UNIVERSITY OF CALIFORNIA,
IRVINE

Community fosters resiliency and growth in plants and scientists

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Biological Sciences

by

Evelyn Valdez-Ward

Dissertation Committee:
Professor Travis E. Huxman, Chair
Professor Kathleen K. Treseder
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2022

DEDICATION

To

Leo and Chris

Gracias por todo su amor y apoyo

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VITA
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EDUCATION

2022	Ph.D., Biological Sciences, University of California – Irvine Advisors: Travis Huxman and Kathleen Treseder
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PUBLICATIONS

Merkle, B.G., **Valdez-Ward, E**., Shukla. P., and Bayer, S.R. Sharing science through shared values, goals, and stories for an evidence-based approach to making science matter. *Human-Wildlife Interactions*. 2021. (*Invited, in press*)

Valdez-Ward, E., Ulrich, R., Bennett, N., Cat, L., Marcus, T., Menezes, S., Mattheis, A., Tresder,K.,ReclaimingSTEM: a model for inclusive science communication and policy training. *Frontiers in Communication* (SPECIAL ISSUE: Helping Scientists to Communicate Well for All Considered: Strategic Science Communication in an Age of Environmental and Health Crises). 2021. (*Accepted, in review*)

Gaieck,W.,Lawrence, J.P, Montchal, M., Pandori, W., **Valdez-Ward, E**., "Opinion: Science policy for scientists: A simple task for great effect". *PNAS*. August 2020.

SELECTED NON-ACADEMIC SCIENCE WRITING

Valdez-Ward, E., "The End of DACA Would be a Blow to Science". Scientific American. December 2019.

Valdez-Ward, E., "I'm an undocumented scientist fighting for my Dream". *Science Magazine*. November 2017.

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ABSTRACT OF THE DISSERTATION

Community fosters resiliency and growth in plants and scientists

by
Evelyn Valdez-Ward
Doctor of Philosophy in Biological Sciences
University of California, Irvine, 2022
Professor Travis Huxman, Chair

Climate change and environmental degradation resulting from anthropogenic activities disproportionately affect vulnerable and marginalized populations. Yet, these same populations are often excluded as participants and audiences from science communication and engagement efforts. Thus, we must provide resources and opportunities in science communication spaces that are accessible, inclusive, and co-created in collaboration with vulnerable communities. As a lesson learned from plants and microbes, we must work in partnership with marginalized populations to truly understand and develop effective systems of change to combat the effects of climate change.

Plants do not respond to a change in the environment in isolation—microbiomes that contain mutualists and pathogens are ubiquitous in nature. The influence of such interactions is poorly constrained in our understanding of ecological and evolutionary responses of plants to climate change. To investigate how plant-soil microbiomes and drought interact, I conducted a greenhouse experiment with two California grassland plants, *Stipa pulchra* and *Phacelia parryi*, exposed to soil inocula collected from a long-term water manipulation experiment in a natural setting. In a greenhouse, we varied soil moisture and hypothesized that the long-term history of drought provided by soil inocula results in "drought-tuned" soil microbial communities that alter subsequent plant growth under water-limited conditions. For my first chapter, we found watering treatment and soil treatment interacted for *S. pulchra*, such that plants exhibited greater drought

tolerance when grown with drought-tuned microbes than with microbes associated with ambient water availability. No significant interaction was present for *P. parryi*, but plants exposed to high and low water treatments both yielded reduced total plant biomass when grown with drought-tuned microbes. These results help us better understand how the plant-soil microbe interactions can direct plant growth patterns and highlight the importance of appropriate eco-evolutionary contexts to be considered in understanding species response to climate change.

Similarly, marginalized identities in STEM cannot navigate academic spaces in isolation. To support and empower people from marginalized communities in STEM, it is critical for universities and scientific societies to consider how to make their science communication and policy training spaces accessible and engaging to broad audiences, including to scientists with a wide array of educational backgrounds and social identities (i.e: race, ethnicity, sexual orientation, immigration status, disabilities, etc.). To create inclusive training spaces, and truly foster a sense of community within STEM, it is critical to go beyond simply acknowledging or accommodating people of different backgrounds, and instead, intentionally create training spaces that are designed to be accessible and attainable to everyone from the outset. Therefore, I co-founded Reclaiming STEM, a workshop centering science communication and science policy training specifically for marginalized scientists (LGBTQ+, POC, femmes, disabled people, first-generation, etc.).

For my second chapter, I present our workshop model grounded in evidence-based practices, present the main themes and key takeaways from the past five years of the Reclaiming STEM workshops, and share lessons we learned from attendee reflections. For my third chapter, I analyzed over 700 applications for our workshop to understand how marginalized populations use their identities in science communication. I found that based on applicants' experiences in

STEM, they wanted to foster a sense of STEM belonging to their own communities through using emotion and identity centered styles of science communication. These findings highlight a critical need to overhaul current science communication training programs to account for marginalized participants' needs and communication goals.

INTRODUCTION

REFLECTION:

While I started my PhD in studying the effects of drought on plants and soil microbes, I could not combat climate change without addressing the inequalities and injustices in our society. During my first semester, President Trump was elected. As an undocumented immigrant at the time, this meant a lot of fear for my own family, my ability to remain in the program, and my ability to continue doing my science. One of the promises of the Trump administration was to remove the Deferred Action for Childhood Arrivals (DACA) program, a permit that allowed me to pursue my PhD and get grant funding. The rescinding of DACA in 2017 led me to become politically active, and thus started my work in advocacy. This shift made me reconsider my career and research choices, from the traditional science academic path, to seek an academic career in science communication.

My advocacy began when I joined the University of California's lawsuit against President Trump's decision to end DACA. This led to being trained in media engagement and lobbying to push for immigration reform. However, I noticed the sciences were not speaking up against anti-immigrant policies. To resolve this, I wrote my story in *Science* to share how DACA allowed me to continue my research. I was then invited by SACNAS to speak at the March for Science rally in D.C, was interviewed by Telemundo in Spanish, and was voted the best 2018 of Story Collider in LA. My story was told by Senator Dick Durbin on the senate floor, and shared by Speaker Nancy Pelosi during her filibuster in 2018. Additionally, I was asked to participate in a public discussion about STEM inclusion with the ambassador of Mexico in 2020. To continue my training, I tried to merge my science with social justice. As a Switzer Foundation fellow in 2020, I pushed for justice and inclusion in environmental spaces, and was trained by COMPASS

in policy engagement. As a 2020 AAAS Mass Media fellow, I wrote 10 clips where I highlighted marginalized voices as I covered environmental news for the San Luis Obispo Tribune.

My visibility and advocacy brought harassment, microaggressions, and threats, which impacted my ability to feel safe on campus, and in the sciences. I felt uncomfortable and outcasted from everyone else as a minority in a white, male dominated ecological field. It was difficult to navigate academia when I was clearly being pushed out by academic and federal policies. I was constantly seen for my immigration status despite my scientific ability. However, I found refuge within UCI working with Drs. Travis Huxman and Kathleen Treseder who saw me for who I was: a scientist. Through my PhD work, I have found that the diversity of plant communities, as well as soil microbial communities, improve ecosystem resilience to the effects of drought. Likewise, the diversity of STEM academic environments is essential in order to produce a resilient scientific community.

However, I cannot combat climate change without addressing the inequalities and injustices in our society. Policies within higher education perpetuate harmful environments for scientists from marginalized backgrounds. Therefore, throughout my PhD career, I have worked to lower barriers of accessibility to STEM careers, and advocate for increased diversity and inclusion. Thus, I co-founded ReclaimingSTEM to help create a community of margnized scientists seeking to use science for social justice. The unique training model of Reclaiming STEM—matching the diversity of speakers to attendees—provided a safe and inclusive training environment. The attention the workshop received highlighted the immense need to create spaces catered to diverse scientists. The workshop not only taught scientists to be unapologetic about their identity, but also empowered them to use their identity to strengthen their science. Creating

this workshop changed my dissertation, and I dedicated the last two chapters to studying the use of science communication among marginalized scientists.

CHAPTER ONE: HOW DO SOIL MICROBIAL COMMUNITIES AFFECT PLANTS?

For my first chapter, I test the overarching hypothesis that the co-evolutionary relationships between plant-soil microbe interactions that occur during altered precipitation (drought vs. ambient) field conditions influence overall grassland response to subsequent severe drought. There is an immediate need to understand how terrestrial ecosystems respond to altered precipitation, and other external drivers, in order to predict and forecast the potential biosphere feedback to natural and anthropogenic changes (Schimel et al., 2001). Additionally, climate change is predicted to alter precipitation patterns, with important consequences for ecological communities (IPCC 2014). Water is a primary resource limiting terrestrial biological activity (Rosenzweig 1968; Lieth 1975; Webb et al., 1986; Sala et al., 1988), and its availability mediates the responsiveness of communities and ecosystems to global changes (Shaw et al., 2002).

Grasslands are particularly sensitive to changes in climate relative to other ecosystems (Alward et al., 1999; Knapp et al., 2008), and the structure and function of grasslands is more responsive to precipitation than other drivers of climate change (Tilman & ElHaddi 1992; Knapp et al., 2002). Previous work has shown that the interactions between plants and soil microbes play an important factor in the structure of grassland communities (Klironomos 2002; Reynolds et al., 2013; Bauer et al. 2015), however, how plant soil microbe interactions will respond to changes in precipitation, and whether the sensitivity of grasslands to changes in precipitation are influenced by plant-soil microbe interactions, is still unknown. To address this gap, I aim to quantify the effects of long-term (9 year) altered precipitation on the interactions between plants and soil microbes in a native California grassland.

Extreme rainfall and drought are known to directly influence the soil biota (Fierer et al., 2003; Schimel et al. 2007). Upon rewetting, a short-term increase in microbial activity occurs, while drought can reduce soil microbial activity (Birch 1958). Apart from changes in microbial activity, the microbial community composition also can be altered by exposing soil to drought (Fierer et al., 2003). Additionally, previous studies have shown that drought and rainfall treatments can remain as a legacy in soil microbial communities, which become apparent when testing their responses to subsequent drying and rewetting (Evans & Wallenstein 2012). However, whether and how legacy effects of drought on soil biota may affect native plant response to subsequent drought is unknown.

To investigate the effects of drought-tuned soil microbial communities on subsequent plant drought response. We hypothesize that the long-term history of drought will remain as a legacy in soil microbial communities such that it will alter subsequent plant growth under drought conditions.

CHAPTERS TWO & THREE: HOW DOES IDENTITY INFLUENCE SCIENCE COMMUNICATION?

In the past few years, leaders from multiple scientific societies and communities have been strongly encouraging scientists to increase their science engagement efforts with the public. As a result, there has been a significant increase in science engagement training programs in the US. As such, science communication is now recognized as a core skill to incorporate into scientific training (Chilvers, 2013; Dudo & Besley, 2016). However, there is a lack of inclusive science communication training spaces (Canfield et al., 2020). Additionally, science communication training programs lack diversity, both within their leadership and the trainers

themselves, and the trainings fail to meet the needs of diverse participants, where the majority are white and female (Canfield & Menezes, 2020; Dudo et al., 2021; Ecklund et al., 2012). These training spaces are not intentional in their efforts to broaden the participation of the participants (Besley et al., 2018) nor the audiences they target (Dudo et al., 2021). Moreover, they do not center or implement inclusive approaches (Besley et al., 2018; Canfield & Menezes, 2020; Dudo et al., 2021; Yuan et al., 2017).

I addressed this need with a healing-centered approach rooted in the key principles of inclusive science communication: ReclaimingSTEM. ReclaimingSTEM is a science communication and science policy training space that centers the experiences, needs, and wants of people from marginalized communities. ReclaimingSTEM problematizes and expands the definitions of "what counts" as science communication, asserting that how we define this term is not neutral. We also organize ReclaimingSTEM with intentionality, emphasizing inclusion at every part of the process. Since initiating in 2018, five ReclaimingSTEM workshops have been held in multiple locations, both in-person and virtually, with more than 700 attendees from all over the globe. In my second chapter, I share the model for ReclaimingSTEM, reflections of workshop attendees and speakers, barriers faced during organizing, and recommendations for creating truly inclusive practices. Our aim in this study is to examine the model proposed for these training spaces, and whether it was effective for the attendees present. We hypothesized that creating a counter space such as ReclaimingSTEM for marginalized attendees helps to create community and address the needs of marginalized scientists in science communication spaces.

With the increase in science communication training programs, there is a lack of evaluative data across these training spaces (Patrizi & McMullan, 1998; Salmon & Roop, 2019;

Storksdieck et al., 2018). This lack of research presents a challenge to understanding the impact and effectiveness of science communication programs, especially when it concerns creating inclusive science communication training spaces (Canfield & Menezes, 2020). Additionally, little work has been done to focus on junior scientists' interest, access, and experiences related to science communication (Howell et al.,2019, Dudo et al., 2021). Therefore, for my third chapter, we use data from the applications for the workshop to better inform science communication training models. In this study on the applicants for the ReclaimingSTEM aims to look at how scientists from marginalized identities are using science communication. We hypothesize that based on the marginalized scientists experiences in STEM, they aim to use science communication to aid their communities in feeling like they belong in STEM spaces.

CHAPTER 1

Effects of drought-tuned soil microbes on two native California grassland plants

ABSTRACT

Plants do not respond to a change in the environment in isolation—microbiomes that contain mutualists and pathogens are ubiquitous in nature. The influence of such interactions is poorly constrained in our understanding of ecological and evolutionary responses of plants to climate change. To investigate how plant-soil microbiomes and drought interact, we conducted a greenhouse experiment with two California grassland plants, *Stipa pulchra* and *Phacelia parryi*, exposed to soil inocula collected from a long-term water manipulation experiment in a natural setting. In a greenhouse, we varied soil moisture and hypothesized that the long-term history of drought provided by soil inocula results in "drought-tuned" soil microbial communities that alter subsequent plant growth under water-limited conditions. We found watering treatment and soil treatment interacted for *S. pulchra,* such that plants exhibited greater drought tolerance when grown with drought-tuned microbes than with microbes associated with ambient water availability. No significant interaction was present for *P. parryi*, but plants exposed to high and low water treatments both yielded reduced total plant biomass when grown with drought-tuned microbes. These results help us better understand how the plant-soil microbe interactions can direct plant growth patterns and highlight the importance of appropriate eco-evolutionary contexts to be considered in understanding species response to climate change.

