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SCIENCE COMMUNICATION FOR SOCIAL JUSTICE

Science communicators from marginalized backgrounds challenge STEM cultural norms to promote community belonging

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Abstract

In the U.S., navigating STEM with marginalized identities can affect scientists' communication practices. There is a critical need for science communication training that accounts for the historical oppressions, discriminations, and inequities of marginalized communities. In this paper we analyzed 712 participant responses from ReclaimingSTEM science communication workshops to understand how marginalized scientists' identities influence their science communication practices. We found that participants' experiences of exclusion and hostility in STEM spaces influenced their engagement in science communication. Scientists from marginalized backgrounds aim to change the culture of STEM through their communication efforts to promote a sense of belonging for their communities.

Keywords

Professionalism, professional development and training in science communication; Scholarly communication; Science communication teaching

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Introduction

In recent years, there has been a growing recognition for the importance for scientists to engage with publics and communicate scientific concepts effectively. This emphasis has sparked an increase in science engagement training across the United States (U.S.) [Vickery et al., 2023], where integrating science communication skills into scientific training is becoming essential [Chilvers, 2013; A. D. Dudo & Besley, 2016]. Despite these efforts, a significant issue persists — participants from historically excluded backgrounds are often marginalized and undervalued within the field of science communication [Dawson, 2014; Vickery et al., 2023]. This problem is directly linked to the absence of inclusive science communication training spaces [Canfield et al., 2020].

The current state of STEM in the U.S. perpetuates inequalities, with dominant voices in science communication being predominantly white, educated, and male [Bennett, Dudo & Besley, 2022; Callwood, Weiss, Hendricks & Taylor, 2022]. This lack of diversity influences inclusivity and validation for marginalized individuals [Chen et al., 2022; Puritty et al., 2017]. Such dynamics stem from systemic issues like racism, sexism, and ableism, resulting in the continued marginalization of people from diverse backgrounds in the scientific community [Reich, Price, Rubin & Steiner, 2010; Dawson, 2014; Valdez-Ward et al., 2023; National Research Council, 2014; Rainey, Dancy, Mickelson, Stearns & Moller, 2018]. Access and influence in science communication have historically favored historically favored white, neurotypical, non-disabled, heterosexual, and highly educated people. [Bennett et al., 2022; Dawson, 2014; Guenther & Joubert, 2017; Canfield et al., 2020; Judd & McKinnon, 2021].

Nevertheless, the empowerment of scientists from marginalized backgrounds is achievable. Empowerment, in this context, refers to how individuals from marginalized backgrounds redefine their participation in STEM through science communication [Collins, 2002]. Science communication and public engagement have the potential to redefine participation in STEM, foster a sense of belonging, and reshape the beneficiaries of STEM research [Dawson, 2018, 2019; Canfield & Menezes, 2020]. There is a pressing need for science communication training that acknowledges historical oppressions and inequities faced by marginalized communities [Canfield et al., 2020; Dawson, 2019].

The ReclaimingSTEM workshop model

ReclaimingSTEM, established in 2018 by graduate students with diverse, intersectional identities, focuses on marginalized individuals in science communication. Through five workshops since 2018, engaging over 700 participants, ReclaimingSTEM emphasizes inclusive communication principles: intentionality, reciprocity, and reflexivity. Deliberately centering on the lived experiences of marginalized creators, the workshops feature trainers committed to social justice [Valdez-Ward et al., 2023].

Unlike conventional approaches, ReclaimingSTEM workshops exclusively prioritize marginalized identities, shaping a unique space where participants explore the intersection of identity and science communication. The initiative aims to transcend typical training, which often perpetuates whiteness and cis heteronormativity, instead centering solely on marginalized identities. Employing intersectionality [Crenshaw, 2013], the workshops recognize participants' diverse identities — sexual orientation, gender, race, physical abilities, and socioeconomic status — acknowledging how these intersect to shape experiences within STEM. The application process allows participants to self-identify, embracing a multidimensional perspective beyond predefined categories, combating historical survey limitations in capturing diverse identities. ReclaimingSTEM's approach fosters inclusivity, countering the flattening effects of traditional categorization methods.

The ReclaimingSTEM application process poses the question, "With which groups do you self-identify?" This inquiry remains open-ended, encouraging participants

to share a multitude of identities beyond what predefined categories or checkboxes could capture. Opting for self-identification rather than conventional categorization enables a multidimensional and intersectional perspective of individuals. This approach counters the flattening and invisibilizing effects associated with historical census-based survey items, as highlighted by Irizarry [2015] and López, Vargas, Juarez, Cacari-Stone and Bettez [2018].

All our participants are scientists, and a significant portion of our participants identifies as Black, Latine, LGBTQIA+, first-generation students, disabled, and/or women, among other identities. Workshops address this diversity by exploring themes such as navigating STEM spaces, exploring identity and intersectionality, and topics related to self-care.

ReclaimingSTEM's focus on marginalized identities also provides an opportunity to delve into why individuals from these backgrounds enter science communication spaces. Workshop applications posed the question: "How does your identity influence and impact your science and communication style?" Using responses to this question from 712 workshop participants, this study responds to the paucity of research that explicitly relates identity and communication efforts.

Using Science Identity Theory [Carlone & Johnson, 2007] and Communication Theory of Identity [Hecht, Warren, Jung & Krieger, 2005] as theoretical frameworks, this study asks the following questions:

RQ1. How do participants self-identify in STEM spaces?

RQ2. How do participants leverage their identities for science communication?

The study analyzed self-identifications of 712 workshop participants, revealing diverse intersectional identities, including LGBTQ+, ethnic/racial backgrounds, first-generation students, and various gender identities. It explored the science communication practices of marginalized scientists, highlighting their inclusive communication approaches rooted in community-driven motivation. The findings from this study indicate a shift in science communicators' priorities towards issues of identity within STEM. Participants aim to use science for service towards their communities to foster a sense of belonging, and advocate for a broader definition of science communication that embraces diverse forms of engagement.

