Berkeley Museum for Vertebrate Zoology, such as specimens and maps, supported amateur collectors and museum professionals to come together to develop the museum. These differences in position and perspective matter in working toward something new and different that could not be achieved without that difference. Boundary objects mediate across difference while centering commonality (Wenger, 2010). As strategy tools they allow for coordinated discourse and activity toward advancing individual and collective understanding and linking communities toward a common task (Spee and Jarzabkowski, 2009). They are referred to as "boundary" because they literally help to bring people together from differently bounded worlds, reshaping relationalities among people, and how such objects are used and understood (Fleischmann, 2006).

Boundary objects not only bridge understanding across people from different positions and locations, they also challenge boundaries, expanding upon who belongs, how and why. This last point is particularly important when considering the practices of broadening participation and their impacts. We see these tools as not only coordinating activity that allows for knowledge integration across positions/perspectives, but also allowing for the transformation of the participating communities or of the nature of the boundary itself.

TABLE 1 | Barriers and briefs.

Systemic barrier	Sub-topics for practice briefs
Narrow definitions of broadening participation in STEM	• Why broaden perspectives on broadening participation in STEM? • What does learning have to do with science communication? • What does asset-based STEM learning look like?
Dominant cultural norms of STEM	• What are the cultural norms of STEM and why do they matter? • What counts as STEM? • How can we help scientists adopt equity approaches to science communication?
Learning ecosystems framing	• What is a STEM learning ecosystem? • How can we re-think assumptions about parent engagement? • How can we build on existing assets within a community?
Institutional prioritization	• How can institutions model inclusion in the workplace? • What does working "with" (not "for") our communities look like?

To develop a set of broadening participation boundary objects for the science communication field, the CAISE task force explored a strategy, developed by the NSF-funded Research+Practice Collaboratory, to work with mixed teams of researchers and practitioners to identify key topics they felt the field was struggling with and produce double-sided, one page "practice briefs" summarizing the evidence base from both research and practice. Practice briefs—unlike most research briefs—are designed to start with the questions and daily decisions of practitioners, and draw on research to address these questions on a single, pithy, double-sided document. Practice briefs are meant to be easy to use, quick to read, and concrete in their implications (Bell and Rhinehart, 2015). They are used to foster professional learning conversations as well as to guide practice. An external evaluation found the Collaboratory practice briefs to be productive boundary crossing tools because they were research-based but reflected practitioner perspectives, came from a trusted source, were at the right "grain-size," were succinct and well-organized, and provided links to additional resources (Anderson et al., 2019). This model seemed well-suited to the goals of the CAISE task force and the needs of the science communication field.

To foster productive conversations about the four systemic barriers, we expanded the task force to include 15 additional collaborators. This group collectively explored specific aspects of the four barriers, identifying 11 practical questions that could serve as generative ways into the larger conversation (See **Table 1** for the list). Each brief drew on the evidence base, from both research and practice, to describe the salience of the issue, ideas to consider for practice, recommendations for action, and reflection questions. Links to other tools and resources were included for those who wanted to read further.

To support the use of the briefs, the task force produced additional mediating tools that science communication professionals could use to prepare for engaging in the conversations with their staff, colleagues, and boards, including:

- **Structural Analysis:** A report that summarizes four structural barriers to broadening participation efforts at scale. The report discusses each issue in depth and also provides examples of efforts that exemplify positive inclusive public engagement in STEM.
- **Summary for Stakeholders**: An overview to be shared with organizational boards, CEOs, funders, or other stakeholders to develop support for internal discussions. It explores how engaging in broadening participation can enhance the relevance and impact of the organization in its community.
- **Conversation Guide:** To help those championing equity efforts, a guide for facilitating discussions centered on the briefs. It summarizes key issues and provides tips for leading reflective conversations with staff and team members.

These tools, constituting a Broadening Participation Toolkit, can be downloaded for free from https://www.informalscience.org/broadening-perspectives.

REFLECTION ON PRACTICE IN PRACTICE

We piloted the practice briefs at four different informal science centers, one STEM-focused community-based organization, and a large national conference attended by 250 science communication and engagement leaders who had grants from the National Science Foundation's Advancing Informal STEM Learning (AISL) program. The piloting organizations used the briefs in small reflective discussions with small staff teams (4), board and executive teams (3), and a youth group. Individuals at the conference discussed briefs with colleagues both new and known to them.