INTRODUCTION

Mycorrhizal relationships, nitrogen fixation, disease, and other interactions between plants and soil microbes can determine the structure of grassland communities (Klironomos, 2002; Reynolds et al., 2003; Bauer et al. 2015). In addition, drought can alter microbial community composition and function (Hawkes et al., 2011; Allison et al., 2013; Maestre et al., 2015; Andrew et al., 2016), and these changes can persist years after drought has ceased (Martiny et al., 2017). How might such legacies of drought modify plant-microbe interactions in grasslands, and what are the consequences for plant growth? This information would help us better understand grassland responses to the increases in drought frequency and intensity that is expected in some regions of the globe, such as the southwestern United States (Seager & Vecchi, 2010).

Interactions between plants and soil microbes can influence plant growth and fitness, carbon sequestration, and nutrient cycling (van der Heijden et al., 2006; Kulmatiski et al., 2003; Laliberté et al., 2014; Keller & Lau 2018). On the one hand, greater microbial diversity often leads to increased plant growth (Wagg et al., 2021; van der Heijden et al., 1998) and a more resilient ecosystem functioning in stressful environments (Wagg et al., 2019). On the other hand, negative feedbacks can form between plants and microbes, wherein microbial communities in the rhizosphere of a given plant species may reduce the fitness of later generations of the same species (Klironomos, 2002). Additionally, drought stress could affect the relative abundances of mutualists and pathogens in soil microbial communities (Lau & Lennon, 2012), and this could affect the plant fitness benefits of associating with mutualists (Yang et al., 2009) and their susceptibility to pathogens (Garret et al., 2006). Plant-microbe interactions like these are likely operating as grasslands respond to climate change.

Excess rainfall and drought can directly affect the soil biota (Fierer et al., 2003; Schimel et al., 2007). For instance, microbial activity briefly increases after rewetting but often declines following drought (Birch, 1958). Furthermore, the microbial community composition can be altered by drought (Fierer et al., 2003; Hawkes et al., 2017; Martiny et al., 2017; Ochoa-Hueso et al., 2018; Preece et al., 2019). Previous studies have shown that drought and rainfall treatments can create a legacy effect in soil microbial communities. For example, Preece et al. (2019) found that soils with a history of drought had higher overall bacterial alpha diversity following a subsequent drought, and authors note it could be due to the bacterial community acclimating to drought conditions. Additionally, Canarini et al. (2021) noted that recurring drought increased the dissimilarity of microbial communities beyond the effects of a single drought event. However, it is unknown how legacy effects of drought on soil biota may mediate plant response to subsequent drought.

These drought-induced changes in the microbial community, and their potential impact on subsequent plant growth, may elicit consequences for ecosystem-level carbon dynamics (Schimel, Balser & Wallenstein, 2007). For example, drought-induced shifts in composition of soil microbial communities could alter the capacity for plants to tolerate drought in subsequent generations (Lau & Lennon, 2012). Via temporal dynamics in interactions like these, plants and microbes may co-respond to drought or other stressors in meaningful ecological and evolutionary relationships that influence ecosystem processes.

We can think of soil microbial communities that are exposed to long-term drought as "drought-tuned"; they likely exhibit physiological, demographic, or evolutionary changes that remain for some time after drought has ended. In this thought, if the drought-tuned microbial communities feature a persistence of relatively greater abundance of drought-tolerant mutualists,

plants with positive associations with these taxa may perform better during later droughts (Figure 1.1). Conversely, if drought selects for persistent drought-tolerant pathogenic microbes, plant growth and fitness may suffer during future droughts. During those subsequent droughts, plants may experience these legacy effects in addition to any direct, immediate effects of the droughts themselves (Figure 1.1). Especially where changes in frequency and intensity are predicted, it is likely that such soil-microbe legacies could generate new outcomes not observed under current climate scenarios assessing drought impacts on ecosystems (Gilman et al., 2010; Blois et al. 2013).

Because California grasslands are vast, at nearly 10 million ha, and economically important (Harpole et al., 2007), we must understand how California ecosystems will respond to projected climate change. Within the Loma Ridge Climate Change Experiment in Orange County, California, long-term drought manipulation significantly alters grassland community composition of plants and microbes alike. Within the first five years, drought increased non-native annual grass cover (Kimball et al., 2014; Kimball et al., 2016).

Additionally, bacterial and fungal community composition on surface plant litter in the grassland also responds to drought (Allison et al., 2013; Berlemont et al., 2014; Martiny et al. 2017). For example, Allison et al.,(2013) found reduced bacterial abundances in a southern california grassland following a drought event (Allison et al., 2013). Moreover, these alterations in microbial community composition could remain as long as 3 years after drought has ceased (Martiny et al., 2017). This system provides an opportunity to test how this legacy in microbial communities might influence future responses of native plant species to drought.

We conducted a factorial greenhouse experiment in which we grew two native California plant species, *Stipa pulchra* and *Phacelia parryi*, with soil inoculum collected from long-term (9

years) drought versus ambient field plots from the Loma Ridge Climate Change Experiment. We imposed high versus low watering treatments over eight weeks and assessed aspects of plant growth. We hypothesized that the microbial composition of 'drought-tuned' soil innocula will influence subsequent soil microbial communities and affect plant growth under water-limited conditions (Figure 1.1). More specifically, we predicted that drought-tuned microbes would either improve or reduce drought tolerance of the plant species, depending on plant species response.

MATERIALS AND METHODS

Field source

We obtained inoculum from drought and ambient plots from the grassland plots at the Loma Ridge Global Change Experiment in Irvine, California (117.704°W, 33.742°N) established in 2007. This field site is located on the traditional territory of the Acjachemen and Kizh communities (KIZH Nation, n.d.; Haas, 1995). At the time of this study, water manipulation had been maintained for 9 years. This field site is dominated by native and invasive annual grasses and forbs, including Avena, Bromus, Lolium, Erodium, and Lupinus, and native perennial grass Nassella pulchra (Potts et al., 2012; Martiny et al., 2016). In Southern California, grasslands can be water limited due to a Mediterranean climate (Tustin Irvine Ranch weather 1981–2018; Western Regional Climate Center, https://wrcc.dri.edu/). Most precipitation falls during the winter, while droughts occur during the summer when growth conditions are otherwise optimal.

Specifically, half of the plots were fitted with retractable plastic canopies that were closed during certain rainstorms, reducing precipitation by 50%. The other plots remained unmanipulated and received ambient precipitation (Potts et al., 2012; Kimball et al., 2014). Soil

moisture consequences, soil microbial dynamics, and plant response in situ are presented elsewhere (Allison et al., 2013; Martiny et al., 2017; Finks et al., 2021). The significant length of these treatments presents a rare opportunity to test for the ecological legacy of such rainfall and resource availability conditions inclusive of the complexity present from natural systems.

Inoculum

In Spring 2016 and Spring 2017, we collected inoculum in the grassland plots from the top 3 centimeters of soil from four drought and four ambient plots. Soil was collected from four random points within each treatment plot. Plant material and litter was removed from the top of the soil, then soil was collected. The soil was placed into sterilized bags and stored in a cooler at 4°C for transport. The soil collections were then all combined within treatments, and sieved to remove any remaining plant litter, and stored in a sterile container at 4°C until used.

In Matulich's study (2015) on the microbial composition of the field site at Loma Ridge, bacterial operational taxonomic units (OTUs) were classified as Proteobacteria (28%), Bacteriodetes (16%) or Actinobacteria (15%), with Planctomycetes (11%) and Firmicutes (10%). Most of the fungal OTUs were classified as Ascomycota (92%) or Basidiomycota (8%), and Chytridiomycota or Blastocladiomycota were also detected. Drought had a significant effect on community composition, where drought treatments explained approximately 3% of the bacterial and 6% of the fungal community composition (Matulich et. al., 2015).

Plant species

We selected *S. pulchra* (Poaceae) and *P. parryi* (Boraginaceae). *Stipa pulchra* is a perennial bunchgrass native to grasslands throughout California, and is occasionally found in the

experimental field site. *Phacelia parryi* is an annual herb native to Southern California coastal sage scrub, and a closely related species, *Phacelia cicutaria* occurs at the field site.

Planting

We grew *S. pulchra* in Fall of 2016, and *P. parryi* in Fall 2017. We sterilized potting mix at 121 °C at 103 kPa for 1.5 hr, and filled each pot (6.35 cm diameter x 25.4 cm deep pots) with 500 ml of sterile potting mixture. We then mixed 50 ml sterilized potting mix with 100 ml inoculum and added it on top of the sterilized potting mix. We sowed 3 seeds 1 cm apart in the center of each pot (1 cm apart) and watered the pots to field capacity to start germination. After the seeds germinated, we thinned extra plants to retain only one seedling per pot (n=6 for *S.pulchra* and n=8 for *P.parryi*). Afterwards, we imposed either a high watering treatment of 75 ml every other day or a low watering treatment, in which we watered only when plants exhibited obvious stress (i.e., visual wilting), which was about once a week all low watering plants received 75 ml. No fertilizer was added. Every two days, plants were rotated clockwise to minimize block effects. Plant height and leaf number was measured weekly. Roots and shoots were harvested after 8 weeks of growth. We chose this harvesting time because these plants are annuals, which when combined with the short life cycle of microbes, can enable rapid assessment in mesocosms of the feedbacks involved in interactions between plants and soil microbes.

Biomass

We collected biomass at the end of the eight weeks by removing each plant from their pot and rinsing adhered soil from the roots with water. The shoots were separated from the roots, and

each stored in different collection bags. The bags were then placed in a drying oven at 65 °C for 72 hours to obtain a constant mass. Shoots and roots were then weighed separately.

Statistics

Our hypothesis would be supported if inoculum source (ambient versus drought) interacted significantly with greenhouse watering treatment (high versus low). To test for significant interactions, we conducted a series of fully-factorial analyses of variance (ANOVAs) with inoculum source and greenhouse watering treatment as independent variables; and shoot biomass, root biomass, total biomass, or root-to-shoot ratios as the dependent variable. The two plant species were assessed separately. Where appropriate, a post hoc Tukey's test was used to check for pairwise differences. All data were ranked owing to outliers. Effects are discussed below as being significant when $P \leq 0.05$ and marginally significant when $P \leq 0.10$.

RESULTS

Stipa pulchra

For *Stipa pulchra*, we found significant or marginally significant interactions between inoculum source and watering treatment in total biomass ($P = 0.096$), root biomass ($P = 0.031$), and root-to-shoot ratio ($P = 0.003$, Table 1.1). Specifically, drought tended to reduce root ($P = 0.081$) and total ($P = 0.066$) biomass when plants were inoculated with microbes from ambient plots (Fig. 2). Yet, this drought effect was negated when plants were grown with drought-tuned microbes—there were no significant differences between the high and low watering treatments for roots ($P = 0.884$) or total ($P = 0.997$) biomass under those circumstances. In addition, root-to-shoot ratios were higher in the low versus high watering treatment when plants were grown with drought-tuned microbes ($P = 0.014$), but these differences were not significant with ambient

microbes (P = 0.559, Fig. 2). In contrast, although shoot biomass was marginally significantly greater with drought-tuned microbes than ambient microbes (P = 0.085), there was no significant interaction between microbe source and watering treatment (P = 0.973). Aside from the shoot biomass results, these interactions supported our hypotheses that drought-tuned microbes would influence the growth of this plant species during drought.

Phacelia parryi

Unlike *S. pulchra*, *P. parryi* displayed no significant interactions whatsoever between microbe source and watering treatment (Table 1.1, Fig. 3). Instead, across both watering treatments, shoot biomass was 38% smaller with drought-tuned microbes than ambient microbes (P = 0.050). In addition, the low watering treatment reduced total (P = 0.024), shoot (P = 0.038), and root (P = 0.031) biomass. Nevertheless, since there were no significant interactions between treatments, we rejected our hypothesis for *P. parryi*.

DISCUSSION

In this controlled greenhouse experiment, *S. pulchra*, a native bunchgrass, tended to exhibit better drought tolerance, which we documented as continued biomass production upon exposure to water limitation, when grown in the presence of drought-tuned microbes than with microbes that had experienced ambient water availability (Table 1.1, Figure 1.2). In this species, drought-tuned microbes were associated with an increase in biomass allocation to roots. This pattern of plant growth is a common drought-response allocation strategy that may have improved the plants' water uptake (Sperry et al., 2002). *Stipa pulchra's* response suggested that long-term drought could select for drought-tolerant microbes that are mutualistic.

Drought-tuned microbes did not seem to change how the native herb *P. parryi* responded to drought, as inoculum source did not interact significantly with watering treatment (Table 1.1, Figure 1.3). We did note, however, that regardless of watering treatment, drought-tuned microbes yielded significantly lower shoot biomass than did ambient microbes. Although drought-tuned microbes did not significantly alter *P. parryi's* drought tolerance, they seemed less beneficial (or more detrimental) to this plant's growth than their non-drought-tuned counterparts. Altogether, our hypothesis was supported for *S. pulchra* but not *P. parryi*.

Martiny et al. (2017) had previously documented that bacterial and fungal communities shift in response to drought at the Loma Ridge Climate Change Experiment. This pattern is not unique to this ecosystem. In fact, the community composition of soil microbes often shifts along precipitation gradients and following droughts (Sheik CS, et al., 2011; Angel et al., 2010; Bachar A et al., 2010; Schwartz E, Adair KL, Schuur EA., 2007). In the Loma Ridge site, legacy effects of drought conditions reduced bacterial abundances, such that litter decomposition rates remained low even with increased watering treatments within a California grassland (Allison et al., 2013).

In a Kansas, USA grassland study, the response to a historical legacy of rainfall was measured in both the plant response and soil response. In response, one study found altered anatomy and physiology when comparing a grass and forb in the grassland (Fay et al., 2002). Additionally, the historical legacy of intensified rainfall altered microbial function in response to drying and rewetting events, shifting fungal:bacterial ratios (Evans & Wallenstein, 2012).

The shifts in microbes might mediate long-term responses of plants to drought in our systems as well. For example, drought stress may have changed the relative abundances of drought-tolerant pathogens and mutualists. This would provide some explanation for the species-

specific responses we demonstrated among our experimental plants. Alternatively, drought could shift soil microbial activity and communities, and could select for drought-tolerant groups such as fungi, which have a lower nutrient requirement and a higher water acquisition capacity, or select for Gram+ bacteria, with a thicker peptidoglycan cell wall layer (Williams & Rice, 2007; Manzoni et al., 2012). If the community shifts to include more soil mutualists, such as arbuscular mycorrhizal (AM) fungi and plant growth-promoting bacteria, this response can promote the resistance of plant growth to drought (Mariotte et al., 2017; Rubin et al., 2017; Wu, 2017; Armada et al., 2018; Z. Zhang et al., 2019) and may preferentially influence perennial species. Such shifts in the soil microbial communities at Loma Ridge (Martiny et al., 2017) may have resulted in *S. pulchra* exhibiting better drought tolerance when grown with drought-tuned microbes.