Literature review

Navigating STEM spaces

Systemic racism in the U.S. stems from ingrained Eurocentric thinking, leading to policies and practices that harm people of color [Elias & Feagin, 2016]. The U.S. National Science Foundation (NSF) uses the term Underrepresented Minority (URM) for racial and ethnic groups with lower representation in STEM than expected based on their population share [National Science Foundation, 2019]. However, this term doesn't address the underlying oppressive forces, like racism, that contribute to the disparities in STEM. Therefore, in this paper, we use the term historically marginalized communities. This term acknowledges the lived experiences these communities face within the white supremacist, racist contexts

that mark their everyday lives [Calabrese Barton & Tan, 2018]. Additionally, instead of grouping identities, we acknowledge the various, unique, intersectional identities of the communities we are working with.

Hooks [2014] advocates for education as freedom, emphasizing that schools should be places of belonging where students are valued for their entire selves. Similarly, STEM spaces should foster a sense of acceptance for people to participate as whole individuals. However, documented instances of bias, harassment, and discrimination create hostile environments in STEM, particularly for those from marginalized backgrounds [Mattheis, De Arellano & Yoder, 2019; Berhe, Hastings, Schneider & Marín-Spiotta, 2020].

As communicative exchanges can marginalize, stigmatize, and exclude others, representation of marginalized people and intentional communication about access barriers are important in helping create a sense of belonging and retaining scholars from marginalized backgrounds. Research consistently highlights the hostile STEM environments experienced by individuals from marginalized groups, including Black, Indigenous, People of Color, white women, transgender individuals, those with disabilities, and foreign-born or international scholars [Atherton et al., 2016; Camacho & Lord, 2011; Postel, 2015; Sian, 2017]. Recent research further uncovers inequities related to sexual orientation and gender identity [Riegle-Crumb, King & Irizarry, 2019; Sansone & Carpenter, 2020].

STEM identity

There is a demonstrated link between science identity and STEM engagement. Science identity encompasses an individual's self-perception as a scientist and their feeling of belonging within the community of scientists [Huffmyer, O'Neill & Lemus, 2022]. Science (STEM) identity theory (SIT), as a theoretical framework, helps us understand how experiences influence persistence in STEM [Carlone & Johnson, 2007]. Tytler [2014] attributes the growth of this framework to its ability to blend psychological and sociological elements, explaining how students navigate encounters with science (p. 89). More precisely, students' actions and decisions related to their careers are influenced by whether they perceive themselves and are perceived by others as a particular type of person (e.g., a "science person") [Hazari, Sonnert, Sadler & Shanahan, 2010].

Carlone and Johnson [2007] show that there are different science identities, particularly among women of color. In their study looking at successful women of color in STEM, they identified three trajectories: research scientist, altruistic scientist, and disrupted scientist. A research scientist is passionate about science and is recognized as such by faculty. An altruistic scientist sees science to promote altruistic outcomes, redefining concepts like 'science' and 'recognition'. A disrupted scientist seeks recognition but often faces challenges in finding a sense of belonging. Despite their success, women of color face extra hurdles because of how their gender, ethnicity, and race affect recognition in academic contexts. SIT has many implications, including rethinking recruitment and retention strategies for women of color in science, and scientists from marginalized backgrounds more broadly.

A great number of our participants identified as LGBTQ+. According to Roberson and Orthia [2021], while some attention has been given to queer communities, it's often superficial or tangential. There's a dearth of work considering queer individuals as communicators and audiences in science communication. They suggest that queering science communication involves not only acknowledging the presence of queer individuals but also challenging deeply ingrained cultural norms within the field to create a more inclusive and diverse future. To that end, our study also involves the use of queer theory, a critical academic framework, questions conventional understandings of gender, sexuality, and identity, aiming to dismantle normative categories and expose systems of oppression while advocating for inclusivity and social justice. It challenges binaries and explores the fluidity and complexity of human experiences, emphasizing intersectionality and the recognition of diverse identities [Mattheis et al., 2019].

STEM identity is how individuals perceive themselves as scientists, influenced by their interactions with scientific contexts [Kim & Sinatra, 2018]. SIT suggests that a strong STEM identity leads to greater pursuit and persistence in STEM careers and studies [Carlone & Johnson, 2007; Kim & Sinatra, 2018]. Factors like personal interests, experiences, and societal norms shape STEM identity. It can be shaped by early interests, educational experiences, family and socio-political contexts, and professional experiences [Mattheis et al., 2019].

This study bridges SIT and the Communication Theory of Identity (CTI), which suggests that communication practices in STEM careers shape individuals' self-perception and how they are seen by others, influencing their STEM identity and career goals. CTI posits that identity is shaped through communication [Hecht et al., 2005]. It identifies four frames through which this occurs: personal (self-image), relational (how one is perceived by others), enacted (expressed identity), and communal (collectively defined). These frames can interact and overlap, influencing how a person forms their identity.

Rodrigues, Takahashi, Tiffany, Menezes and Valdéz-Ward [2023] found that communication integrates various aspects of identity, fostering a dynamic awareness of self and communication style rather than a fixed self-concept. The results of the study by Rodrigues et al. [2023], underscore a gap in most science communication training programs, including both short-term skills-based training [Baram-Tsabari & Lewenstein, 2017] and longer fellowships [Bennett et al., 2022; Roca, Coleman, Haelle & Lee, 2020], where full integration of participants' identities for culturally responsive training is often lacking. Considering these findings, there is a need for science communication training that considers the priorities of individuals from diverse cultural and ethnic backgrounds rather than adopting a one-size-fits-all approach [Baram-Tsabari & Lewenstein, 2017; Bennett et al., 2022; Roca et al., 2020].