In all cases, participants read one or more briefs selected as relevant to the focus of their work. For example, several of the staff groups read briefs related to pedagogy, such as *How Can We Build on Existing Assets Within A Community?* Whereas, a board of directors read briefs addressing institutional positioning issues, such as *What is a STEM Learning Ecosystem?* Participants at the national conference read *What Does Learning Have to Do with Science Communication?, What Are the Cultural Norms of STEM And Why Do They Matter?,* and *What Counts as STEM?*

When asked if their project teams would benefit from reading briefs together, individuals attending the AISL PI conference commented that the briefs could help their teams be more strategic in their program design (36%), more impactful in their Diversity, Equity, Inclusion, and Access [DEIA] efforts (35%), and better equipped to support their own/their staff's professional learning (21%). *What Are the Cultural Norms of STEM and Why Do They Matter?* was assessed as potentially the most beneficial brief for supporting professional learning and developing more strategic DEIA programs. Addressing the open-ended question: "My project

team could benefit from reading this brief together because…" responses included:

> *Our work involves co-creation with community partners; [but it] could be compromised by well-intentioned but biased cultural norms impacting the partnership and communication.*

> *We are working with communities that are culturally diverse and different from culture of [the project principal investigator].*

> *It would help us become more effective in engaging communities outside traditional ISE learning venues.*

> *We currently miss opportunities or don't have the full impact that we could if we addressed/thought about cultural norms in STEM.*

> *Culture is one of the most resilient barriers but also a powerful and under-leveraged solution space for inclusion.*

Results of the pilot testing suggest that the boundary objects may be helpful in three different ways: advancing shared understanding and thinking about DEIA, strengthening program design or approaches to advance DEIA, and building staff capacity to engage in productive reflective practice. In the next sections we discuss each one.

Advancing Shared Understanding and Thinking About DEIA

Importantly, the five pilot test organizations were already engaged in conversations about broadening participation in STEM, and there was awareness about the importance of this work. Further, at the national convening of 250 science communication and engagement leaders, by virtue of their success at securing NSF funding, it can be assumed that most individuals—because they would have read the NSF solicitations and their proposals would have been reviewed with the foundation's broadening participation goals in mind—would have been at a minimum aware of the need to deepen our understanding of how to broaden participation in STEM and in some cases might be field leaders in such efforts.

> *The briefs are super helpful because they get everybody on the same page. The conversation about diversity, about who you are serving, can be so complicated. There are people who have committed a lifetime of research to it—to assume any one of us would be an expert in this would be difficult. So, having a resource that gives us a shared view and shared things to consider is a huge help.*

One piloter described how the briefs generated discussions among her education team about the terms "equitable" and "equal" and their use throughout the science center. Another described how the "pathways" vs. "pipeline" metaphor described in the brief *Why Broaden Perspectives on Broadening Participation in STEM?* started a "great conversation about different metaphors for broadening participation." Another commented that the briefs helped her team identify not only areas they needed to work on, but things they were already doing that they hadn't realized were helping to broaden participation in their contexts.

Several participants at the AISL conference noted how the briefs, as boundary objects, could help to bridge conversations between scientists and science communicators and educators. For example, the brief *What Does Learning Have to Do With Science Communication?* was seen as potentially helping scientists, who already focused on teaching in their professional practice, see themselves as communicators. Another noted that thinking about the connection would help scientists realize the need for more careful pedagogical reflection:

> *Having our scientists understand more about how learning happens and the sociocultural context of learning will make their science communication more effective and meaningful.*

Others commented on how discussion of *What Are the Cultural Norms of STEM and Why Do They Matter?* could be helpful:

> *Dominant norms are so prevalent in physics outreach. Being able to identify them will help to push back /challenge/ constructively create new, more inclusive norms for programs and activities.*

> *We help natural scientists become more effective communicators. Often these science researchers have not thought about their cultural assumptions.*

In sum, the briefs helped respondents negotiate complex topics, opening up a space and time for reflection on assumptions, definitions, and intentions that could help to clarify whether and how science communication efforts were strongly aligned to support broadening participation in STEM or not.