Root-associated microbes can influence plant phenology, expression of functional traits, and survival (Van der Heijden et al., 1998; Friesen et al., 2011; Wagner et al., 2014; Lau & Lennon 2011). Additionally, beneficial soil microbes can improve plant nutrition and overall plant fitness (Jacoby et al., 2017). Other studies have suggested that rapid responses of the surrounding soil community can buffer plants to drought stress (Lau & Lennon 2012). For example, shifts in microbial community composition could cause changes in the biogeochemical processes that influence the availability of resources that can limit plant growth and fitness, such as nitrogen (N). In Lau and Lennon (2012), drought adapted soils had less N availability than wet-adapted soils, which affected the plant fitness response to drought. In our experiment, we did not fertilize our plants. Perhaps N limitation contributed to the decline in plant growth in *P. parryi* when grown with drought-tuned microbes.

Previous studies have investigated direct effects of water availability on *S. pulchra*. In a mesocosm experiment on *S. pulchra* individuals from the San José Hills of Southern California, water additions increased aboveground (but not belowground) biomass and number of flower culms while decreasing root-to-shoot ratio and water stress (Fitch et al., 2019). Likewise, in field settings, greater soil moisture improves *S. pulchra'*s aboveground biomass, seedling recruitment, and survivability (Hamilton et al., 1999, Lombardo et al., 2007). The increases in *S. pulchra's* shoot and total biomass with watering in our greenhouse experiment are consistent with these previous findings.

Drought can be more detrimental to herbs than grasses, leading annual plant communities to become dominated by grasses (Hoover et al., 2014; Liu et al., 2018). In Liu et al. (2018), a warming and drought treatment led to an increase in grass abundance at the expense of herb biomass. Hoover et al. (2014) found there was a large shift in plant community composition plots with previous drought treatments. They found that grasses dramatically increased in abundance, while forbs decreased. Similarly, we found a significant decrease in biomass of the herb *P. parryi* when grown with less water. By comparison, watering effects on the grass *S. pulchra* were only marginally significant.

It is likely that the different mechanisms by which changes in soil microbes can influence plant performance (direct species interactions versus shifts in soil hydro-bio-geo-chemistry) have implications for predicting plant diversity response to drought. Where climate change results in differential changes in rainfall intensity versus frequency, the relative influence of such species interactions and soil nutrient/water feedbacks can independently affect different plant functional types (such as the annual and perennial species in this study). Such decoupling has implications for differential plant performance and ultimately the assembly and coexistence of species.

Studies that further investigate the mechanisms of such microbe-plant interactions along with the role of temporal variation would be especially helpful in placing such findings in context.

CONCLUSION

Our results suggest that plant responses to drought depend on soil legacy, and specifically whether the soil microbial community had previously been exposed to drought. These findings highlight that plant responses to climate change can be influenced by the soil microbial community, likely independent of the long-term changes in nutrient and water availability mediated by microbes. Perhaps the relatively fast responses of soil microbes to climate change may in turn accelerate plants' responses. This study contributes to a mechanistic understanding of feedbacks that underlie plant-soil microbe interactions, improving predictions of plant community responses to environmental changes.

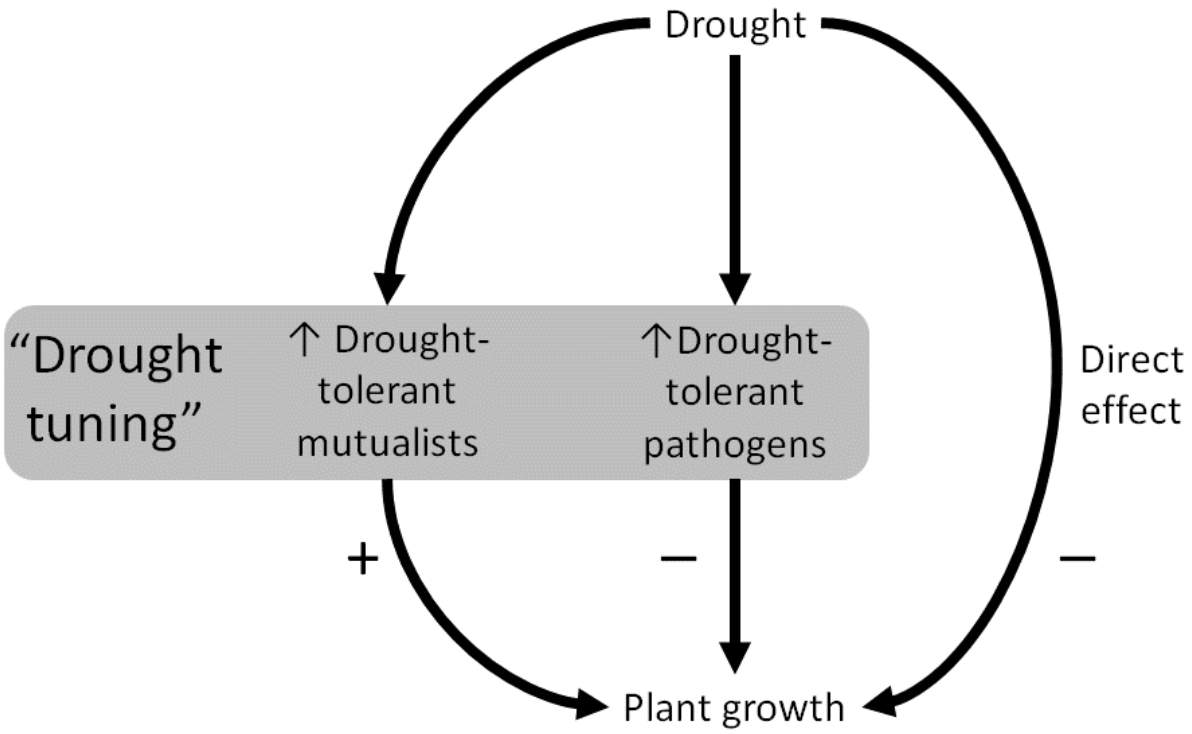

Figure 1.1 Theoretical framework for legacy effects of drought on interactions between plants and soil microbes. We hypothesize that the long-term history of drought will remain as a legacy in soil microbial communities such that it will alter subsequent plant growth under drought conditions.

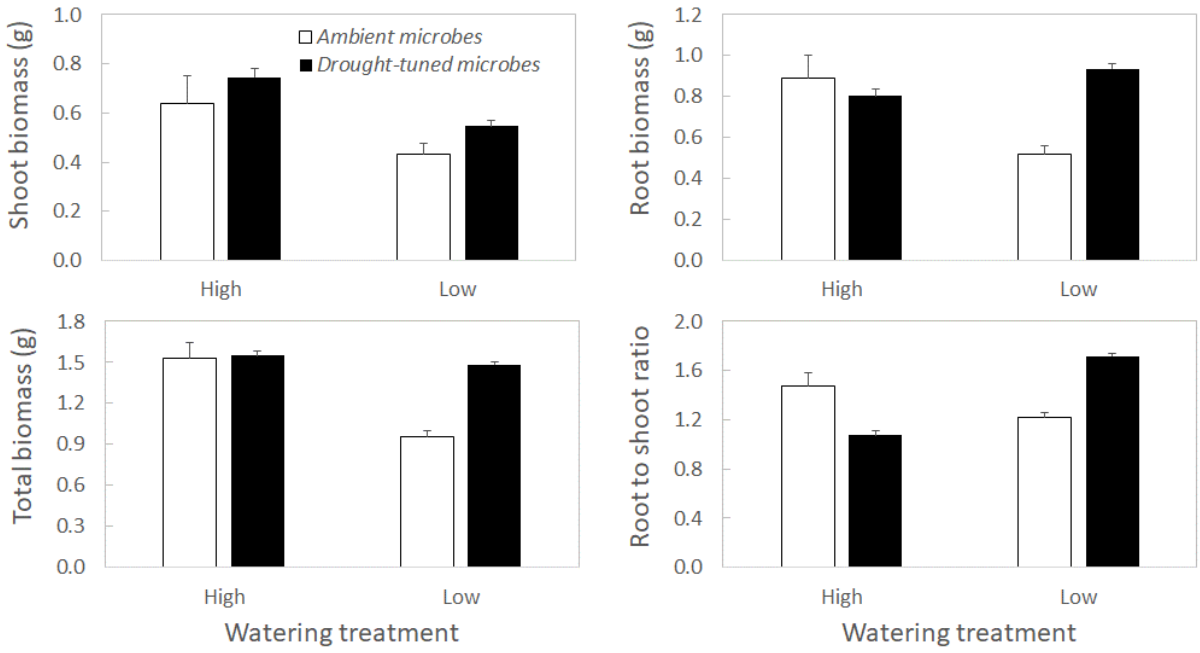

Figure 1.2. Biomass and root-to-shoot ratios of *Stipa pulchra*. Inoculum source x watering treatment interactions were significant or marginally significant for root biomass (P = 0.031), total biomass (P = 0.096), and root-to-shoot ratio (P = 0.003). Bars are means +1SE of 6 replicates.

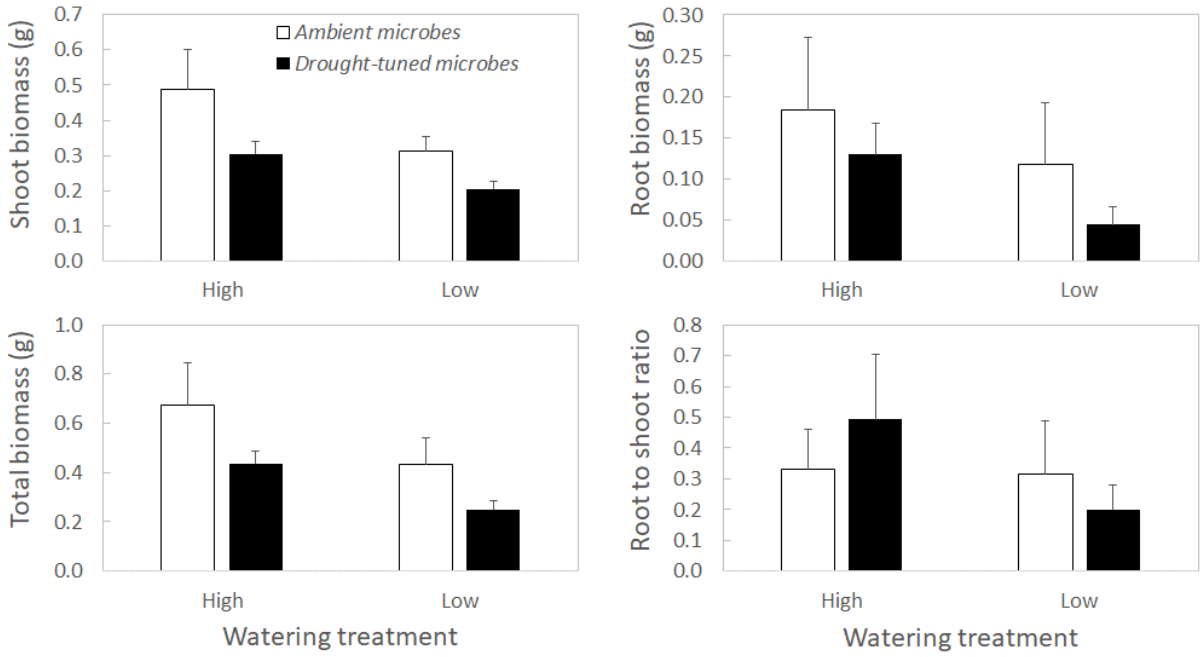

Figure 1.3 Biomass and root-to-shoot ratios of *Phacelia parryi*. There were no significant interactions between inoculum source and watering treatment. Bars are means +1SE of 5 – 8 replicates.

Table 1.1 Statistical results of analyses of variance. †

Dependent variable	Inoculum source x watering treatment	Inoculum source	Watering treatment
Stipa pulchra			
Shoot biomass	$F_{1,20} = 0.001$ $P = 0.973$	$F_{1,20} = 3.275$ **P = 0.085**	$F_{1,20} = 9.234$ **P = 0.006**
Root biomass	$F_{1,20} = 5.396$ **P = 0.031**	$F_{1,20} = 1.665$ $P = 0.212$	$F_{1,20} = 1.665$ $P = 0.212$
Total biomass	$F_{1,20} = 3.058$ **P = 0.096**	$F_{1,20} = 4.071$ **P = 0.057**	$F_{1,20} = 4.071$ **P = 0.057**
Root:shoot ratio	$F_{1,20} = 11.093$ **P = 0.003**	$F_{1,20} = 0.005$ $P = 0.945$	$F_{1,20} = 2.123$ $P = 0.161$
Phacelia parryi			
Shoot biomass	$F_{1,21} = 0.372$ $P = 0.549$	$F_{1,21} = 4.312$ **P = 0.050**	$F_{1,21} = 4.884$ **P = 0.038**
Root biomass	$F_{1,21} = 0.189$ $P = 0.668$	$F_{1,21} = 0.524$ $P = 0.477$	$F_{1,21} = 5.335$ **P = 0.031**
Total biomass	$F_{1,21} = 0.535$ $P = 0.473$	$F_{1,21} = 2.673$ $P = 0.117$	$F_{1,21} = 5.948$ **P = 0.024**
Root:shoot ratio	$F_{1,21} = 0.124$ $P = 0.728$	$F_{1,21} = 0.199$ $P = 0.660$	$F_{1,21} = 2.105$ $P = 0.162$

†Significant and marginally significant P-values in bold.

CHAPTER 2

ReclaimingSTEM: a healing-centered model for inclusive science communication and policy training

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ABSTRACT

The dominant U.S. cultural norms shape science, technology, engineering, and math (STEM), and in turn, these norms shape science communication, further perpetuating oppressive systems. Despite being recognized as a core skill of scientific training, science communication research and practice lack inclusive training spaces. We address this need with a healing-centered approach rooted in the key principles of inclusive science communication: ReclaimingSTEM. ReclaimingSTEM is a science communication and science policy training space that centers the experiences, needs, and wants of people from marginalized communities. ReclaimingSTEM problematizes and expands the definitions of "what counts" as science communication, asserting that how we define this term is not neutral. We also organize ReclaimingSTEM with intentionality, emphasizing inclusion at every part of the process. Since initiating in 2018, five ReclaimingSTEM workshops have been held in multiple locations, both in-person and virtually, with more than 600 attendees from all over the globe. In this paper, we share our model for ReclaimingSTEM, reflections of workshop attendees and speakers, barriers faced during organizing, and recommendations for creating truly inclusive practices.