Numerous studies have investigated scientists' perspectives on public engagement and its significance in shaping their professional identity [Besley, Dudo, Yuan & Lawrence, 2018]. In one study by Murphy and Kelp [2023] looking at motivations of undergraduate STEM students in community engagement, authors found science communication skills, science identity, and science self-efficacy were all predictors of student motivation and behaviors in STEM engagement with communities outside of academia. However, the authors note that their study

population was disproportionately white and female. Given the intentionally diverse demographics of the ReclaimingSTEM workshops, our study aims to uncover the priorities and motivations of marginalized scientists' participation in science communication.

Sense of belonging

The universal human need for social connection, essential in accessing resources and crucial emotional support [Nagoski & Nagoski, 2019] is intricately linked to the concept of a sense of belonging. This fundamental aspect encompasses feelings of fitting in, comfort, connections, respect, safety, mattering, and importance within a social setting [Vaccaro & Newman, 2016]. Serving as a binding force, the sense of belonging connects individuals to their environments [Strayhorn, 2018]. Strayhorn emphasizes that it extends beyond a basic human need, intersecting with and influencing social identities ([2018, pp. 122–123]. Those lacking a sense of belonging may not derive the same benefits from experiences as those with a stronger connection.

Standpoint theory, as advocated by Ladson-Billings [1995], underscores how an individual's social position shapes their perspective (on the world. This theory posits that marginalized groups provide unique insights into social structures and power dynamics. ReclaimingSTEM workshops and their participants are distinctive in that the workshop intentionally privileges marginalized viewpoints. This emphasis aligns with standpoint theory, as the workshop creates a platform where marginalized perspectives can offer unique insights into social structures and power dynamics with STEM. Moreover, it can provide insights into why scientists from marginalized backgrounds approach science communication training.

Communication approaches

Freire [1996] criticizes traditional education styles as one-way knowledge transfer, akin to a "banking" model. Similarly, science communication often follows a deficit model, if more information will change beliefs or behavior [Simis, Madden, Cacciatore & Yeo, 2016]. This approach can be inefficient and may reinforce marginalization. Scientists traditionally focus on sharing knowledge without considering their audience's needs [A. D. Dudo & Besley, 2016]. This one-sided approach can be improved with more audience-centered strategies, particularly for scientists from diverse backgrounds [Canfield & Menezes, 2020].

In addition to the calls for more audience-centered and engaging models of communication, science communication scholars have emphasized the value of trainings that emphasize self-reflection and strategic communication practices, among other competencies [Baram-Tsabari & Lewenstein, 2017; Lewenstein & Baram-Tsabari, 2022; A. D. Dudo & Besley, 2016; Bennett et al., 2022; A. Dudo, Besley & Bennett, 2020]. Studies have explored the communication goals of scientists, including personal and societal benefits, as well as building trust and excitement for science [Besley, Dudo, Yuan & Abi Ghannam, 2016]. However, there is little research in U.S. settings about how marginalized scientists approach their communication efforts and what their goals are. Our study aims to address this

gap by delving into the motivations, goals, and communication approaches used by scientists from marginalized backgrounds.

Methods

Positionality statement

This study arose from the increased need for spaces like ReclaimingSTEM, which was organized by co-authors, Valdez-Ward and Ulrich. The full list of authors often faced toxicity in their own STEM spaces based on their identities (Latina, Woman, Queer, Previously Undocumented, Biracial, Southeast Asian, Non-binary, chronically ill). We came to science communication from a shared desire to give back to our communities. All co-authors on this paper have shared interests but originate from diverse backgrounds and currently inhabit distinct social spheres. We leverage these variations to enhance our collective viewpoint as research collaborators. While we share many identities with our participants, we also differ in many ways. Therefore, we approach their stories with an awareness of the inherent limitations in our perspectives. We as co-authors are constantly listening and reading and learning from one another as we approach the data and analysis with the upmost respect for our participants' identities and experiences.

Sampling

Five ReclaimingSTEM workshops have occurred since 2018 in the United States. Years 2018 and 2019 were in person, one-day workshops, while 9 2020 and 2021 were virtual, encompassing 3 or 4 3-hour sessions each. More than 700 workshop applications were received (Table 1).

We mainly reached our participants through Twitter (now "X") advertisements, announcing our workshop as a place where science communication and policy merge with social justice, along with some email advertising through listservs with collaborators and sponsors. Most participants were students, with a large portion being doctoral students (Table 2).

Application questions asked about:

- Level of education (Undergraduate, Master's, PhD, Postdoc, Faculty, Other)
- What groups do you self-identify with? (open-ended)
- How does your identity influence and impact your science and communication style? (open-ended)

Coding and analysis

We apply grounded and queer theory to explore how power, oppression, and inequities impact individuals and groups [Charmaz, 2011, p. 362; Mattheis et al., 2019]. Grounded theory is a qualitative approach that builds theory from data [Strauss & Corbin, 1990, p. 15]. This process involves iteratively organizing data to

Table 1. Participants for the ReclaimingSTEM workshops.

Year	Participants
2018 In person	45
2019 In person	190
2020 Virtual	387
2021 Virtual	90
Total	**712**

Table 2. Education level for participants.

Education level	Participants
PhD Student	348
Master's Student	88
Undergraduate Student	110
Postdoc	37
Faculty	40
Other (industry, etc)	89
Total	**712**

construct themes, essences, descriptions, and theories [Walker & Myrick, 2006, p. 549].