Strengthening DEIA Practices in Programs and Engagement Activities

The pilot sites reported impacts on their programs and practices in three areas: public engagement, museum exhibits, and evaluation. For example, after discussing the brief *What Are the Cultural Norms of STEM and Why Do They Matter?*, a museum staff person reported that their team realized that although they organized their public programs to involve collaborative team work, their exhibit floor had a large number of images of individual scientists, inadvertently reinforcing common perceptions of science as the work of the "lone genius." They began to explore how they might illustrate the collaborative nature of science on their exhibit floor. Reading the brief *How Can We Re-Think Assumptions About Parent Engagement?* led another informal educator to reconsider the kinds of prompts they gave parents to engage their children in the programs and to include activities and ideas that parents could pursue with their children when they returned home. Another museum educator noted that the brief *What Does Learning Have to Do With Science Communication?* led her staff team to explore how they could extend participant sharing and reflection that already happened in their summer programs to the field trip programs that occurred during the school year. A museum leader said that

his brief led their staff to consider how they might better evaluate their programs on an expanded set of learning outcomes. In all cases, the pilot users noted that the questions and recommended actions to take on the briefs helped to focus their conversations and thinking toward action steps.

A museum director at a Midwestern science museum noted that staff reflection on the full suite of briefs had led to two specific changes at her museum. In the first instance, the museum was in the process of renovating its classrooms, which had been named after figures such as Galileo and Newton. Through discussing the specific actions they could take to signal more inclusion on their museum floor, the group began to consider other scientists whose names could be used for the classrooms. For the first classroom they selected African-American astronaut Mae Jemison. Because the classrooms were used not only for programs but for birthday parties for museum member families, her team is currently considering how they can develop background material to familiarize classroom users with the work of Jemison and of other scientists, representing more diverse experiences and backgrounds, whose names will be attached to future classrooms.

Second, the director noted that discussing if and how their summer programs were accessible to the broad community led them to look into the files to see how many of the 90 young people who had attended summer camp the prior year had attended on one of the scholarships offered by the museum. They found to their surprise that they had only issued one scholarship. This discovery led them to reflect on the strategies they had used to ensure that families who did not already come to the museum were aware of the programs and the financial support. The museum took two concrete actions: first, it set aside a number of camp spots only for scholarships, which placed a financial onus on the staff to make sure that they found students to fill the scholarship spots. Second they began an intensive effort to engage a range of community educators, teachers, parents, and youth at the school programs, the afterschool community programs, and the local refugee support agencies to inform parents of the programs, the financial support, and what to expect in terms of transportation, food, and the science focus. These efforts led to a significant uptick in the number of scholarships offered, going from one to 20 in the first few months.

Several participants at the AISL conference noted how using *What Are the Cultural Norms of STEM and Why Do They Matter?* could help scientists be more effective in their work:

> *It would better prepare students and scientists from my campus to communicate their science message more effectively to diverse audiences.*

Overall, participants discussed how the briefs could lead to more intentional program design decisions and implementation efforts.

Building Staff Capacity for Reflection and Discussion About DEIA

One of the pilot users noted that she had had an ongoing research-practice partnership with an informal science education researcher that had productively evolved both of their thinking about equity and learning. The briefs gave her a concrete tool to begin to extend these conversations about equity to her staff. In particular, she noted that in addition to establishing shared knowledge, the briefs' questions for reflection helped to launch and focus discussions, connecting the big ideas to their specific context and work.

> *We have everybody from exhibits to finance to education on the management team. They all have a different view of things. The reflection questions on the brief forced us to talk together in a specific direction. We would read them all out loud, and then one of us would call out one question. We made some initial changes to programs based on those conversations. Now, we are building our 5 year strategic plan, and the pillar of DEIA and how we can achieve mission has been at the forefront of our strategic planning. Thinking about our practices across the organization and what they have been and what they could be, and what that looks like.*

Several piloters noted that discussing the briefs led to reflections on the kinds of partnerships the organizations had. For example, the *What is a STEM Learning Ecosystem?* brief posed the question "Who is missing from your STEM ecosystem and why?" This prompted the group to think deeply about who they were not working with, which led them to begin to explore working with libraries more deeply. Partnerships discussions included thinking about who they were serving as well as who they were collaborating with. The Executive Director at one of the piloting organizations became enthusiastic about how he could use these specific ideas emerging from the discussions to talk to donors about new possibilities.