INTRODUCTION

STEM (science, technology, engineering, mathematics) has been shaped by the values of the dominant U.S cultural norms that are traditionally Eurocentric, white, masculine, heteronormative, non-disabled, affluent, and neurotypical (Atchison & Libarkin, 2016; Chambers, 2017; Eisenhart & Finkel, 1998; Johnson, 2001; Nespor, 1994; Seymour & Hewitt, 1997; Traweek, 1988, Cobern & Loving, 2001; Finlay et al., 2021; Medin & Bang, 2014). Success in STEM fields tends to privilege the cultural traits of the dominant culture, and this can create structural inequities that create structural inequities that can further marginalize scientists of non-dominant identities (Cech & Pham, 2017; Wilder, 2014; Isler et al., 2021). These STEM cultural norms directly impact science communication, as the main and dominant voices in this field are predominantly white, educated, and male (Puritty et al., 2017). The current demographic make-up of science communicators can affect marginalized individuals' science communication efforts, as it can affect what counts as science communication, and who can participate (Reich et al., 2010; Dawson, 2014a). Thus, this can further perpetuate the systems of oppressions within science communication fields (Bonilla-Silva, 2006).

Science communication is recognized as a core skill that should be incorporated into formal scientific training, and the interest in science communication and public engagement has grown (Chilvers, 2013; Dudo & Besley, 2016). Yet, there is a lack of inclusive science communication and policy training spaces (Canfield et al., 2020), and participants from marginalized backgrounds remain largely overlooked and undervalued in science communication efforts (Dawson, 2014b; Feinstein & Meshoulam, 2014; Streicher et al., 2014). Research shows that marginalized communities living in Western countries experience science communication as Eurocentric and filled with racist stereotypes, recreating the systems that marginalize people in

the first place (Dawson, 2019). As a result, marginalized groups' involvement in science communication is narrow as they experience exclusion due to feelings of cultural imperialism and powerlessness (Dawson, 2018). Recent studies have advocated for a radical change within science communication spaces to counter the dominant practices that cause the exclusion of marginalized communities, highlighting a critical need for science communication and policy training that accounts for the historical oppressions, discriminations, and inequities of marginalized communities (Brown, Roche, & Hurley, 2020; Canfield et al., 2020; Dawson, 2019; Márquez & Porras, 2020; Mignan, 2020; Neeley et al., 2020; Orthia, 2020; Rasekoala, 2020; Smith et al., 2020; Finlay et al., 2021).

Science communication and policy trainings need to account for the challenges individuals from marginalized communities face. ReclaimingSTEM workshops train scientists to communicate their science at the intersection of research and social justice. ReclaimingSTEM programs are designed to decenter whiteness and cisheteronormativity. This is partly achieved by identifying and inviting speakers who are, themselves, from historically marginalized communities. ReclaimingSTEM has been hosted five times since 2018 and has reached over 700 attendees internationally. The overwhelming response to this workshop demonstrates the need in the scientific community for space to discuss diversity, inclusion, justice, and advocacy in STEM within science communication and policy training spaces.

In this paper, we present our workshop model for ReclaimingSTEM, as an example of an inclusive approach to science communication and policy training. We present this work as a program evaluation of our workshop. Grounded in healing centered engagement, our framework addresses the key traits of inclusive science communication: intentionality, reciprocity, and reflexivity (Canfield et al., 2020). We aimed for ReclaimingSTEM to be a model for inclusive

science communication and policy training. Here, we first present our guiding framework for creating and implementing inclusive science communication and policy training. Then, we describe the outcomes and participant reflections of our workshop. Last, we discuss implications and recommended practices for creating inclusive science communication spaces.

DEFINITIONS

Inclusive Science Communication

Science communication is defined in many ways. We broadly define science communication as community engagement about science that includes informal science learning, journalism, and formal science education, through varying methods (art, music, podcasts, media, etc). We advocate for science communication that is grounded in the values of inclusion, equity, and intersectionality (Canfield & Menezes, 2020).

Marginalized communities

Our workshop aims to address the needs of marginalized communities in science communication spaces. We define marginalized communities as those that "have been excluded from mainstream social, economic, educational, and/or cultural life" (Sevelius et al., 2020). Examples may include groups that are excluded based on their sexual orientation, gender identity, race, physical abilities, age, language, and/or immigration status (Sevelius et al., 2020). Marginalization can also occur when there is a power imbalance between social groups (Baah et al., 2019).

Healing-Centered

Racial trauma is often shaped by oppression, racism, and structural violence, and this impacts people of color. Ginwright (2018) writes that trauma-informed approaches can often limit the practitioners' view of individuals through their trauma. Instead, we must move towards engagement that is healing-centered, in which we can acknowledge that trauma and healing are experienced collectively. Approaching engagement as healing-centered in training practices can offer a more holistic approach to fostering the wellbeing of marginalized participants. Healing centered engagement starts with empathy, emphasizes collectivity, spirituality, embodiment, and uses radical imagination to intentionally confront racism and racial inequity.

Brave vs. Safe spaces

Safe spaces are typically used in higher education settings with the intention to create an "environment in which students are willing and able to participate and honestly struggle with challenging issues" (Holley & Steiner, 2005, p. 49), without regard to identity, power, and privilege. These spaces are meant to have people engage in discussion free from risk, danger, harm, controversy and other difficulties; however, safe spaces usually work to keep out discomfort and protect white feelings.

By comparison, when facilitating spaces on topics of social justice and advocacy, participants need to feel they can authentically engage with with gender, cis/binary privilege, heteronormative power and oppression (Flensner & Von der Lippe, 2019). Thus, brave spaces are needed. Brave spaces include creating a challenging environment in which there is equal participation across representative identities. In these spaces, discomfort and controversy are welcomed to enact change towards a more inclusive culture (Arao & Clemens, 2013).

Intersectional identity

The term intersectionality is a theory of oppression that helps to understand how identities are developed, enacted, understood, and marginalized or privileged in an existing social structure (Crenshaw, 1989). In our workshop design, we understand and take into account that attendees each have individual characteristics, such as sexual orientation, gender, race, physical abilities, and socioeconomic status, that can overlap with one another to form their identities.

A HEALING-CENTERED APPROACH TO INCLUSIVE SCIENCE COMMUNICATION TRAINING

As the field of science communication grows, so does the abundance of training programs. However, science communication training programs lack diversity, both within their leadership and the trainers themselves, and the trainings fail to meet the needs of diverse participants, where the majority are white and female (Canfield & Menezes, 2020; Dudo et al., 2021; Ecklund et al., 2012). Additionally, these trainings are not intentional in their efforts to broaden the participation of the participants (Besley et al., 2018) nor the audiences they target (Dudo et al., 2021). Moreover, they do not center or implement inclusive approaches (Besley et al., 2018; Canfield & Menezes, 2020; Dudo et al., 2021; Yuan et al., 2017). Designing science communication training with inclusive practices can promote a sense of belonging for participants who are marginalized in STEM (Carlone & Johnson, 2007). Without centering inclusive approaches, trainings can further perpetuate inequities within science communication fields (Dawson, 2014a; Finlay et al., 2021; Medin & Bang, 2014; Smith et al., 2020; Taylor, 2018). This can affect who can access these trainings, who feels welcome to those training spaces, and who is included in science communication. Therefore, we must root training in an ethic of inclusion and equity (Canfield et al., 2020).

For our workshop, ReclaimingSTEM, we decenter whiteness and cisheteronormativity. We design the events with a healing-centered framework (Ginwright, 2018) rooted in the key principles of inclusive science communication: intentionality, reciprocity, and reflexivity (Canfield et al., 2020; Canfield & Menezes, 2020). Intentionality in science communication training spaces is defined as being deliberate about how marginalized identities are represented and supported. It also purposefully names how terms in science communication are defined and takes into account the target audiences. Reciprocity is creating equitable relationships that recognize and value the various forms of expertise in science communication. It advances asset-based approaches, and ensures benefits are co-created between audiences and communicators, researchers, and practitioners. Lastly, reflexivity is an ongoing, critical, and systematic reflection on the communicators' and target audience's personal identities, practices, and outcomes. It is also followed by adapting as needed to remedy inequitable interactions (Canfield & Menezes, 2020). These key concepts are embedded in our workshop design to create effective programming. In doing so, our workshop approach accounts for intersectional identities, is equitable, and acknowledges the essential role of culture.

ReclaimingSTEM specifically caters to our key trainee audience: early career scientists who are members of marginalized groups. The workshops were designed by placing marginalized identities and experiences at the center of science communication and policy training. Centering marginalized identities and experiences allows ReclaimingSTEM to serve as an identity-affirming "counterspace" (Carter, 2007; Tatum, 2017; Margherio et al., 2020; Isler et al., 2021), a resistance space in which participants can maintain a strong sense of their own intersectional identities while pursuing excellence in science communication, policy, and advocacy. The workshop content reaches beyond typical science communication and policy

skills building, and includes more specific topics on identity, community engagement, advocacy, education, and social justice. In this, ReclaimingSTEM problematizes and expands the definitions of "what counts" as science communication, asserting that how we define this term is not neutral. By centering marginalized identities in our training design, our workshop is mindful of the inequities, discrimination, and oppressions faced by our partipants. As a "counterspace" (Carter, 2007; Tatum, 2017; Isler et al., 2021), ReclaimingSTEM offers participants a reprieve from the psychological, emotional, and physical stress associated with oppressive environments, and a space to claim as their own, reducing the alienation and otherness felt in mainstream STEM spaces. ReclaimingSTEM serves as a space to elevate marginalized voices in science communication and policy spaces, and provides a brave space to build community among marginalized participants to discuss the challenges faced in STEM spaces.

Creating a truly inclusive workshop starts with our leadership team, which we composed of people from marginalized identities. ReclaimingSTEM's diverse leadership stands in contrast to many other science communication organizations, which have low diversity in their leadership (Dudo et al., 2021). The diverse leadership of ReclaimingSTEM not only resists the racialization of organizations but also interrupts and resists the reproduction of social inequity (Ray, 2019). Because our leadership is representative of marginalized identities, we can ensure we broaden our reach of our target participants and can account for marginalized perspectives in the trainings we design each year.

For our sessions, we seek speakers and trainers who are from marginalized backgrounds themselves, which enables participants to envision themselves in science communication and science policy spaces. This practice not only increases representation of who can do science communication and science policy, but also demonstrates the variety of forms that science

communication and science policy can take. We also remove barriers to participation for both speakers and attendees through free attendance, providing meals (when in-person), providing ASL and captioning services while in-person and online, and compensating speakers for the time and energy required to share their experiences in our workshops.

ReclaimingSTEM intentionally addresses intersectionality (Crenshaw, 1989). For each workshop, applications ask participants a variety of questions to ensure we are building brave spaces and are reaching a diverse audience of attendees. Our applications ask attendees, "What groups do you self-identify with?" This question is left as an open-ended question, leading attendees to share more identities than one could assess with predefined categories or check boxes. Having participants self-identify rather than using conventional categories allows for a multidimensional and intersectional view of individuals; rather than the flattening and invisibilizing effects that historical census-based survey items confer (Irizarry, 2015; López et al., 2018). ReclaimingSTEM views each participant as a complex, intersectional individual. The majority of attendees are Black, Latinx, LGBTQIA+, first generation students, disabled, and women, along with many other identities. Based on this information, we make sure to include workshops outside of skills building workshops that address themes such as navigating STEM spaces, exploring identity and intersectionality, and workshops on the basics of decolonial theory.

Our first few workshops were trauma-driven. While we gave speakers the freedom to speak on their stories, this often included presenting their own obstacles and experiences navigating STEM. Our topics of conversation included discussing themes on queer idenitity, diversity, extra labor by marginalized individuals, social justice, and more. Often in these workshops, participants would share their own stories and experiences with each other,

exchanging trauma. We changed our approach after a 2019 reflection piece mentioned “I felt the weight of the diversity problem in STEM, and honestly, I had to step out of the workshop...I was overwhelmed, and sad, and tired. Minority scientists are tired” (Hoefelle, 2019). This comment sparked the realization that we had not created spaces for healing, nor provided the tools to help participants to cope.

Now, our workshops begin with self-care sessions, and time to cope and heal in solidarity. In doing so, we build a stronger, more resilient community. These sessions include coping practices such as meditation, yoga, journaling, and learning to say no. In the 2020 ReclaimingSTEM workshop, we included a comedy show. We brought together funny, sad, and personal stories of the attendees' experiences in STEM in a way that brought solidarity and community.

PARTICIPANT RESPONSES AND REFLECTIONS

In 2020, as an answer to the question “How would the ReclaimingSTEM experience benefit your career?” one respondent wrote:

> Having an invisible disability has often made me feel like I don't belong, like I'm incapable, and like I'm way behind my peers...I don't have any experience in science communication, but if I could get involved in it and impact even a single person's perception about how they view their disability, or their ethnicity, or their socioeconomic status in relation to STEM and academia, that would be so rewarding.-Respondent 1

Many applicants want to reach beyond general knowledge-sharing in science communication, they want to change the meaning of who belongs in STEM, and who can participate. While mainstream science communication forms continue to rely on the deficit

model (one-way knowledge sharing that assumes a lack of information on the part of the audience), this is often at at the expense of more diverse and effective approaches (e.g. relational communication) (Dudo et al., 2021; Simis et al., 2016). The responses from ReclaimingSTEM participants suggest that diversifying who participates in and what counts as science communication may be one key route to richer forms of science-society interactions.

Our workshops merge diverse identities and lived experiences in a way that addresses attendees goals; they simultaneously aim to improve technical science communication skills, increase representation in STEM spaces, and reach diverse audiences with their communication and/or policy efforts. With this in mind, we make sure we include workshops that address community building, allyship, advocacy, and social justice.