To authentically represent participants' responses and their lived experiences, we aim to describe our findings in a way that is not limited by existing theories. Therefore, we also applied Timmermans and Tavory's [2012] approach to data analysis, in that the data were analyzed using abduction, a qualitative approach to theory construction that relies on iterative moves between data and theory building, with particular attention given to unanticipated and surprising observations.

Given that many of our participants identified as LGBTQ+, we employed queer theory in our analysis. This theory encourages researchers to seek unique insights and disrupt social constraints on identity and expression [Mattheis et al., 2019].

For this analysis, we coded the participants' responses for the questions "What groups do you self-identify with?" and "How does your identity influence and impact your science and communication style?" We completed a thematic analysis using NVivo software to identify key themes within the application responses. E. V.-W. did the primary round of coding, checking with co-authors on emerging themes and sub codings. Discussion with co-authors determined those themes to appropriately encompass the response data. E. V.-W. then returned to continue coding, and several meetings with co-authors were held to develop a framework as the process progressed.

Table 3 presents all identities offered by participants when prompted with an open-ended question. We coded identities to account for similar reporting of participant identities (For example: Queer, Lesbian, Bi, was coded under LGBTQ+). However, please note, this is not truly representative of our participants' identities,

as there are many intersectional identities (ex: Black, Queer, First-Gen, Woman). We therefore included broad category labels to each identity label to look at groupings mentioned (for example: First-generation, LGBTQ, Education Status). We then counted how many intersectional categories were mentioned (Table 4).

For the question on identity and communication style, we identified topics in three major categories: 1) Experiences in STEM, 2) Communication Style and Approach, and 3) Goals. For Experiences in STEM, we coded any instance or experiences that participants may have had in STEM that led to them to desire entering STEM, science communication spaces, or to attend our workshop. As for Communication Style and Approach, we coded any mention of how they aim to do science communication. For Goals, we coded any instance in which respondents mentioned what they aimed to achieve with their science communication.

This study was determined exempt under the UCI Exempt Self-Determination Tool obtained from the IRB department. As part of using the Exempt Self-Determination Tool, the lead researchers provided their assurance that they followed relevant Human Research Protection Program policies and procedures, among other criteria.

Results and discussion

Intersectional identities were common among ReclaimingSTEM workshop participants

An analysis of the question "What groups do you self-identify with?" comprises responses from 712 workshop participants, categorizing their identities across various dimensions (Table 3). One of the largest groups identifies as LGBTQ+, with 253 respondents identified within this spectrum. Ethnic and racial identities were mentioned by 305 respondents, encompassing various designations. Additionally, 119 respondents identified as first-generation students, while gender identities varied widely, with 197 respondents identifying as women, female, non-binary, and various other designations. Socioeconomic status, disability and neurodiversity, religion and cultural identity, nationality and immigration status, academic and professional identity, allyship and advocacy, and other identifiers were also represented in the responses, providing a snapshot of the diverse range of backgrounds and identities represented in the applicant pool.

When analyzing the number of identities mentioned by participants at the ReclaimingSTEM workshop, most participants mentioned 2 or more categories of identities (n= 603), while fewer mentioned only one category (n=109) (Figure 1). The analysis of self-identifications of identities from 712 workshop participants revealed a diverse range of intersectional identities. These results align with current research findings from Rodrigues et al. [2023], where research scientists from BIPOC backgrounds saw their identities as fluid, layered, and complex.

Interestingly, although we had 153 types of categories and lists of categories (ex: First generation, LGBTQ, Race/Ethnicity), the most mentioned category types include a variation of mention of First Generation, Race/Ethnicity, LGBTQ+, and Gender. In Table 4, we include the most mentioned intersectional categories from our participants.

As most of our participants have intersectional identities, it gives us the rare opportunity to understand scientists from historically marginalized communities'

Table 3. All identities of ReclaimingSTEM participants.

Identity Category	Count
LGBTQ+	**253**
LGBTQ+	128
Lesbian	11
Gay	8
Bisexual	26
Queer	35
Transgender	13
Non-binary	15
Intersex	3
Asexual	5
Pansexual	9
Ethnic and Racial	**305**
African American/Black	61
Latinx/Hispanic	98
Asian/Asian American	57
Native American/Indigenous	14
Pacific Islander	3
Middle Eastern/Arab	9
Indigenous	5
Mixed Race/Multiracial	29
Caucasian/White	13
Filipino	3
South Asian	12
Mixed (Chicano and white)	1
First-Generation Status	**119**
Gender Identity	**197**
Woman	83
Female	59
LGBTQ+	2
Non-binary	19
Genderqueer	5
Transgender	21
Genderfluid	4
Gender-non-conforming	4
Socioeconomic Status	**23**
Low-income	14
Low-socioeconomic background	9
Nationality and Immigration Status	**32**
Immigrant	13
International	11
Second-generation Immigrant	4
Undocumented	3
Refugee	1

Identity Category	Count
Disability and Neurodiversity	**88**
Disabled	21
Neurodivergent	12
Disability	20
ADHD	6
Chronic illness	9
Mental illness	9
Learning disabilities	5
Autism/Asperger's	4
Lupus	2
Religion and Cultural Identity	**21**
Muslim	7
Jewish	5
Atheist	3
Buddhist	2
Indigenous/Taino	2
Hindu/Brahmin	1
Sikh	1
Academic and Professional	**138**
STEM	46
Women in STEM	16
Non-traditional student	15
Woman in Science	4
LGBTQ in STEM	4
Scientist/Researcher	8
PhD Student	7
Grad Student	8
First-gen Grad Student	3
Student	23
Woman in Chemistry	1
Marine Biologist	1
Yogi	1
Allyship and Advocacy	**3**
Ally to LGBTQ	2
Ally to African American Youth	1
Other Identifiers	**30**
Person of Color (POC)	23
Marginalized	2
Minority	4
Orphaned	1

inclusion of identity in science communication. Intersectionality is a concept that seeks to account for the complexity of identities and social inequalities. In accordance with queer theory, we also find evidence that identities are not fixed, and rather fluid and complex. Understanding the various intersectional identities of participants in the context of science communication goes beyond mere acknowledgment of various systems of oppression; it involves comprehending how these categories interact to create and sustain social disparities [Reznik, Massarani & Calabrese Barton, 2023].