Above all, piloters noted that using the briefs gave gravity and specificity to discussions about equity in their workplaces. As one person described, "Once you raise that level of conversation in any setting and continue to build awareness of it, you let people know that it is an important thing to talk about." Another piloter noted that reflective discussions then circled back to concrete issues: "We were talking about our team, our organization, what is the next step and how we serve another community we want to serve and how is it that we continue to seek out support for the things we don't know. And hiring practices came up over and over again... That was so exciting to the team because they lead a lot of our people and are passionate about that. So a lot of discussion about how do we recruit folks, where do we put out postings, what is the language we use? It generated so much exciting conversation."

Participants at the AISL conference noted the professional capacity building benefits for scientists. For example, *What Does Learning Have to Do With Science Communication?* was described as being useful for helping "scientists (university faculty) to consider pedagogical practices." Another noted that the brief's reflection questions could be prompts in science communication trainings. Yet another noted that it could serve as a useful tool for science communication training programs:

> *...it will support public engagement with science professional development workshops for scientists… because scientists often do not realize the connection between teaching (in classroom) and*

communicating research to a broader audience. [And] it would give us a chance to all get on the same page about what we think learning is, and this encapsulates a lot of the learning lit that they need to know.

Several also noted also how the briefs could help science communication trainers to reflect on their own professional practices as trainers, considering what ideas and resources were most important to include in their work with scientists.

Because we train scientists and engineers in a variety of disciplines from a variety of places—[it will be] useful for us as we develop our programs and in how we provide resources to those we train.

DISCUSSION

In this section we discuss how the practice briefs hold possibilities as boundary objects. Importantly, briefs focus attention, raise questions, and seed dialogue around broadening participation and its intersection with inequality. They do not propose solutions, which will vary widely by local context. As boundary objects, they create the conditions in which solutions can be identified, considered, and tried out in good faith with full support of relevant stakeholders. Our project raised many questions about both why and how these tools can engage diverse stakeholders in dialogue about structural and institutional barriers to broadening participation in science communication.

The briefs and other boundary objects create space for dialogue that may allow for differences in views to surface, allowing people and organizations to work toward deeper, more critical shared understandings. But as people in organizations come together to reflect forward on broadening participation participants will necessarily come from different positions, locations, and perspectives.

First, the practice briefs, as boundary objects, support developing understandings on what broadening participation is and may be. As boundary objects, the practice briefs present users with commonplace scenarios and reflection questions that open up shared questions on what participation in science communication could be. These are meant to spark dialogue on the assumptions that different individuals bring to broadening participation, as well as to provide information and resources for digging deeper into issues salient to groups. Consider, for example, how organizations may currently address access and opportunity: The undergirding assumption often held by science communicators and informal science educators is that increasing access and opportunity alone will increase broadening participation. Without reflection on undergirding assumptions about why people do or do not participate (addressing issues such as the cultural norms of STEM, asset-based vs. deficit-based approaches, etc.) such assumptions built into organizational and institutional practices may actually work against broadening participation.

Information and reflection questions around why and how the "access-alone" approach places the burden of participation on non-dominant populations can yield powerful dialogue on how the lack of participation may not simply be an issue of individuals' lack of awareness, availability, cost, or physical barriers such as transportation (i.e., access), but rather to histories of systemic exclusion. As boundary objects, these briefs and documents, may support take up of if, how, and why an organization's engagement programs and opportunities may be designed, intentionally or not, to reproduce existing patterns of STEM participation.

Second, the practice briefs, as boundary objects to engage professionals with varied and disparate experiences, may promote deepening awareness of current practices and their impacts, as well as developing ideas/plans for new practices. For example, across the suite of tools, four questions are posed that expose differing perspectives while centering on the commonalities of STEM engagement: (1) Why do people choose to engage in STEM? (2) How are people asked to engage with STEM? (3) When do critical approaches to broadening participation need to happen? and (4) Where do critical approaches to broadening participation need to happen? By working through these questions, these tools support people and organizations in articulating a vision of what broadening participation means and how that vision directly impacts the *how, when,* and *where* of programs, approaches and practices. The briefs then dive into specific critical areas of broadening participation, providing brief snapshots of how these strategies and approaches work in context with the possibilities for seeding dialogue on how these practices, and variations of them, may work—or not—in one's own local context.