Our speakers are integral to our workshop model design. As they are also from marginalized backgrounds themselves, we take care not to tokenize them. Instead, speakers are encouraged to be themselves in the workshop spaces. To that end, we not only ensure our speakers are paid for their labor, but we also allow them to speak on whatever topic they would like. In our invitations we write " this is your platform to lead the session in any way you'd like, any format. There is no need for filters or code-switching." This can sometimes leave speakers feeling nervous, and they often ask us for guidance. We reassure them that they are experts on their topics and their stories. This is their chance to have a platform to teach a workshop or lead a talk in any way they wish. After the 2021 workshop, one speaker reflected:

> Even though I tend to present myself consistently across all spaces,
> I usually feel varying degrees of anxious activation when speaking from my heart in spaces that I know are not going to hold my heart with respect and kindness. While presenting at ReclaimingSTEM, I felt more comfortable than I ever have, knowing that

> my WHOLE self was not only accepted, but requested! I was able to share my expertise, which comes from indigenous healing practices, completely openly, and without fear/expectation of being received with criticism and disrespect. This made everything easier: coming up with a title, deciding what content to share, preparing slides, even getting dressed for the event was easier, because I didn't have to fight through a fog of anxiety and white expectations. -Respondent 2

Inviting speakers in this way not only brings about unique content, but allows speakers to bring their full selves into these spaces, authentically. ReclaimingSTEM intentionally acknowledges sources of community cultural wealth (Yosso, 2005), rather than privileging traditionally revered forms of capital. In these ways, the ReclaimingSTEM counterspace invites participants to affirm their intersectional identities, especially those that are perceived negatively or stereotyped in mainstream STEM spaces. Participants can be their authentic selves, drop code-switching behaviors, and embrace style, speech, behavior, and ways of thinking that perform and reclaim their intersectional identities (Carter, 2007; Tatum, 2017; Margherio et al., 2020; Isler et al., 2021).

FINDING AND BUILDING COMMUNITY

Often, this workshop may be the first time marginalized participants are in community with each other, and see speakers from marginalized backgrounds on a platform. One attendee following our 2018 workshop reflected “The WokeSTEM presentation had the greatest impact because I had never seen a Black scientist present their science in a raw manner that didn't censor their identity.” Speakers who are allowed and encouraged to bring their whole selves to our

workshops to deliver content also impact the attendees. This can influence how attendees see and envision themselves in science communication and policy spaces.

When asked "What was the most memorable thing you learned or best piece of advice from ReclaimingSTEM?", one participant said: "I learned that the feeling I have always had in my heart, that academia is stacked against anyone who is different, is actually true. I affirmed my own feeling of not belonging. I think the best advice to tackle this is to make my nonconformity look intentional." Another participant reflected, "That I am not alone, I found community, and that I can succeed by being myself and not muting myself to be like the majority."

ReclaimingSTEM brings attendees together in ways that are novel for them and that build solidarity. Rather than asking participants to assimilate to the dominant culture (as they are often asked to in mainstream STEM spaces), ReclaimingSTEM encourages the development of critical consciousness that challenges conformity and embraces authentic expressions of intersectional identity (Solórzano and Delgado Bernal, 2001).

Many attendees have mentioned feeling excluded in STEM spaces and seeking to find community with "like-minded people". In this way, our workshop also addresses the attendees' desire to mobilize and build community. This notion is often not rewarded in STEM spaces, as social justice or science communication activities don't always count as academic. In our workshop, we take a broad, inclusive definition of science communication. We include workshops that include tracks on advocacy, social justice, and reform. We also design our space to include time to have participants connect, network, and collaborate. Therefore, our workshop is designed with awareness of attendees' lived experiences (Banks et al., 2007; Calabrese, Barton, & Tan, 2010; Hernández-Saca et al., 2018). Additionally, bringing together diverse backgrounds and experiences creates and encourages innovative ways to communicate science

and reach new audiences that have been historically excluded (Cheng et al. 2018). One attendee in 2021 reflected, “The most memorable thing I've learned from ReclaimingSTEM 2021 is that we have the power to reimagine STEM if we decide to come together so that we can achieve the belonging, purpose, and joy in our STEM journey.”

INCLUSION IN A VIRTUAL WORLD

Since the founding of ReclaimingSTEM in 2018, we have organized five workshops; three of which were in-person (2018, 2019 West Coast, 2019 East Coast). In 2020, with the transition to a virtual format due to the global coronavirus pandemic, we had to adapt our content to an online platform while staying true to our core values of equity and inclusion. To that end, we chose a format everyone can have free access to, ensuring accessibility online (i.e., captions). We refused to simply use auto-captioning systems, as they can be inconsistent, and unreliable (Këpuska & Bohouta, 2017). Therefore, we ensured our budget accounted for hiring live captioners, providing transcripts at the end of our events, and budgeted for ASL interpreters.

To avoid Zoom fatigue, we split up our training in 2020 over the course of four Saturdays, and over three days in 2021, with each day starting with a self care session. We then included main keynote sessions that addressed key conversations, and had four breakout tracks: advocacy, education, science communication, and policy.

Our online event was able to expand our reach to new audiences, leading to more participants who were not able to attend our workshop before. For the first time, ReclaimingSTEM was able to reach international attendees. The virtual format also allowed us to expand our reach for speakers we could invite, including international speakers. Additionally, the virtual format proved to be more accessible for disabled participants and caregivers, as we saw

an increase in participants from these backgrounds. We made space by holding key conversations focused around topics of being disabled, Native, and Black in STEM. We also created a community by engaging attendees on Slack and hosting coffee hours in between workshops. These considerations are critical as we can move toward always providing hybrid attendance options to increase accessibility of events.

BARRIERS TO ORGANIZING AN INCLUSIVE SCIENCE COMMUNICATION TRAINING SPACE

It is not easy to construct inclusive training spaces. We faced several challenges and barriers, especially funding. As this workshop was built by graduate students, we were limited to small grants from organizations or school departments, which often came with limitations on how we could spend the money. This constraint was especially difficult in the context of paying speakers, which, as noted previously, is a central aspect of our workshop design. Institutional rules on spending significantly limited our options, and led to our decision to create a separate non-profit.

Accessibility is a non-negotiable aspect of ReclaimingSTEM workshops, yet this commitment poses a challenge when planning in-person workshops, especially given the funding considerations noted above. In addition, the spaces we could obtain at universities could, themselves, cause or recall trauma. Hosting in-person workshops also limited who could access our workshops if they could not travel, or had other accommodation needs.

DISCUSSION

We are often asked how we can recommend that other spaces create inclusive practices. There is no simple procedure that, once followed, will create an inclusive space. Creating these spaces requires systemic restructuring and moving beyond a checklist of actions. This means starting with uncomfortable self-reflection about the ways in which organizations may be continuing to reproduce social inequities.

We suggest organizations begin with restructuring their leadership, mission, vision, and values. We recommend organizations first reflect on their own leadership and practices: who are you? What do you represent? What is your organization's history? Inclusion begins with leadership, and no space will feel welcoming if there is a strong history of oppression, exclusion, or marginalization. Then, find places where things can be changed to create intentional inclusion at every level of the organization. Additionally, we recommend placing a strong emphasis on supporting existing programs led and/or conceived by people from marginalized communities. The Inclusive Scicomm Symposium is a great community and a good place to start to get familiar with the initiative and communities currently building a truly inclusive science communication community (Canfield et al., 2020).

To radically change science communication and training spaces, and increase participation of marginalized communicators in these fields, intentional organizing is vital for building inclusive communities and training spaces. It is imperative that inclusive practices are interwoven in every part of the organizing process. Starting with organizational leadership and values all the way to facilitating the space, it is clear that treating inclusion as an afterthought is detrimental. By centering inclusive practices, ReclaimingSTEM serves as a valuable and authentic model for inclusive science communication and policy training.

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CHAPTER 3

Identity and Science Communication

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Abstract

Science communication interest has been increasing, with a rapid increase in science communication training programs. However, few programs evaluate the science communication goals and objectives of their participants. Further, many training programs ignore the needs of marginalized participants. ReclaimingSTEM is a healing-centered model for inclusive science communication that aims to resolve this gap. The ReclaimingSTEM workshop has been hosted five times, and centers marginalized identities as participants. For this chapter, I analyzed over 700 applications for the ReclaimingSTEM workshop to understand how scientists from marginalized backgrounds use their identities in science communication. I found that based on applicants' experiences in STEM, they wanted to foster a sense of STEM belonging to their own communities through using emotion and identity centered styles of science communication. These findings highlight a critical need to overhaul current science communication training programs to account for marginalized participants' needs and communication goals.

INTRODUCTION

In recent years, leaders across scientific societies and communities have encouraged scientists to communicate science and engage with the public, resulting in an increase in science engagement training in the United States (U.S.) and it being recognized as a core skill to incorporate into scientific training (Chilvers, 2013; Dudo and Besley, 2016). However, in these spaces, participants from marginalized backgrounds are overlooked and undervalued in science communication efforts (Dawson, 2014; Feinstein & Meshoulam, 2014; Streicher et al., 2014), and there is a lack of inclusive science communication training spaces (Canfield et al., 2020). The lack of inclusion in science communication is a direct result of STEM (science, technology, engineering, mathematics) cultural norms that are shaped by the dominant U.S. cultural norms: Eurocentric, white, masculine, heteronormative, non-disabled, affluent, and neurotypical (Atchison & Libarkin, 2016; Chambers, 2017; Eisenhart & Finkel, 1998; Johnson, 2001; Nespor, 1994; Seymour & Hewitt, 1997; Traweek, 1988; Cobern & Loving, 2001; Finlay et al., 2021; Medin & Bang, 2014).

STEM spaces have the ability to empower marginalized individuals, as science communication and public engagement can influence who can participate in STEM, create a sense of belonging, and influence who benefits from STEM research (Archer et al., 2015; Bell et al., 2009; Dawson, 2018, 2019; Dewsbury & Brame, 2019; Canfield & Menezes, 2020). However, the current approaches of STEM spaces perpetuate inequalities (National Science Foundation, 2014; Schell et al., 2020). Current STEM cultural norms directly impact science communication training spaces, as the main and dominant voices in this field are predominantly white, educated, and male (Puritty et al., 2017). This main demographic of science communicators affects marginalized individuals' science communication efforts. It influences

what counts as science communication, who feels included, and who can participate (Reich et al., 2010; Dawson, 2014, Valdez-Ward et al., 2022 (in review)).

There is a critical need for science communication training that accounts for the historical oppressions, discriminations, and inequities of marginalized communities (Brown, Roche, & Hurley, 2020; Canfield et al., 2020; Dawson, 2019; Márquez & Porras, 2020; Mignan, 2020; Neeley et al., 2020; Orthia, 2020; Rasekoala, 2020; Smith et al., 2020; Finlay et al., 2021). The ReclaimingSTEM science communication training workshop addresses this need with a healing-centered approach rooted in the key principles of inclusive science communication: intentionality, reciprocity, and reflexivity (Valdez-Ward et al., 2022, in review). Briefly, ReclaimingSTEM is a workshop that trains scientists from marginalized backgrounds to communicate their science at the intersection of research and social justice. The programs are designed to decenter whiteness and cisheteronormativity and only invite and center marginalized identities (Valdez-Ward et al., 2022 (in review)).

As this workshop centers marginalized identities, it is important to review and understand why marginalized identities enter the science communication spaces, to more directly address their needs in creating the workshops and training. ReclaimingSTEM has an application based system, in which attendees are asked: "How does your identity influence and impact your science and communication style?". This workshop has been hosted five times since 2018, and this paper aims to analyze and review the answers of over 700 applicants to the workshop.

POSITIONALITY STATEMENT

This study arose from the increased need for spaces like ReclaimingSTEM, which was organized by the main co-authors (Evelyn Valdez-Ward (E.V-W), and Robert N. Ulrich (R.N.U)). After years of reading the applications for the workshop, the co-authors wanted to go

back and look at attendee responses for “how does identity influence your science communication style?”. In reading these responses, the co-authors saw aspects of themselves, in which it seemed many attendees felt excluded, silenced, and harassed in STEM spaces, and aimed to find and build community in ReclaimingSTEM workshops. The authors themselves often faced toxicity in their own STEM spaces based on their identities (E.VW: Latina, Woman, Queer, Previously Undocumented; R.N.U: Biracial, Southeast Asian, Non-binary, Queer), and science communication was a way to give back to their communities. In forming and hosting these workshops, they found community, and thus looking back at these application responses seeked to find how marginalized attendees felt about their own experiences in science, and how they used science communication. As the main co-authors are scientists, they sought the outside help of a variety of social scientists to oversee the development of the manuscript.

METHODS

ReclaimingSTEM has been hosted five times since 2018. Years 2018-2019 was in person hosted on either the west or east coast, while years 2020-2021 were virtual via zoom. The workshops hosted on the West coast were held at the University of California Irvine, over the course of a single day. The workshop on the east coast was hosted at the University of New Hampshire, also over the course of a single day. The virtual workshops were hosted over the course of 3-4 Saturdays, lasting only 3 hours each day. We have received over 700 applications for the workshop over the past five years (Table 2.1). We reach our applicants through Twitter advertisements mainly, announcing our workshop as a place where science communication and policy merge with social justice. Our application process is all done via Google Docs and is all

accessible online. We do some email advertisements through listservs with our collaborators or sponsors, but many applicants indicated applying because of the Twitter advertisements.

In the application, one of the questions asked was “How does your identity influence and impact your science and communication style?”. Other questions on the application are listed below.

- Level of education
- What groups do you self-identify with? (Note: this was an open-ended question)
- How would the Reclaiming STEM experience benefit your career? Reflect on your current level of experience in communicating science (~200 words).
- How does your identity influence and impact your science and communication style (~200 words)?

For the level of education, we did a simple count of the participants' education level. Most of our attendees are students with the majority being PhD students (Figure 2.1). For identity, we coded identities to account for similar instances (For example: Queer, Lesbian, Bi, was coded under LGBTQ+). However, please note, this is not truly representative of our attendees’ identities, as there are many intersectional identities (ex: Black, Queer, First-Gen, Woman). Here, we display this chart simply with the intention to demonstrate that the majority of the identities were Latinx, Black, LGBTQIA+, first generation students, disabled, and women (Table 2.2).

CODING

For this analysis, we coded the responses for the question “How does your identity influence and impact your science and communication style?”. We did a thematic analysis using NVivo software to identify key themes within the application responses. We identified topics in

major three categories: influence, goals and objectives, and style. The present research drew on existing theories of belonging in STEM, and this guided our coding and analysis. However, several concepts emerged that are not currently examined by existing theories; therefore, we used a quasi-grounded theory approach (Strauss & Corbin, 1998). The key themes are discussed in the Findings section.

For influence, we coded any instance or experience that attendees may have had in STEM that led to them wanting to enter science communication spaces, or attend our workshop. For goals and objectives, we coded anytime they mentioned what they aimed to achieve with their science communication. As for style, we coded any mention of how they aim to achieve their goals through their science communication. The results are presented in this paper.