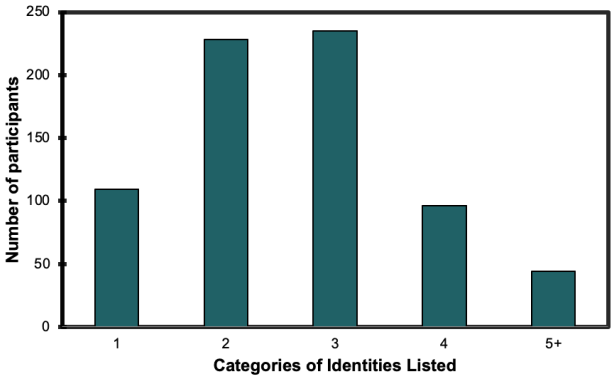

Figure 1. Intersectional identities of participants. Most participants (y-axis) at the ReclaimingSTEM workshop mentioned various categories of identities ranging from 2 identities or more (y-axis).

Table 4. Participants at ReclaimingSTEM workshops with 2 or more identities mentioned and their most mentioned identity category types.

Intersectional Categories	Instances
First Generation, Race/Ethnicity	53
First Generation, Race/Ethnicity, LGBTQ	40
LGBTQ, Race/Ethnicity	34
Gender, Race/Ethnicity	30
First Generation, Gender, Race/Ethnicity	28
Gender, LGBTQ	28
Gender, LGBTQ, Race/Ethnicity	16
First Generation, Gender	13
First Generation, LGBTQ	12
First Generation, Race/Ethnicity, LGBTQ, Gender	10

Navigating STEM spaces

Scientists from marginalized backgrounds often experienced STEM spaces as an obstacle course that had to be navigated [Berhe et al., 2020]. This obstacle course in STEM was described by many of the participants in ReclaimingSTEM workshops. An overwhelming majority of the participants described their relationship with science as hostile. Several participants cited times in which they experienced discrimination and discouragement, imposter syndrome, the isolation of being "the only one", or felt that STEM was not welcoming, or had to combat identity-based stereotypes. To that end, responses highlighted experiences in STEM as hostile and filled with obstacles, highlighting a need for greater inclusion. Additionally, responses mentioned needing to shift identities and seeking strong support systems to persist.

Experiencing hostility in STEM

Workshop participants described incidents of discrimination, imposter syndrome, and the struggle to be taken seriously. Many also expressed the isolation of being the only representative of their identity in their field.

> "As a young scientist, I did not see my Queer Butch self reflected back to me in any of the scientists I saw. As a result I always felt like an outsider within the STEM community and even within the entire academic system. I felt alone." (reference 33)

Shifting identities

Some respondents expressed being compelled to hide or downplay their identities to navigate the STEM landscape.

> "Unfortunately as a Bisexual Black Cis-Gendered Man I had to learn how to hide my identity or selectively mute it to survive. This survival skill which was part code-switching and part learning how to selectively choose which pieces of me to reveal added to my capacity for compassion." (reference 6)

Navigating obstacles in STEM

Many participants wrote that they understand that navigating STEM spaces is difficult, and thus want to help others navigate these same systems, especially through representation.

One applicant wrote about how the visibility of their identity can help others navigate STEM spaces and feel more welcome. This person changed their mind about publicly acknowledging a marginalized identity specifically to support others' experiences of inclusion.

> "A year ago, I never would have openly admitted I was disabled. Now, I am embracing my disabled experience in order to normalize the disabled experience for others, which will ultimately create more inclusivity. As someone who is first-generation, I also know the struggles of just not knowing anything." (reference 9)

Pushing for inclusion and belonging in STEM spaces

Despite these obstacles, participants demonstrate resilience and determination to combat stereotypes and promote inclusivity. They emphasize the importance of role models, mentorship, and supportive environments in overcoming these challenges. Some also acknowledge the shifts in their own identities and the need for empathy towards others facing similar hurdles,

> "As a queer Hispanic [scientist], I've always felt an unspoken pressure to prove myself. To work harder and show that I'm just as good as my peers, that my identity didn't define my abilities. However, I've come to realize how critical it is to keep my queerness and Hispanic roots at the center of everything I do. That is not about fitting the mold of success that has been designed, but changing the mold to fit me and all my layers." (reference 4)

Support systems

Strong support systems, including affinity groups and mentors who share their identities, prove invaluable in overcoming barriers and achieving success in STEM.

> "As an Indigenous scientist, I rarely get the opportunity to interact with native mentors. I have found that the times I have interacted with fellow native academics has shaped my science and communication styles." (reference 79)

For several participants, having mentors who shared their identities was important in learning how to navigate STEM spaces,

> "During my time in grad school, I was extremely fortunate to work under incredibly bright, compassionate, and successful women scientists. I learned to show enthusiasm for my science, consider my audience, ask questions, be curious, and I gained some of my confidence back. I was also taught how to use my gender successfully in a field dominated by men because successful women have a different approach than successful men." (reference 50)

The narratives shared by participants in the ReclaimingSTEM workshops offer profound insights into the dynamics of STEM identity formation and communication practices, resonating strongly with theoretical frameworks SIT and CTI. SIT suggests that individuals' perceptions of themselves as scientists are shaped by their interactions and experiences within STEM contexts [Carlone & Johnson, 2007]. Participants' accounts of navigating STEM spaces underscore the significant influence of personal identity on their sense of belonging and persistence within the field. These narratives illuminate how individuals from marginalized backgrounds negotiate their identities in response to the challenges and biases inherent in STEM environments, highlighting the dynamic nature of STEM identity formation as described by SIT.