Tensions

The positive results reported by pilot users are highly encouraging. But there are also tensions in the use of briefs that may be relevant to other efforts to engage practitioners with research-based evidence on equity and inclusion.

First, reflection and sharing requires time as well as trust. Providing the time and cultivating the trust requires organizational leadership.

Second, several pilot users noted the need for concrete examples or illustrations of the points being made in the briefs. People noted the need for specificity, and even for examples relevant to the many different roles and responsibilities entailed in science communication and engagement. Research suggests that practitioners are more likely to embrace research findings when the contexts are the same (Nelson et al., 2009). But this creates a significant challenge to science communication, where contexts, settings, and content, and audience vary so widely. The single sheet practice briefs are necessarily limited in what they can include, and there are limited examples in the field that they can point to. This remains an ongoing tension.

Third, several pilot users noted that language could sometimes be a barrier. One person commented that when terms needed to be defined (in sidebars) she wondered if they needed to be used at all. We posit that oftentimes engaging research and practice in science communication requires people to move outside of their comfort zones and to try on new language with specific meanings. If attention is paid to definitional work, this process can strengthen conversations and collaborations (Ryoo and Shea, 2015).

Fourth, and more challenging, a few of the piloters noted their sensitivity to difficult conversations about dominant cultural norms in science and society. For example, one person noted that all of the people in her discussion group reading *What Are the Cultural Norms of STEM and Why Do They Matter?* were women. She wondered how a white male might have felt if he were in the group, and/or if that would have affected the conversation. Another pilot user said that she tested it with a group whose supervisor she supervised—being higher up in the hierarchy, with less direct contact with this group may have been responsible, she felt, for a lack of engagement with the ideas in this particular group. They may have felt uncomfortable sharing their thoughts. Another pilot user noted that not all staff are ready for the conversation at the same time.

These comments remind us that there are strong power dynamics in the workplace that must be considered, and may sometimes dissuade people from taking initial steps to be reflective about organizational practices. It is well-documented in the literature that discomfort in talking about race is a symptom of whiteness. These tools are meant to provide supports that allow movement into uncomfortableness (Swanson and Welton, 2019) because we hold the stance that white professionals in science communication must confront their own complicity and their white fragility in racial inequality that is often reproduced in their own organizations (DiAngelo, 2011). As described, these power dynamics may include race and culture, age/tenure, organizational hierarchies, and tenuousness of some professional relationships. While these structures are real and create challenges, they may also be at the heart of institutional inertia or even resistance to seriously addressing organizational histories of bias or exclusion.

Fifth, because boundary objects work at the boundaries of communities, they necessarily surface tensions as differences in language, meaning and practice inevitably emerge (Oswick and Robertson, 2009). We suggest that it is important to view working with boundary objects in efforts to broaden participation as an emerging and continual process, such that arising tensions can be considered important fodder, and collective critical insight, for next steps.

Finally, because participation in this project was voluntary, we believe that most users had achieved a particular level of "readiness" to lead and have these conversations. While this issue needs to be explored more thoroughly, it begs the question of how to generate readiness.

The CAISE task force produced the overview for organizational leaders and the conversation tips for the toolkit users as a way to begin to address and bridge these power dynamics. We posit that organizational leadership buy-in is crucial. Further research and evaluation are needed to understand whether and how conversations might want to start with those committed to addressing organizational histories and then slowly expand to include others in the organization. Further, more research is needed on whether such cultural, dialogic, and boundary crossing approaches can lead to more inclusive and productive science communication in the long run. What is clear from the organizational change literature is that any change process needs a champion(s), and that the champion needs support, which the tools are intended to provide. Ideally these conversations would take place among multiple organizations, with the leaders of the conversations participating together in a community of practice that could offer each other support and opportunities for reflection on the process. Collectively, this could create greater levels of "uptake" and changes to practice at the field level.