When hosting this workshop, we did not have the intention to use it for research purposes. We mainly present these results as a program evaluation to analyze our participants identities and responses, to better inform our training workshops. Therefore, this work is IRB exempt, as determined by a self-evaluation tool by the University of California, Irvine.

FINDINGS

In this study, we analyzed the responses of 712 applicants to the ReclaimingSTEM workshop in the question for "How does your identity influence and impact your science and communication style?". We analyzed the responses and coded each response in regards to experiences, style, and goals and objectives.

Overall, the applicants to the ReclaimingSTEM workshop have had negative experiences navigating STEM spaces. Their relationships with science spaces was largely negative, and this influenced their communication styles to include audience-centered, identity-focused, and

emotion-driven, in addition to traditional science communication methods (i.e., inform, avoid jargon, etc). We found that participants mainly felt othered in their science spaces, and therefore through their science communication to aim to foster a sense of belonging for their communities in STEM spaces. As such, the applicants aim to achieve this with their science communication goals and objectives including advocacy, increasing representation, service to their communities, creating spaces, and bringing their full-self into STEM spaces (Figure 2.2). Detailed findings and analysis are presented below.

EXPERIENCES

STEM is hostile:

Inequities within STEM spaces prevail along the cultural norms that are associated with privilege and dominance in society. Previous research has documented the disparities faced by cis-gender women in STEM as well as people from racial and ethnic groups that are underrepresented in STEM. Recent research also reveals inequities along the lines of sexual orientation and gender identity (Chen, 2013; Gayles & Ampaw, 2014; Riegle-Crumb et al., 2019; Lysenko & Wang, 2020; Sansone & Carpenter, 2020). hooks' (2014) work through the lens of Black Feminism and Engaged Buddhism, theorizes education as freedom. They argue that schools should not be a place of marginalization, and instead serve as a place of belonging, where students can be valued for their entire selves (hooks, 2014). Similarly, STEM spaces, which are also places of learning, could foster a sense of belonging, and accept scientists as their full selves. Yet, it has been widely documented that bias, harassment, discrimination and other exclusionary behaviours create especially hostile STEM spaces for people from marginlized

backgrounds (Dutt, 2020; Mattheis et al. 2019; Berhe et al. 2020; Atchison & Martinez-Frias, 2012; Stokes et al. 2019; Baber et. al, 2020; Huntoon et al., 2007; Miller et al., 2007; Wechsler et al., 2007).

Recent research continues to document hostile work environments for people from marginalized backgrounds, including scholars who identify as BIPOC, white women, transgender, genderqueer, non-confirming, relgious minorities, academics with disabilities, and foreign born or international (Davis et al., 2015; Camacho & Lord, 2011; Sian, 2017; Atherton et al., 2016; Postel, 2015). As accurately stated by Berhe et al. (2022), STEM spaces are more of an obstacle course to navigate through for scientists from marginalized backgrounds. The obstacle course in STEM was described by many of the applicants in the ReclaimingSTEM workshop. An overwhelming majority of the applicants describe their relationship with science as *hostile.* Several applicants cite times in which they *experienced discrimination and discouragement*, have *imposter syndrome*, feel that *STEM is not welcoming,* were often the *only one in their field*, and often work to *combat identity-based stereotypes*.

Experienced discrimination and discouragement: Many applicants described *experiencing discrimination and discouragement* from being or feeling they can pursue STEM, "Fags don't belong in healthcare. It was a simple message I received early on. As a first-gen, queer individual, with multiple disabilities, this materialized into a narrative of, 'STEM isn't for me'." (reference 5, 2020 workshop).

Another attendee wrote about how their peers reinforced the idea that they do not belong in their field,

> [I]t has been so often the case that my impostor syndrome has been reinforced by white peers and colleagues telling me that I don't belong and that I am a diversity hire. Finding my 'new' identity within my new context has been challenging. (reference 260, 2020 workshop)

In many of the attendees' responses, they often felt *judged and stereotyped* based on their identity, which affected their experience in STEM spaces,

> The PI I worked with had no respect for me (a woman) and said things to me like, ‘lab staff are like tissues, disposable’ and ‘women in science get abused, learn to deal with it.’ This experience made me incredibly wary of working with male scientists. (reference 36, 2020 workshop)

Another attendee wrote about how their queer identity was not percieved as someone who could be a scientist, “Growing up queer I always struggled with identifying as a science lover. I was commonly told that I do not ‘act’ like a scientist or they would ‘never guess’ that I completed my undergrad in Physics.” (reference 57, 2021 workshop). One attendee wrote how they received judgment based on their identity, “As a Hispanic woman in STEM, I have received "feedback" in this style: "she has the potential to be a decent scientist one day". I know the potential of other demographics is not questioned the way it is for POCs.” (reference 171, 2020 workshop). Several other attendees described experiencing *sexism*, *homophobia*, *racism*, explicitly told they *cannot achieve their dreams*, *faced retaliation due to their advocacy*, and *dealt with micro and macro aggressions*.

***Imposter syndrome**:* Often, many applicants wrote about feeling *imposter syndrome*,

> As I became a STEM student and became involved in research at my university, that self-imposed imposter syndrome began to extend into other spaces. I would often doubt my ability and chalk up my accomplishments to tokenization because of my identity, and not because of my hard work. (reference 152, 2020 workshop)

This feeling of imposter syndrome often leads applicants to feel like they need to worker harder to *prove themselves*,

> As a black and gay male in science, I fit into a very small niche. At times, I sometimes get the impression that I am an item for the department to showcase. There are times where I suffer from imposter syndrome and have to remind myself that I do belong. Being black and gay has a huge impact on my science as I feel like I have to succeed because failure is not an option and if success if not reach, it will impact future persons of color. (reference 59, 2019 workshop east)

Another applicant wrote and described how they feel they need to fight for their place in STEM, "As a BIPOC woman, I needed to fight to be included in STEM conversations by constantly trying to prove that I understood the topics." (reference 81, 2021 workshop)

STEM is not welcoming: Several applicants mentioned they find that *STEM is not welcoming* and feel that STEM spaces were not meant for them, "The higher I climb academia, the more it

becomes evident how certain areas are not meant to serve me and my community." (reference 22, 2018 workshop). Another applicant wrote, "As a woman and person who struggles with mental health issues, I am acutely aware of the ways the culture of science and academia are not always welcome spaces." (reference 20, 2020 workshop).

Another applicant wrote about how this unwelcoming environment makes STEM difficult to navigate with their identity,

> The institution of science has not and is still not the most welcoming environment to individuals from underrepresented communities. As a queer Latinx undocumented person, science has not been the easiest to navigate. However this is what also keeps me moving forward in this field. (reference 25, 2018 workshop)

Other attendees felt like they were being *othered in STEM* and often feel like they *are not taken seriously*, "my short stature and youthful appearance, and often the fact that I'm a woman, make it difficult to be taken seriously. In the scientific community I am initially observed by many as a young inexperienced student." (reference 53, workshop 2019 east coast).

Another applicant wrote about how they feel they are being othered due to their visible identities, and this impacts their ability to communicate,

> My blackness enters a space before I do (because it's the first thing people see when they look at me). My womxnness enters a space before I do. I communicate from a desire to

> be heard and have my thoughts valued, as they historically have not been. I communicate in pursuit of proving myself - my strength, my knowledge, my capabilities. It's honestly exhausting and oftentimes, it keeps me from communicating at all. (reference 111, 2019 west coast workshop)

Only one in their field*:* Others describe they often felt like they were the *only one in their field*, and often feeling they are not being represented 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, workshop 2019 west coast)

Another attendee wrote about how isolating it can be when you feel like you are the only one, “Seeing so few people in the department from a similar background and knowing that only 2 of the ~15 research faculty are women can feel incredibly isolating even though everyone is welcoming and helpful in every aspect of my program.” (reference 21, east coast workshop 2019).

Often, based on being one of the only ones who present their identities in their field, applicants feel they need to make their presence known,

> [I]n most professional forums I find myself the youngest person in the room by a decade or more, and often the only woman in the room. I have had to learn how to present calm, grounded, and fact-based arguments in language that can be heard by people in positions of power, even as the fierce urgency of climate change, biodiversity loss, and water shortage issues that already curtail underserved communities' ability to fulfill their potential fill me with anger, intensity, and passion. (reference 251, 2020 workshop)

Combat stereotypes: Several applicants wrote their need to *combat stereotypes* due to the culture of STEM. For some applicants, they want to represent their cultures and identities through example,

> As a queer Hispanic engineer, 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, workshop 2020)

Other applicants also wrote about wanting to prove people wrong, and combating stereotypes through visibility, "The common negative attitude about women in computational sciences is that 'women can't code', or are less capable than men in the computational field. As a result, my communication style leans toward giving women researchers more visibility to challenge these toxic notions. (reference 50, 2019 west coast workshop).

<u>Obstacles in STEM</u>:

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

> As someone that has overcome many obstacles to reach my current position as a junior scientist, I know how difficult things can get along the way, however, I seek to use my identity and experience to mentor and motivate individuals from similar backgrounds to become scientists and engineers. (reference 26, 2018 workshop)

Another applicant wrote about how their visibility with their identity can help others navigate STEM spaces and feel more welcome,

> 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. I went to a liberal arts college where STEM was not a focus, so I did a lot of legwork on my own to figure out post-bac opportunities and what being in graduate school looks like. (reference 9, 2020 workshop)

Lack of access to STEM: Other applicants write they have a *lack of access to STEM* from an educational standpoint due certain circumstances, such as economic backgrounds, which caused a *lack of exposure to STEM,*

> I often organize bootcamps for young aspiring minority students with the purpose of exposing them to STEM. I was never made aware that being a part of the STEM community was a possibility. I come from poverty, and I understand that education is not often not made a priority. (reference 44, 2018 workshop)

Others have mentioned a lack of access due to a *lack of accommodations,*

> Lack of accommodations and ableism have affected how I approach science and communication. As a disabled person, I have had to build a career from my bedroom. For example, all of my communication is online at the moment. (reference 257, 2020 workshop)

> As someone with dyslexia, I approach teaching with an empathy that can be lacking in some professors approached with an individual with learning differences. In college, I've been met with professors unable and/or unwilling to modify their teaching styles to accommodate someone like me, which made succeeding in those classes (often science classes) difficult. (reference 23, 2019 east coast workshop).

Others cite examples of *culture barriers,* and *immigration status,* as obstacles to their access to STEM.

Lack of role models: Many applicants write they *did not see themselves represented* in their fields,

> I am an African American woman and oftentimes I am aware that I am the only one in the room. When I do have opportunities to speak, it's usually to a room of people that don't look like me or have a similar background to mine. I am aware as I move forward in my science, this will continue to be the case. (reference 19, 2019 workshop)

This lack of representation, means a *lack of role models*. This often lead applicants to want to be that role model for others to look up to,

> Being a queer woman, however, I don't have a ton of role models or mentors in STEM that are like me. I try to be as open with my identity as I feel safe doing when communicating so I can model what a queer scientist can look like for others. (reference 146, 2020 workshop)

For other applicants, *lack of mentorship* was an obstacle for them navigating STEM spaces,

> I genuinely believe if I had mentors with correct, up to date information on studying engineering in college or LGBTQ STEM figures to look up to I would be further ahead than where I am right now. (reference 65, 2019 west coast workshop)

Inclusion:

Applicants in the workshop have experienced lack of role models, and thus, often feel it is their *responsibility to represent their identities* in STEM spaces, in an effort to help others feel included,

> As a first-generation afro-Latina and the first among my family to earn a college degree, I believe that it is my responsibility to be a communicator instead of just "researcher". My identity is what requires me to be able to effectively and concisely communicate my science because I am a representation of my culture and generation. This is important not only for the way I choose to present myself, but for others that choose to follow in my path because they are able to see that it is possible. (reference 5, 2018 workshop)

Others feel the need to *advocate for others like them,*

> Being a queer woman in STEM made me realize very early on that I would not just be communicating my research, but also on behalf of that community. (reference 50, 2021 workshop)

Applicants write they believe *visibility matters* as doing so can bring representation,

> [T]aking pride in my identity is really important in STEM because it's a field that has historically left BIPOC, women, disabled people, queer people, and any combination of the sort, out. (reference 89, 2020 workshop)

Other want to help address issues affecting their communities through their science and communication,

> As a transgender person, I am a member of a group that is underrepresented and often misrepresented in research. We are also highly vulnerable to harm based on this misinformation. Therefore, it has become a goal of mine to increase accurate representation of LGBT+ people in science communication. (reference 386, 2020 workshop)

Shifts in identity

Based on their experiences in STEM spaces, many applicants have had a *shift in their identity.* They write about how they have become *aware of their privilege,*

> My identity helps me to recognize instances of bias and barriers to inclusivity/access through my own experiences with bias and barriers I have faced and the empathy this has cultivated in me for others facing barriers. (reference 55, 2020 workshop)

Another applicants write how they manage their mixed identities as they experience both privilege and marginalization,

> My identity as a queer woman works in contrast to the privilege I hold as a white, cis, straight-passing person who is a 3rd generation PhD. I have both experienced discrimination due to my identity, but also am given the benefit of the doubt due to my ethnicity and educational background. (reference 91, 2020 workshop)

Additionally, applicants also write how their experiences have caused them to have *empathy for others* in similar situations,

> I identify as a bi Chicana and believe that this has influenced my acceptance of others, openness to communicate to those that differ from me, and desire to help marginalized groups in society. (reference 114, 2019 workshop)

Hiding identities and code switching: Most troubling is the need for applicants who feel they must assimilate to the STEM cultural norms by hiding their identities or code switching,

> 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, 2020 workshop)

Others write how they feel they need to hide their identity in fear of the reaction or judgment from their peers,

> It's hard to say. I have only come out to a small group of people as non-binary. I am scared of the broader reaction in my department and research collaborations and the loss of privilege as a more masc[uline] presenting and passing person. I refrain from mentioning this to broader spaces to avoid judgment. (reference 8, 2020 workshop)

<u>Support systems</u>

For several applicants, their connection with their *family*, *cultural backgrounds*, *identities*, and their *support systems* influences their relationships with science. For some, it is *why they chose their field of research*,

> My grandmother is indigenous and hails from Northern Mexico. As a child she taught me about the importance of medicinal herbs from her ancestral lands. The trees in her region have long been used as an aseptic. My cultural heritage has had a tremendous influence on my decision to study trees as a doctoral student. (reference 1, 2018 workshop)

Others feel their chosen field of study is meant to help serve their communities,

> The motivation for my scientific research is inextricably linked to my identity. Growing up in a xenophobic Nairobi as a child of Eritrean refugees, a lot of our outcomes were not within our control. Plastic-heavy trash piles were commonplace on my walk to the school bus stop and "solutions" we heard uttered by tourists remained only accessible to them. (reference 61, 2019 west coast workshop)

Affinity spaces and good support systems: Of course, for other applicants, good support systems were essential to navigating STEM barriers. This included having *affinity spaces*, and finding people in their fields who share their identities,

> 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, 2020 workshop)

For several applicants *having mentors who looked like them* was important to teach them 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, 2020 workshop)

STYLES

Freire (2018) terms most education styles as "banking", in which there seems to be only one-way to transfer knowledge. This style treats students as knowledge deficient, and the teacher needs to fill this void (Freire, 2018). Similarly, science communication traditionally stems from a deficit model, in which the scientist tries to fill the deficit in knowledge when they set out to pursue science communication goals. The deficit model also assumes that people will change their minds or their behavior if they get enough scientific information (Simis et al., 2016). Scientists with the deficit model simply share science knowledge, without consideration for the audience in their communication goals. This "soap-box" approach is inefficient, and leaves all

the power to the knowledge sharer. This style of communication can further lead to systems of marginalization.