Furthermore, CTI provides a framework for understanding how communication practices shape individuals' self-perception and how they are perceived by others within STEM settings [Hecht et al., 2005]. Participants' descriptions of the communication strategies they employ to navigate STEM's challenges, such as code-switching and selective disclosure of their identities, illustrate the multifaceted nature of identity enactment and expression. Additionally, the emphasis on supportive networks and mentorship in participants' narratives aligns with CTI's relational frame, emphasizing the role of interpersonal communication in shaping individuals' identities and sense of belonging within social groups. Overall, these narratives shed light on the intricate interplay between identity and communication within STEM, highlighting the importance of inclusive approaches to science communication and identity affirmation [Canfield & Menezes, 2020; Dawson, 2018].

Communication style

Based on the applicant's experiences in STEM spaces, they engage with their communities' using styles that are audience-centered, emotionally driven, and

identity-centered. Several participants also wrote about traditional science communication approaches, including making topics concise and clear, direct, and avoiding jargon.

Audience-centered

For *audience-centered* communication styles, participants make sure to emphasize *inclusion* and *do not assume prior knowledge*.

> "As a mixed-race Mexican-American, LGBT-identifying woman in STEM, I participate in a lot of communities, and interact with a lot of people who are very different from each other. This has given me the ability to focus on not only making sure that my communication style is inclusive of others, but in finding ways to describe science that are not reliant on coming from a certain background to be understood." (reference 18)

Other participants make sure to center their audience in their engagement through *open, honest, attentive, personal, and respectful* communication, Many participants mentioned their use of *storytelling* to center their audience, as this is how their family communicated with them,

> "My abuelita was a natural born storyteller and had incredibly good memory. Everyday during coffee time she would tell me a different story from her past, this is how I learned a lot of what I know about my family's past, but also about my country's culture and history. It is most importantly, how I developed a love of stories and storytelling. I believe strongly in using human stories to engage people…" (reference 34)

Emotion-driven

Many participants cite using joy and laughter to help encourage engagement. Others wrote about the use of empathy as part of their communication style.

> "I identify as a multi-racial, gay male. I think that being in the closet for so long allows me to empathize with feelings of not understanding what is going on, feeling left out, and feeling left behind. I think these feelings translate to my communication style by allowing me to more easily be understanding and patient when someone does not comprehend a concept or idea…" (reference 9, 2018 workshop)

Identity-centered

When using *identity-centered* styles, participants found it important to incorporate their identities or their communities in their communication styles.

Some participants emphasized needing to be *inclusive* by including the proper use of pronouns. Others write about culturally relevant engagement styles, and often feeling a responsibility to represent their communities,

> "As a Black woman in STEM, I am consistently thinking about how my research…can positively or negatively affect people of color. While it should be everyone's responsibility to be aware of this, I know that it usually is not, so I feel a responsibility to do so. In doing so, I believe it is important to communicate science in a way that is culturally relevant and free of jargon so that all people of color are able to understand and benefit from the information." (reference 109)

Several participants also mentioned a need to be *authentic* in their engagement, to help others feel welcome in STEM spaces,

> "I try not to hide my identity while teaching. I want to be as authentic to myself as I can be without having to sacrifice essential aspects of my identity in order to succeed in science. On a smaller level, I feel like this can help others who may feel marginalized in a similar way to me." (reference 8)

Participants' emphasis on inclusion and accessibility in their communication strategies aligns with the principles of audience-centered communication advocated by SIT, which emphasizes the importance of individuals' perceptions of themselves and their interactions within STEM communities [Carlone & Johnson, 2007].

These responses delve into how marginalized scientists utilize emotion-driven communication styles, like empathy and humor, underscoring the role of emotional resonance in science communication [Canfield & Menezes, 2020; Dawson, 2018], aligning with CTI's framework [Hecht et al., 2005]. It emphasizes the importance of cultural relevance and representation, especially for marginalized groups, in science communication efforts. Furthermore, marginalized scientists' communication practices are deeply rooted in their lived experiences and community ties, offering more inclusive approaches [Canfield & Menezes, 2020; Dawson, 2018]. Their endeavors are often community-motivated, emphasizing the need to prioritize their perspectives in designing inclusive training programs that foster authenticity and inclusivity.

Goals for communication

This study on ReclaimingSTEM workshop participants uncovers that marginalized scientists aim to create a sense of belonging for their communities within STEM.

Their motivation is influenced by personal experiences navigating the STEM environment, leading to a focus on audience, identity, and emotion in their communication styles. Their goal is to empower their communities in STEM, achieved through advocacy, representation, community service, and authentic self-expression in the field.

We found that our participants have different goals through their communication efforts. Mainly, they seek an overall objective of fostering a sense of belonging for their communities in STEM spaces, and they do this through long term goals of *increasing representation, advocacy, creating spaces, serving their communities, and bringing their full selves into STEM spaces*.

Increase representation

Many participants write that they wish to *increase representation* in their fields, or in STEM in general. Several participants also aim to increase representation by spotlighting other scientists from marginalized communities. Many others wrote that they aim to increase representation through being a *role model themselves*.

> "As I began to pursue [my field], I couldn't help but notice the lack of diversity. Representation is vital because it helps children, especially those of color, realize what they can become. As a first-generation, lower-income person of color, I want to become this role model for others who don't get to see this part of education due to the lack of access to it." (reference 58)

Advocacy

Many participants want to use their engagement to advocate for their communities in STEM. Mainly, what they hope to achieve is to *change the culture of STEM*. Others write about *increasing accessibility*. Other participants want to provide accommodation in STEM spaces. Some write about increasing access to science information, for example in different languages.