As flexible and open-ended tools, boundary objects are meant to offer directional guidance for issues to consider rather than a concrete roadmap for exactly what to do. Organizations, audiences, and providers all live and work in unique sociocultural, and geopolitical contexts that shape needs and practices in particular ways. The challenges of working toward broadening participation can be thorny. The Informal Science/Science Communication sector can draw on these resources as it seeks to transform its contributions to broadening participation.

CONCLUSION

Research indicates that the challenge of broadening participation is more complex than simply providing greater access and opportunity (Philip and Azevedo, 2017). Inequalities persist for individuals from non-dominant communities, leading to limited access, encouragement, and opportunity to pursue STEM futures, whether it be STEM professions or civic decision-making (Canfield et al., 2020). The CAISE task force set out to identify key structural barriers in the field regarding more systematic and systemic adoption of DEIA practices in broadening participation. One of these structural barriers involved recognizing the cultural dimensions of science and science communication, and thus the need to approach inclusion as a process of cultural boundary crossing and exchange. Based on its analysis, it then focused on creating tools—boundary objects—for professionals in the field who were committed to making change through starting or deepening reflective dialogues among their staff or peers in the workplace. To create these tools, we leveraged perspectives from both SciComm/ISE researchers and practitioners, and from across a broad range of SciComm/ISE organizations and settings. This means that not all of the practice briefs are relevant to all SciComm/ISE practitioners, but several are relevant to most.

This approach represents a potentially important tool in the toolkit for change. As one of the field testers said: "If you already think you are doing it, the briefs will help you challenge your assumption. If you are trying to move toward more DEIA, the briefs will help you start. Are you really aligned? The best thing about them is that they force a dialogue, but the hardest thing is 'what's next?' It does not take you the next step. That has to come from the organizations' desire to achieve the goal. The briefs represent one tool in the arsenal that is needed for long term change." As this pilot tester noted, the briefs put the onus on the organization: How do we keep it going, what do we do to next, why is this important? This allows each organization, different in size and pace and resources, to determine what makes sense for its specific context.

Change starts with small steps. As interest and buy-in grows, change can spread across an organization and ultimately across a field. These conversations represent a start. This is a long-term process, and toolkit users cannot expect structural field-wide changes to occur overnight. The toolkit needs to be taken up with patience and generosity toward colleagues and even the institutions we work in, understanding that even getting people in a room prepared to be reflective and discuss difficult issues can represent a significant change and opportunity.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

Following 45 CFR 46.101(b)2, Ethical and Independent Review Services, an external ethical review board, reviewed the proposed data collection plan, and has deemed the activities exempt (#16014-04). The review allows CAISE project coPIs and external evaluation partners Inverness Research, to interview and solicit views of pilot testers and participants at the NSF AISL meeting (reported in this paper). All responses reported here were voluntarily provided by project participants.

AUTHOR CONTRIBUTIONS

All authors contributed equally to the conceptualization, implementation, and analysis of the process reported here. They collaborated fully on the creation of the MS and are listed in alphabetical order.

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REFERENCES

Akkerman, S. F., and Bakker, A. (2011). Boundary crossing and boundary objects. *Rev. Educ. Res.* 81, 132–169. doi: 10.3102/0034654311404435

Anderson, K., Podkul, T., Singleton, C., and D'Angelo, C. (2019). *Summative Evaluation of the Research+Practice Collaboratory: Final Report*. (Menlo Park, CA: SRI International).

Babbie, E. R. (2014). *The Basics of Social Research. 6th Edn*. (Belmont, CA: Wadsworth, Cengage Learning).