Scientists from diverse backgrounds wish to go beyond the traditional deficit based model, and employ different strategies that are more audience centered (Canfield & Menezes, 2020). Based on the applicant's experiences in STEM spaces, applicants engage with their communities using styles that are *audience centered*, *emotionally driven, and identity centered.* Several applicants also wrote about traditional science communication approaches, including making topics *concise and clear, direct, and avoiding jargon.* Here, we expand on the non-traditional styles of communication.

Audience centered: For *audience centered* communication styles, attendees make sure to emphasize *inclusion* and *do not assume prior knowledge*,

> My various identities have helped me develop a style of science communication that focuses on finding commonalities among people. 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, 2018 workshop)

Other applicants make sure to center their audience in their engagement through *open, honest, attentive, personal, and respectful* communication,

> As a queer person, I do not think that existing norms are our inherent destiny. Life is a constant process of questioning and challenging established ways. Adaptability and openness is central to my scientific and creative approach, in addition to my personal identity. (reference 223, 2020 workshop)

Many applicants mentioned their use of *storytelling* as a way 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 and share ideas with them about anything, including science!" (reference 34, 2020 workshop)

Another applicant wrote about storytelling being central to their culture,

> My science communication style has drawn both directly and indirectly from my backgrounds. A cultural and religious tradition is applying henna on religious holidays and I have incorporated chemistry and physics into my designs to weave science stories on my hands. I also come from a background where stories are powerful learning tools

> and in my scicomm articles I have written, I use both gentle story telling and reporting of facts to communicate and share my science. (reference 285, 2020 workshop)

Others wrote about how using storytelling could be a way to give others a voice,

> I like to communicate science through stories because stories allow us to have different perspectives, to be able to correlate stories and to share them without limitations. Most importantly, because is a way of being the voice for those voices that are silent. (reference 55, 2019 west coast workshop)

Emotion driven: Many applicants wrote about their style of communication including a lot of *empathy*,

> 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, and gives me the energy to try to think of a way that they can relate to the concept. (reference 9, 2018 workshop)

Others cite using *joy* and *laughter* to help encourage engagement,

> To many, these aversions are a symptom of lack of representation and an accompanying sense of rejection by STEM communities. By practicing empathy towards an audience

> with mathematical anxiety and by mixing in some humor and pop culture, I've found that conversions are more likely to begin rather than end when I mention my work to children in class, or to my friends and family. (reference 87, 2019 west coast workshop)

Some applicants state using *compassion,* and being understanding of people's experiences,

> I identify as a person who has struggled to get to where I am today, and because of this I am compassionate toward others even if I don't know their background. I am deeply aware that life is unfair, and I do everything in my power to help those who were given less (or had more taken from them) because of their identities and socioeconomic statuses. (reference 10, 2019 west coast workshop)

Identity centered: When using *identity centered* styles, applicants found it important to incorporate their identities or their communities in their communication styles.

Some applicants emphasized needing to be *inclusive* by including the proper use of pronouns,

> As someone who identifies as both non-binary (genderqueer) and queer, I believe my science communication style is focused on being inclusive to others - and especially focusing on being respectful of pronouns. (reference 13, 2020 workshop)

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 in carbon dioxide removal and climate change 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, 2020 workshop)

Several applicants 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, 2020 workshop)

GOALS AND OBJECTIVES

While science communication interest is growing, global leaders are urging more participation of scientists and encouraging increased science communication efforts from STEM experts (Cicerone, 2006, 2010; Jia & Liu, 2014; Leshner, 2015; McNutt, 2016; Napolitano, 2015; The Royal Society, 2004; South Africa Department of Science and Technology, 2014; Thorp, 2020). Several surveys have found more increased participation of scientists in public engagement (AAAS; Rainie et al., 2015). Past research on science engagement with the public concluded that scientists have negative opinions about the public, and they feel there are limited

benefits to engagement (Besley & Nisbet, 2013). In follow-up studies, research shows that there was little relationship between how scientists see the public and their views with science engagement (Besley 2015; Besley et al. 2013).

Studies have been conducted to address what goals scientists were to achieve through their communication efforts. In one study by Besley et al. (2016), looking at science communication training programs, their communication goals included both internal (i.e: personal career benefits, societal benefits), and external (i.e: ensuring science is well regarded, and valued, feeling a sense of duty due to funding sources, and wanting to be a role model). Additionally, scientists' objectives through their communication efforts included providing clear and concise scientific information, fostering excitement in science, building trust, and framing issues (Besley et al., 2016). However, we found our applicants have different goals and objectives through their communication efforts. Mainly, our attendees seek to foster a sense of belonging for their communities in STEM spaces, and they do this through *advocacy, increasing representation, creating spaces, doing service for their communities, and bringing their full selves into STEM spaces*.

Increase representation: Many applicants write that they wish to *increase representation* in their fields, or in STEM in general,

> I'm black, and I grew up watching Bill Nye and Mythbusters. Sure there were some black characters on Magic School Bus, but prominent figures in science didn't look like me. I'd want to get to the point some child knows that science has people that look like them too, and it's not an anomaly. (reference 82, 2020 workshop)

Several applicants wrote that they aim to increase representation through being a *role model themselves*,

> As I began to pursue ecology, 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. I believe that having access to a full education is the key to bridging the gap in the representation of the STEM community." (reference 58, 2020 workshop)

Several applicants also aim to increase representation by *spotlighting other scientists* from marginalized communities,

> It's important for me to create a space for women of color in STEM and to highlight the diverse stories of people from around the world. Being an intersectional minority, I am very cognizant of showcasing stories of intersectional minorities. I always use my personal experiences to understand the issues and proudly advocate for understanding the complexities of intersectionality in STEM fields. (reference 44, 2019 east coast workshop)

Advocacy: Many applicants want to use their engagement in order to *advocate* for their communities in STEM. Mainly, what they hope to achieve is to *change the culture of STEM*,

> I want to be one of those women to uplift other minority groups and mentor them to get to wonderful places. For women to leave STEM careers due to unequal burden for taking care of home and child care deeply hurt me. I wish to fix that leaky pipeline and make them more comfortable to raise voice for themselves and take reins of their life" (reference 2019, workshop 2019).

Others write about *increasing accessibility*. 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, similar to how health care providers have a responsibility to communicate effectively in caring for their patients. (reference 65, 2021 workshop)

Other applicants want to provide accommodations in STEM spaces,

> I am a queer woman who has dealt with psychological disabilities (major depression and ADHD) for the last 13+ years. I have personally experienced discrimination and discouragement by the STEM academic establishment. My determination to change attitudes and improve accessibility in science has driven me to advocate for my fellow

> grad students as well as undergrads, especially those from underrepresented/vulnerable communities. (reference 73, 2019 west coast)

Many applicants also wrote needing to *combat stereotypes* in STEM spaces and doing so in their teaching space,

> As a relatively young (biracial) Latina, I am regularly reminded (both implicitly and explicitly) that i do not “look like a scientist.” As a result, on the first day of every class I teach, I invite my students to reflect on their stereotypes about scientists, where those stereotypes come from, and how they impact their beliefs about who can (and can’t) do science. (reference 27, 2018 workshop)

Another applicant wrote,

> Living in America and being an African American woman, when communicating with others I can feel ignored or silenced. When I speak I want to feel empowered and have knowledge of the topic I'm speaking about. I want to show others that the stereotypes created about African American women are false and that we are educated, loud or "ghetto". I have a biology and research background and never felt like I found my “niche” until my current role. I have a very commanding presence, where I have to exude confidence, even when I don’t feel it, because I am a double minority. (reference 44, 2020 workshop)

Create spaces: As many applicants had negative experiences in STEM spaces, these applicants 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,

> As a woman in mathematics, I have often felt like an outsider in my field. Colleagues often dismiss my ideas or do not trust the work I do. Being on the receiving end of these interactions has impacted the way I communicate with others. When communicating with others I try to not only create an inclusive environment, but also aim to make space for all voices to be heard. (reference 30, 2020 workshop)

Another applicant wrote about their experiences as a student influenced their approach as an instructor,

> In every way, from my sexuality to my skin color to my Americanized mother tongue, my identity has impacted how I've experienced and taught science. Having gone to a largely white and wealthy high school, and following that up by attending a college that is part of the ivy league bubble of Columbia, I experienced a dissonance between how I looked and the people around me who were 'scientists', always believing that even though I killed myself to score highly in my courses, that those around me would find out that I was a fraud and "not smart enough" to stand alongside them as a fellow scientist. It didn't matter how hard I'd worked to get to where I was, in my mind, I'd be "lucky" if I grew up to be more than my immigrant mother (a housekeeper with broken English, doing largely invisible work for the white, wealthy, benevolent, and powerful families of Los Angeles).

> Since switching from the role of a student to the role of an instructor, I've been passionate about creating scientific spaces that not only claim to support underrepresented young women like myself, but that actually foster a sense of belonging -- the very thing that I didn't feel throughout my undergraduate career in the same rooms that my students are now learning in. (reference 32, 2021 workshop).

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 and aviation fields are disbanded. However, in the meantime I strive to be a part of the welcoming scientific community for others to share their knowledge, as well as explore for myself the most efficient and effective ways to share my story and science to the world. (reference 8,2019 workshop)

Service: In terms of *service for their communities*, applicants wrote that they conduct science and do engagement activities for their community,

> My ability to communicate and express my ideas are concise and clear. I pride myself in finding solutions where others often don't see any. Hence 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 there conditions and learn more about these neighborhoods' needs, that other don't take the time to care for. (reference 21, 2018 workshop)

Another applicant wrote about collaborating on their communicating with their community,

I live in a community where most parents are immigrants and have not pursued higher education. So when I explain my research, I formulate it in a way that I think they would understand, and implement their feedback if they don't understand. I also wish to make my research community based. I recognize it is a privilege to pursue higher education and explain my research and environmental issues with humility, patience, and eagerness to continuously improve. (reference 340, 2020 workshop)

For other applicants, *service to their community* means *learning to be a better ally,* or *learning to leverage their privilege*,

As a queer woman, I understand how it feels to not see yourself reflected in STEM leadership, and academic leadership more broadly. Over the last few years, I have educated myself about my own internalized homophobia/biphobia and internalized sexism/misogyny, and I have sought out information about barriers to access/opportunities for womxn and queer folx in STEM (rooted in sexism, cissexism, heterosexism, gender racism, etc.). I recognize that these issues are even more severe for scholars of color, particularly Black womxn, Black queer folx and Black trans folx, and it is my goal to continuously educate myself about these issues throughout my career/life. I

> feel that I am still in the early stages of reading and learning about these issues, and that I still have a lot of work to do to make them a core part of my science and my communication, but that is what I am aspiring to do. (reference 96, 2020 workshop)

Another applicant wrote,

> I have a lot of privilege and I intend to use it wherever I navigate by advocating for others. I also grew up as the child of immigrants who did not speak English well, who were undocumented and incarcerated, and made very little money, landing our family below the poverty line. Thus, I have an intimate understanding of what it can be like to come of age without many resources and to prioritize finances and survival over all else. These dual experiences shape my current approach to science and science communication. (reference 84, 2019 west coast workshop)

Bring full-self into STEM: Many applicants 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. My goal in my prior work in science communication has been less about communicating about the actual science I do, and more about communicating the hidden curriculum for success to marginalized students,

> and in communicating the often-overlooked experiences of marginalized students (particularly women and disabled students) to those in positions of power. (reference 10, 2020 workshop)

Another applicant wrote,

> As a trans person, I have personally seen how representation and mentorship affect one's ability to be successful in science. I didn't know that there was a place for me in the chemistry/STEM field until I saw people who were actively pushing boundaries and breaking rules to ensure I had a spot here. For me, there is no way I can leave my identities at the doors of the lab, so I have made it a point to not erase any part of my self in the pursuit of science. The chemistry field needs people within the field pushing to make it truly equitable for all scientists. I have made it a central point of my graduate career to push for LGBTQ+ inclusivity in my department and through my work as a science communicator. (reference 5, 2021 workshop)

Some attendees write about being nervous to bring their full-selves into their science communication, however, seeing other folks do so in science communication inspires them to do the same,

> To be honest, I think in the past I have specifically attempted to not involve my identity into my communication. Because I convinced myself (perhaps wrongfully so) of the following 1) that I didn't think it would resonate with many people 2) because I am still

> early in my STEM career and there is still a lot of stigma around these kind of things 3) and because I think I was telling myself I shouldnt make the communication about me and that meant leaving my identity out of it. BUT since starting SciComm I have seen so many others use their identity to strengthen their messages. I think I would be very keen to learn from others at this event about how they can become more comfortable using that identity publicly, which currently clearly I am not. (reference 26, 2019 west coast workshop)

DISCUSSION

The current study aims to understand marginalized scientists' use of science communication, their goals and objectives, and the styles of communication used to achieve their goals. Many science communication training programs are designed around helping scientists simply fill a public deficit in scientific knowledge. This could mean that training programs need to reevaluate, reframe, and redesign their programing to meet the needs of marginalized participants. These findings suggest that current training programs are not helping marginalized scientists achieve their goals in science communication. In all, we find that scientists and science communicators from marginalized backgrounds possess starkly different values than their majoritarian counterparts. These findings highlight a critical need to overhaul current science communication training programs as they negatively impact equity and diversity in these fields and are detrimental to justice by impeding the greater dissemination of scientific information.