> "As a person of color with immigrant parents, I have always felt the importance of effective communication between experts and the general public, especially with those who are limited in understanding English. I believe that scientists have a critical role in distributing scientific information to the general public in a digestible way…" (reference 65)

Create spaces

As many participants had negative experiences in STEM spaces, these participants are focused on helping to *create spaces* for others, for some this means making sure others do not experience STEM in the way they did. For others, *creating space* means being part of a welcoming STEM community,

> "Through past encounters and facing these challenges head on, I am able to put on a brave face and be proud of my work and thoroughly explain the value of my research to others. Someday I hope the subtle inequalities and imbalances in the STEM…are disbanded. However, in the meantime I strive to be a part of the welcoming scientific community for others to share their knowledge…" (reference 8)

Service

In terms of *service for their communities*, some participants wrote this means learning to be a better ally, or learning to leverage their privilege. Other participants write that they conduct science and do engagement activities for their community.

> "…my research project, low income communities and people of color just like myself deserve the exact same services as any other individual and that it why I place my focus on communities such as these to better their conditions and learn more about these neighborhoods' needs, that others don't take the time to care for." (reference 21)

Bring full self into STEM

Many participants describe their need, or responsibility, to *bring their full-selves into STEM* spaces so that others see themselves represented in STEM spaces. One applicant wrote,

> "As a disabled woman in STEM, my science communication style is primarily motivated by ideas of accessibility and inclusivity in the products I produce, the language I use, and the information I communicate about…" (reference 10)

According to Besley et al. [2016], scientists often join communication training with diverse goals, ranging from personal career advancement to societal impact. While trainers stress the importance of aligning training with scientists' objectives, programs often prioritize skill development, overlooking strategic communication goals such as fostering excitement and building trust. Our study further emphasizes the need for tailored communication training, especially for marginalized scientists, who prioritize representation, advocacy, and inclusivity in STEM. By delving into the specific communication goals of marginalized scientists, our research sheds light on their efforts to increase representation, advocate for underrepresented communities, and create inclusive STEM environments. This comparison highlights a shared commitment among scientists to leverage communication for social change and inclusivity across diverse backgrounds and disciplines.

Our results also suggest that participants aim to use their science for service to their own communities, working towards social change. This is in line with results from a study by Garibay [2018], who investigated the factors influencing long-term development of STEM bachelor's degree recipients' social agency and value for conducting research for social change. Garibay [2018] found that college experiences and institutional contexts played crucial roles, with racial/ethnic identification, gender, socioeconomic status, undergraduate majors, faculty and peer socialization experiences, and institutional emphasis on civic values being significant predictors of these outcomes.

Besley [2020] and Besley and Dudo [2022] write that before engaging in communication efforts, science communicators often fail to clearly identify specific behavioral goals they aim to achieve. Behavioral goals refer to the audience-specific behaviors that communicators want to see from their communication efforts. Our study delves into the goals of marginalized scientists in STEM communication. These scientists know their goals for science communication as they aim to create a sense of belonging for their communities within STEM through their communication efforts. Their motivation stems from personal experiences navigating the STEM environment, leading them to prioritize audience, identity, and emotion in their communication styles. Our study highlights various long-term goals pursued by participants, including increasing representation, advocacy, creating spaces, serving their communities, and bringing their full selves into STEM spaces.

While not explicitly mentioned, we believe our participants have a shared overall objective to use their science communication to foster a sense of belonging in STEM for their communities and science. Besley [2020] and Besley and Dudo [2022]

describe objectives in science communication as intentional, intermediate outcomes that serve as mediators leading to desired behaviors. These objectives focus on cognitive or affective changes that precede observable behaviors. Our participants constantly mentioned serving or giving back to their communities through their science communication.

Identities in science communication

Responses to the question "How does your identity influence and impact your science communication style?" were coded in regards to experiences, style, and goals and objectives.

Overall, the participants to the ReclaimingSTEM workshop have had negative experiences navigating STEM spaces. These experiences influenced participants to use communication styles and methods that are audience-centered, identity-focused, and emotion-driven, in addition to traditional science communication methods (i.e., inform, avoid jargon, etc).

We find that participants mainly felt othered in their science spaces, and therefore through their science communication they aim to foster a sense of belonging for their communities in STEM spaces. Consequently, the participants aim to achieve this objective through long term goals in science communication that include advocacy, increasing representation, service to their communities, creating spaces, and bringing their full-self into STEM spaces. (Figure 2).

Conclusion

The analysis of self-identifications of identities from 712 workshop participants revealed a diverse range of intersectional identities, including LGBTQ+, ethnic/racial identities, first-generation students, and various gender identities. Additionally, participants included aspects of identities and backgrounds, including socioeconomic status, disability/neurodiversity, religion/cultural identity, nationality/immigration status, academic/professional identity, allyship/advocacy, and other identifiers. We suggest that future research should build upon this study by incorporating the various, intersectional aspects of identity into the experiences of scientists engaged in communication and public engagement training activities.

Our findings reveal a shift in priorities for science communicators with historically marginalized identities. Unlike the traditional emphasis on increasing scientific knowledge and societal value [Besley et al., 2016], our participants are more focused on issues of identity within STEM. Previous research by A. D. Dudo, Besley and Yuan [2021] highlights that current training spaces primarily teach scientists to refine their own messages and find opportunities to engage with their science. However, these spaces do not address the specific needs of trainees from marginalized backgrounds.