Bell, P., and Rhinehart, A. (2015). *STEM Teaching Tool Practice Briefs Link Research to Practice*. Available online at: http://researchandpractice.org/stem-teaching-tool-practice-briefs-link-research-to-practice/

Bevan, B., and Xanthoudaki, M. (2008). Professional development for museum educators: unpinning the underpinnings. *J. Museum Educ.* 33, 107–120. doi: 10.1080/10598650.2008.11510592

Biesta, G. J. (2010). Why 'what works' still won't work: from evidence-based education to value-based education. *Stud. Philos. Educ.* 29, 491–503. doi: 10.1007/s11217-010-9191-x

Canfield, K. N., Menezes, S., Matsuda, S. B., Moore, A., and Taylor, C. (2020). Science communication demands a critical approach that centers inclusion, equity, and intersectionality. *Front. Commun.* 5:2. doi: 10.3389/fcomm.2020.00002

Dawson, E. (2014). Reframing social exclusion from science communication: moving away from 'barriers' towards a more complex perspective. *J. Sci. Commun.* 13, 1–5. doi: 10.22323/2.13020302

DiAngelo, R. (2011). White fragility. *Int. J. Critic. Pedagogy* 3, 54–70.

Fealing, K. H., Lai, Y., and Myers, S. L. Jr. (2015). Pathways vs. pipelines to broadening participation in the STEM workforce. *J. Women Minor. Sci. Eng.* 21, 271–293. doi: 10.1615/JWomenMinorScienEng.2015004760

Feinstein, N. W., and Meshoulam, D. (2014). Science for what public? *addressing equity in American science museums and science centers. J. Res. Sci. Teach.* 51, 368–394. doi: 10.1002/tea.21130

Fleischmann, K. R. (2006). Boundary objects with agency: a method for studying the design–use interface. *Inform. Soc.* 22, 77–87. doi: 10.1080/01972240600567188

Martin, L. W., Tran, L. U., and Ash, D. (Eds.). (2019). *The reflective museum practitioner: expanding practice in science museums*. New York, NY: Routledge.

Merton, R. K. (1968). The matthew effect in science. *Science* 159, 56–63. doi: 10.1126/science.159.3810.56

Nelson, S. R., Leffler, J. C., and Hansen, B. A. (2009). *Toward a Research Agenda for Understanding and Improving the Use of Research Evidence*. Portland, OR. Available online at: http://educationnorthwest.org/sites/default/files/toward-a-research-agenda.pdf

Oswick, C., and Robertson, M. (2009). Boundary objects reconsidered: from bridges and anchors to barricades and mazes. *J. Chang. Manag.* 9, 179–193. doi: 10.1080/14697010902879137

Philip, T., and Azevedo, F. S. (2017). Everyday science learning and equity: mapping the contested terrain. *Sci. Educ.* 101, 526–532. doi: 10.1002/sce.21286

Polk, E., and Diver, S. (2020). Situating the scientist: creating inclusive science communication through equity framing and environmental justice. *Front. Commun.* 5:6. doi: 10.3389/fcomm.2020.00006

Ryoo, J. J., and Shea, M. (2015). *Value Mapping: An Activity for Surfacing Power Dynamics and Diverse Perspectives in Research-Practice Collaborations*. Available online at: https://rpp.wtgrantfoundation.org/wp-content/uploads/2019/09/Value-Mapping_Nov2015.pdf

Spee, A. P., and Jarzabkowski, P. (2009). Strategy tools as boundary objects. *Strateg. Organ.* 7, 223–232. doi: 10.1177/1476127009102674

Star, S. L. (1989). "The structure of ill-structured solutions: boundary objects and heterogeneous distributed problem solving," in *Distributed Artificial Intelligence*, eds R. Gasser and M. Huhns (San Francisco, CA: Morgan Kauffman), 37–54.

Star, S. L., and Griesemer, J. R. (1989). Institutional ecology, translations and boundary objects: Amateurs and professionals in Berkeley's

museum of vertebrate zoology, 1907–39. *Soc. Stud. Sci.* 19, 387–420. doi: 10.1177/030631289019003001

Swanson, J., and Welton, A. (2019). When good intentions only go so far: white principals leading discussions about race. *Urban Educ.* 54, 732–759. doi: 10.1177/0042085918783825

Weiser, C. (2015). "Moving in and out of teaching: outlines for an account on mobilisation and transformation of personal educational knowledge for teaching," in *Paper presented at the European Conference for Educational Research (ECER) Education and Transition – Contributions from Educational Research*. (Budapest, Hungary).

Wenger, E. (2010). "Communities of practice and social learning systems: the career of a concept," in Social Learning Systems and Communities of Practice (London: Springer), 179–198.

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The remaining author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.