Little work has been done focusing on junior scientists' interest, access, and experiences related to science communication (Howell et al.,2019; Dudo et al., 2021). This study on the applicants for the ReclaimingSTEM workshop suggests that applicants are aiming to foster a

sense of belonging for their communities in STEM spaces (Figure 2.2). They do so in response to how they experienced their STEM spaces, including feeling that *STEM is hostile*, navigating *obstacles in STEM*, wishing for more *inclusion*, experiencing *shifts in identity,* and how they viewed their *support systems*. As a result, their engagement and communication styles include being *audience centered, identity focused,* and *emotion driven.* They aim to achieve the goals and objectives of helping their own communities navigate STEM spaces and feel a sense of belonging by using their engagement and communication to *advocate, increase representation, provide service for their communities,* and by *bringing their full-selves into STEM.*

Compared to past studies on science communicator goals, most scientists seem to have science-focused goals, such as increasing knowledge, increasing value of science, framing issues, etc (Besley et al., 2016). While some of our applicants did wish to do the same, the majority of our applicants were more focused on issues surrounding identity in STEM spaces. In one study by Dudo et al., they found that most science communication training spaces are focused on teaching scientists to find and refine their own messages and stories, and having scientists find their own opportunities to engage their science (Dudo et al., 2021). Additionally, the trainees interviewed appeared to be diverse in their careers and career stages, but not in terms of gender, cultural, or ethnic backgrounds, and therefore they concluded training spaces are not designed to specifically help trainees from marginalized backgrounds (Dudo et al., 2021). Our results suggest that applicants from marginalized backgrounds are seeking science communication spaces in order to achieve goals and objectives that differ from traditional science communication training spaces goals. Therefore, there should be a push to change the

current science communication training curriculum to include the needs and interests of scientists from marginalized backgrounds.

Empirical research rarely focuses on the expanding field of science communication (Dudo et al.,2021), and these results are among the first of their kind to highlight the science communication goals and objectives from marginalized populations in STEM. As such, we must use these results to understand and inform training spaces in science communication. For example, similarly to the Inclusive Scicomm Landscape report by Canfield and Menezes, which included 30 interviewees from diverse backgrounds, they found there was intentionality in their engagement efforts by centering their audience or community in their communication goals. Additionally, their interviewees also wanted to incorporate their audiences' cultural histories and backgrounds (Canfield & Menezes, 2020). While we found this in our applicants, we also found that applicants wanted to ensure belonging through using emotion and identity centered styles of communication to engage their communities.

Additionally, similar to Canfield and Menezes' study, we also found our applicants wanted to move beyond the knowledge deficit model of communication. In their study they found interviewees wanted reciprocity with their communities in their engagement efforts (Canfield & Menezes, 2020). While these goals still keep science centered goals, we found our applicants mainly wanted to influence the culture of STEM spaces by including goals that help foster a sense of belonging through other ways of engagement, such as advocacy efforts. This further emphasizes Canfield and Menezes' call to change the definition of science communication to include different forms and ways of engaging, to challenge what "counts" as a

scientist, and what counts as science communication (Canfield & Menezes, 2020). We advocate for science communication to also include advocacy, service, and efforts to increase representation and promote inclusion through creating spaces, highlighting different scientists from marginalized backgrounds and efforts to bring full identities into STEM spaces as forms of science communication.

Scientists have a very powerful position, in which they have the power to influence and change the environment which currently exists in STEM. Our results suggest that this burden is primarily felt, and taken on, by marginalized scientists. Scientists from marginalized backgrounds aim to change the culture of STEM through their communication efforts in order to promote a sense of belonging for their communities. This burden must be shared, as the STEM community as a whole should aim to change the culture of STEM. Additionally, as science communication spaces are often a reflection of STEM spaces, training spaces should examine their own cultures and assess whether they are fostering belonging as more marginalized scientists are seeking training in their programs. Doing so, will help to change the culture of STEM spaces, and help to promote equity and inclusion of marginalized communities in STEM and beyond.

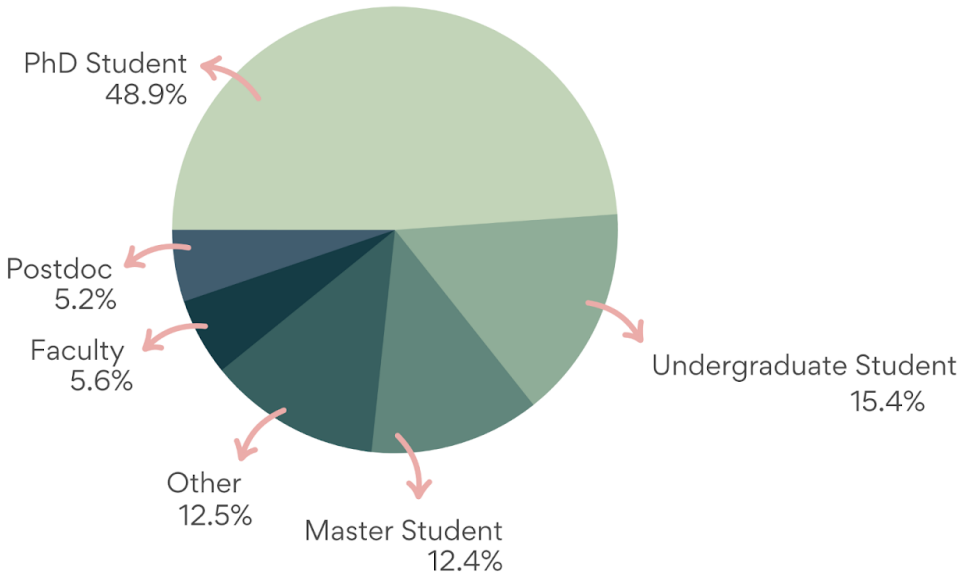

Figure 2.1 Level of education for ReclaimingSTEM participants.

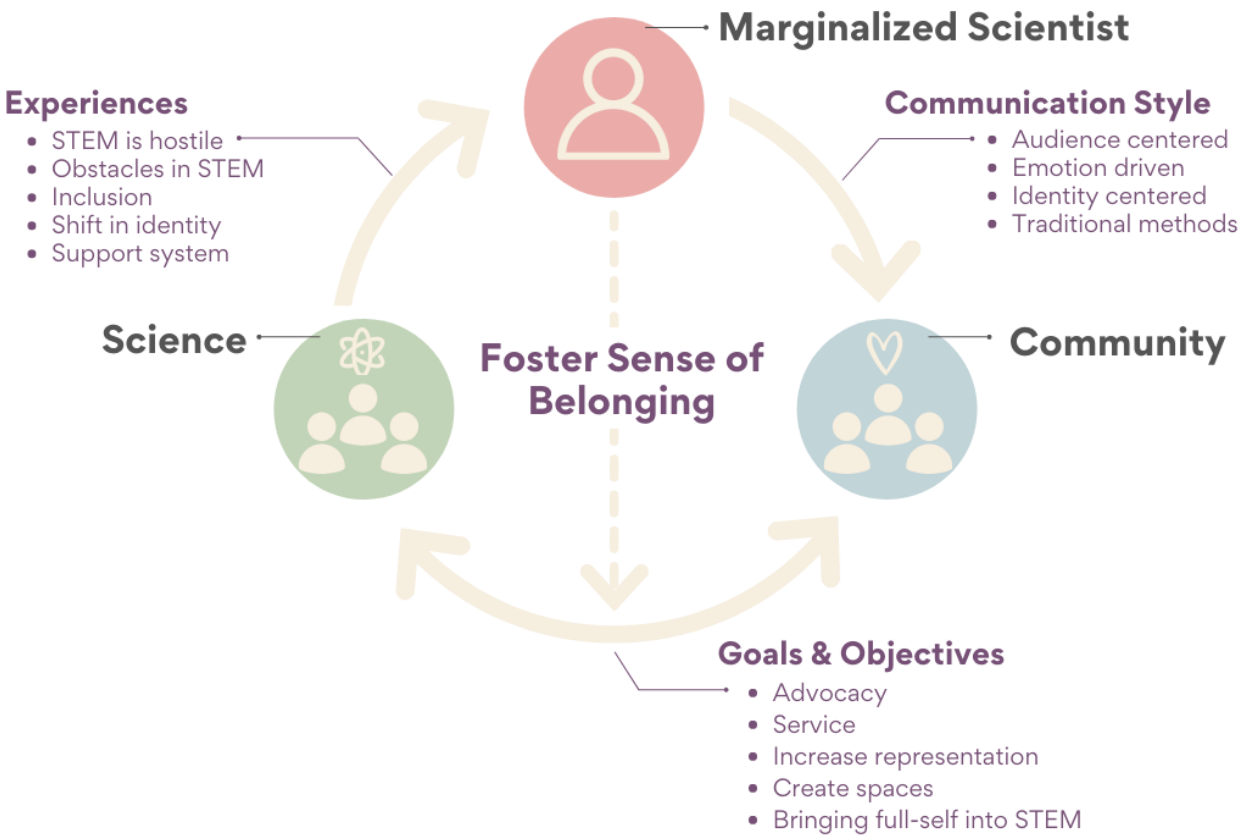

Figure 2.2. Results overview of how marginalized scientists use their science communication. Scientists have an experience as they navigate STEM spaces, which influences their science communication style as they interact with their community. Ultimately, through their goals and objectives, they aim to foster a sense of belonging for their communities in STEM spaces.

Table 2.1: Applicants for the ReclaimingSTEM workshops. The year, location held or virtual, is indicated on the left, while the number of applicants is indicated on the right.

Year	Applicants
2018 West Coast	45
2019 West Coast	114
2019 East Coast	76
2020 Virtual	387
2021 Virtual	90
Total	**712**

Table 2.2 Identities of participants of the workshop. The identities are broken down into categories. The number of participants who mentioned this identity is listed beside the identifier. Under each category, are different ways in which the participants mentioned or specified their identities.

Race and Ethnicity	**460**			**LGBTQIA+**	**341**	**Immigration status or mention**	**54**	**Mental health**	**28**
Latin(a)(o)(x)	126	Afrolatina	2	queer	52	immigrant	29	neurodivergent	16
Black	67	Brazilian	2	bisexual	18	undocumented	5	Anxiety	2
POC	42	Caucasian	2	gay	6	daca recipient	3	mental health disablity	2
Hispanic	32	AAPI	3	lesbian	5	daca-mented	1	mental illness	3
White	31	Filipin(o)(a)(x)	5	pansexual	5	ab540	1	adhd	2
Asian	18	Filipin(o)(a)(x)-American	3	asexual	3	International	4	depression	1
Mixed race	11	Filipinx-American	1	demisexual	2	child of immigrants	3	autistic	1
African american	10	Vietnamese-American	3	**First Generation**	**295**	refugees	1	insane	1
Asian American	9	Vietnamese Chinese	1	**Gender**	**313**	family were refugees and immigrants	1	**Religion**	**18**
South Asian	9	Multi-ethnic	1	woman	173	foreigner	1	Muslim	7
Mexican	8	Mediterranean Arab	1	womxn	27	non-alien resident	1	Jewish	7
Mexican American	7	Costa Rican	1	WOC	14	immigrant parents	1	Sikh	1
Chican(a)(o)(x)	12	Arab-American	1	female	32	newly immigrated	1	Atheist	2
Middle Eastern	5	Non-Black POC	1	non-binary	18	foreign born	1	Buddhist	1
Puerto Rican	5	Mestisx	1	cis-gender	14	former undocumented	1	**Minority**	**16**
BIPOC	5	American-Colombian	1	cisgender	5	**Education**	**48**	Ethnic minority	2
Indian	4	Multicultural	1	transgender	10	international student	9	Under Represented Minority	2
Indian American	3	Bolivian	1	male	7	college student	6	Visible Minority	2
American	4	Salvadoran	1	man	1	grad student	6	**Worldviews**	**4**
African	3	Guyanese	1	genderqueer	3	second generation	5	Socialist	1
Chinese	3	New Mexican Hispanic	1	intersex	1	college graduate	4	Communist	1
Chinese American	2	Mixed-ethnicity	1	Agender	1	non-traditional	3	Futurist	1
Chinese Canadian	1	Cultural heritage	1	they them theirs	1	PhD	2	Anti-capitalist	1
Chinese indonesian	1	Mestizo	1	genderqueer woman	1	returning student	2	**Upbringing or Family Background**	**6**
Chinese American	1	Latin-American	1	femme-appearing	1	transfer student	2	Former foster youth	2
Southeast Asian	3	East Indian American	1	gender-woman	1	nontradional	2	raised in single parent household	1
Multiracial	3	Irish	1	gender-non-conforming	1	international scholar	1	orphaned	1
East Asian	2	Peru	1	femme	1	research	1	transracially adopted	1
West-indian	2	Ghana	1	femme-leaning nonbinary	1	researcher	1	transnational adoptee	1
Biracial	2	Central American	1	**Learning differences, chronic illness, disabled**	67	student	1	**Hobbies or Lifestyle**	**4**
Afrolatina	2	Born in India, raised in Canada	1	chronic illness	9	re-entry	1	yogi	1
Brazilian	2	Afro-Caribbean	1	with a medical condition	1	community college transfer student	2	writer	1
Caucasian	2	Desi	1	person living with multiple sclerosis	1	scientist	37	actor	1
AAPI	3	Chihene Nde	1	disabled	42	**Socioeconomic status**	69	vegan	1
Filipin(o)(a)(x)	5	Middle Eastern Immigrant	1	learning difference	2	low socioeconomic status	24	**Does not know**	**3**
Filipin(o)(a)(x)-American	3	Cuban	1	learning disability	3	low-income	40	**Human**	**2**
Filipinx-American	1	European	1	people with disabilites	2	lower middle class	1	**Hijabi**	**2**
Vietnamese-American	3	Zapoteca	1	physical ability impaired	1	working class	1	**Polyamorous**	**2**
Vietnamese Chinese	1	Pacific Islander	1	dyslexia	1	Third World	1	**Activist**	**2**
Multi-ethnic	1	Brown	1	invisible disability	1	poor	1	**Other**	**1**
Mediterranean Arab	1	from a Brahmin Hindu family	1	differently abled	1	caste priviledge	1	**Veteran**	**1**
Costa Rican	1	Native	13	Deaf	1	**Minority**	**16**		
Arab-American	1	Indigenous	4	disabled lupus ADHD	1	Ethnic minority	2		
Non-Black POC	1	Taino	2	autoimmune disease	1	Under Represented Minority	2		
Mestisx	1	native hawaiian	1	**Ally**	**6**	Visible Minority	2		
American-Colombian	1	Native Pacific Islander	1	**Heterosexual**	**6**	**Parent**	**4**		

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