Our study's findings resonate strongly with both CTI and SIT, offering valuable insights into the dynamic relationship between identity and science communication within STEM environments. By examining the self-identifications of 712 workshop participants, we revealed a diverse array of intersectional

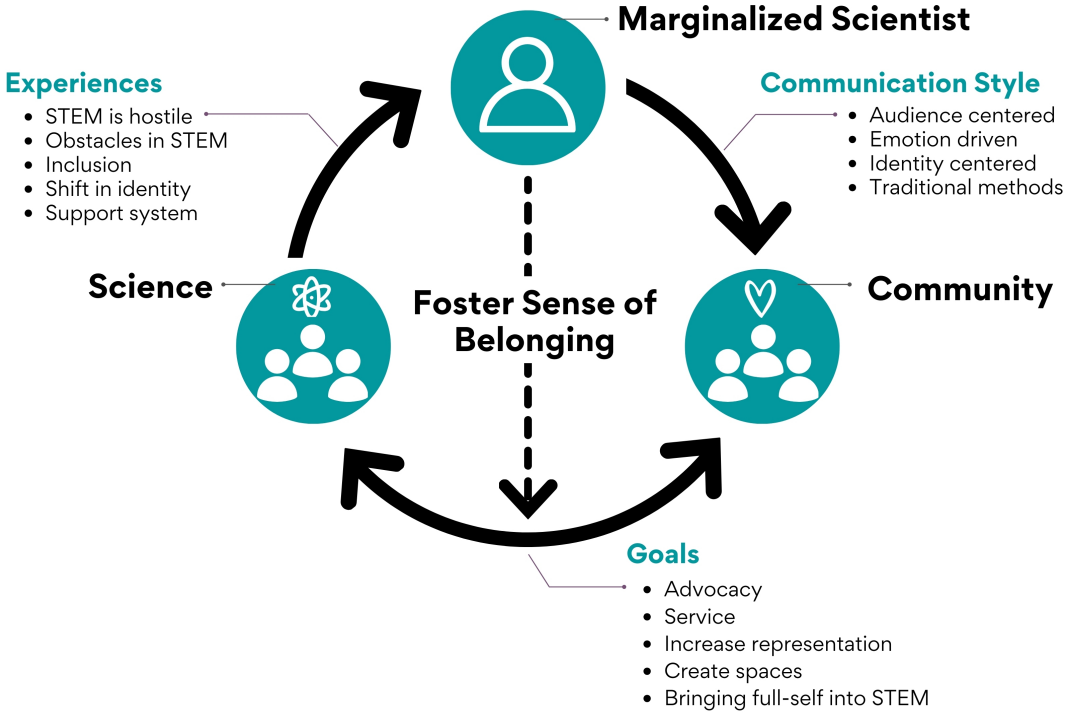

Figure 2. Scientists' experiences navigating STEM spaces influence their science communication style as they interact with their community. Their main objective is to foster a sense of belonging for their communities in STEM spaces.

identities of participants within STEM. This comprehensive exploration aligns closely with CTI's emphasis on recognizing the multifaceted nature of identity and the power dynamics inherent in social structures. Additionally, our study underscores the central tenets of SIT, which posit that individuals derive their sense of identity and belonging from their affiliations with STEM-related groups.

The evolving priorities among science communicators, especially those from marginalized backgrounds, reflect a departure from traditional knowledge-centric approaches, aligning with CTI's principles of challenging power dynamics and elevating marginalized voices. Similarly, our findings underscore the significance of integrating diverse forms of engagement and advocacy into science communication practices, echoing SIT's emphasis on identity's role in shaping STEM interactions. Our study's empirical evidence on how identity shapes science communication within STEM enriches our understanding of these dynamics, paving the path for more inclusive and equitable engagement in STEM fields.

Our participants seek to go beyond the traditional knowledge-based communication approach, aligning with Canfield and Menezes [2020]. While valuing science, their focus is on reshaping the culture of STEM environments to foster a sense of belonging through advocacy. This emphasizes the need for a broader definition of science communication, one that embraces diverse forms of engagement and challenges existing notions. We advocate for incorporating advocacy, service, and increased representation into science communication,

creating spaces that amplify voices from marginalized backgrounds. These efforts will enhance inclusivity by showcasing marginalized scientists and allowing full identities to be expressed in STEM settings as a form of science communication.

This study's findings carry significant implications for science communication training. Current science communication training programs may need to reevaluate their curriculum, goals, and methods. According to Besley et al. [2016], trainers predominantly focus on knowledge building in their training sessions, an approach that does not align with the motivations of participants from marginalized backgrounds. The insights from the participants of our study underscore the pressing need for a thorough overhaul of existing training programs to better engage a more diverse range of participants [Callwood et al., 2022].

This study has some limitations. Primarily, we note that the data predominantly comes from U.S.-based scientists in higher education programs (M.S; PhD), provides insights relevant to similar academic contexts. We had 20 participants from international settings and found no differences in our data and results based on location. Future research could expand on identity and communication questions with participants that include a more internationally diverse participation group. Additionally, while our study focused on identity within STEM spaces, this is just one aspect of a multifaceted and context-dependent concept [López et al., 2018; Irizarry, 2015]. We encourage researchers to include multidimensional measures of race, ethnicity, and other identity aspects in their studies. Further studies should explore identity within and beyond STEM spaces in relation to science communication training.

Scientists, particularly those from marginalized backgrounds, are driving transformative change in STEM, reshaping its culture beyond mere knowledge dissemination. As more marginalized scientists seek training, there's a pressing need to reassess cultural norms within programs to ensure inclusivity. Communication stands out as a vital tool in fostering belonging in STEM. Our study suggests that prioritizing the experiences of marginalized scientists can help training programs recognize and address their exclusivity, enabling the adoption of more inclusive and effective communication styles and goals. This shift will catalyze transformative change, advancing equity and inclusion in STEM and beyond.

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