TYPE Original Research
PUBLISHED 10 August 2023
DOI 10.3389/feduc.2023.1173661



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RECEIVED 24 February 2023
ACCEPTED 25 July 2023
PUBLISHED 10 August 2023

CITATION
Alderfer S, McMillan R, Murphy K and Kelp N (2023) Inclusive Science Communication training for first-year STEM students promotes their identity and self-efficacy as scientists and science communicators.
*Front. Educ.* 8:1173661.
doi: 10.3389/feduc.2023.1173661



# Inclusive Science Communication training for first-year STEM students promotes their identity and self-efficacy as scientists and science communicators

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**Introduction:** It is critical for STEM students to be able to discuss science with diverse audiences, yet many STEM students do not receive adequate training in these skills. When students have the skills to communicate about science, they may feel a resulting sense of empowerment as a scientist as well as help members of society understand science.

**Methods:** In this study, we developed, implemented, and evaluated a workshop that gave students understanding of and practice in applying Inclusive Science Communication. We assessed the workshop via a mixed-methods approach.

**Results:** We quantified student affective measures that are associated with STEM persistence, such as science self-efficacy and science identity, showing that the workshop increased these measures both for students of marginalized identities and for students who do not hold these identities. We also assessed student open-ended responses for themes related to the Theory of Planned Behavior, Community Cultural Wealth, and White Supremacy Culture, finding that forms of cultural capital empowered students to perform science communication behaviors while power imbalances, fear of conflict, and perfectionism presented barriers to these behaviors.

**Discussion:** This study highlights the importance of providing explicit training and practice in Inclusive Science Communication for undergraduate STEM students. Our results also suggest that students need the opportunity for reflexivity – that is, the practice of reflecting upon their identities and motivations – in order to develop in their identity and confidence as scientists and science communicators.

KEYWORDS
**inclusive science communication, science identity, science self-efficacy, reflexivity, community cultural wealth**

## Introduction

Of many calls for change in undergraduate STEM education, two include better supporting historically marginalized students (Arif et al., 2021) and training students in professional skills such as science communication (American Association for the Advancement of Science, 2009;

Brownell et al., 2013; Bankston and McDowell, 2018; Dahm et al., 2019). In this study, we present a theoretical rationale for connecting these two goals via inclusive and humanistic approaches to science communication. We also present the development, implementation, and evaluation of an Inclusive Science Communication training that helps undergraduate STEM students recognize and utilize their strengths.

## Inclusive Science Communication as a tool to support historically marginalized students

Students of low socioeconomic status (low SES), first generation college (FGC) students, and students who identify as Black, Indigenous, and People of Color (BIPOC) face many challenges to success in STEM fields. These may include lack of access to resources, lack of educational preparation for college, stereotype threat, and systemic barriers of exclusion or lack of support by the institution (Montgomery, 2020), which can all lead to lack of confidence, self-efficacy, or motivation on the part of the student (Rangel et al., 2020). This unfortunately contributes to many of these students not completing degrees in STEM fields (Olson and Riordan, 2012; Rainey et al., 2018) or lacking empowerment and inclusion if they do continue in STEM. Much work has been done to address these issues and promote underrepresented and disadvantaged student persistence in STEM (Estrada et al., 2016), including active learning in the classroom (Ballen et al., 2017; Theobald et al., 2020) and faculty mentoring outside of the classroom (Haeger and Fresquez, 2016; Estrada et al., 2018). While these strategies are helpful, data on retention indicates that there is still more work to be done to promote the inclusion and success of low SES, FGC, BIPOC, and other marginalized students in STEM degrees and careers (Fry et al., 2021; Stockard et al., 2021).

An additional group of helpful strategies for both historically marginalized and non-marginalized students relate to diverse form of communication in STEM. Communication training within STEM disciplines, including training in science writing and oral presentations, has been shown to increase students' science identity (Cameron et al., 2015; Linvill et al., 2019). Writing-to-learn activities instituted in the STEM classroom have been shown to increase performance, especially for first generation and minority students (Balgopal and Montplaisir, 2011; Balgopal et al., 2016). Training in professional skills including effective communication also supports marginalized students (Mackiewicz et al., 2022). The positive outcomes of these various studies suggest that science communication training may present a unique opportunity for supporting these students.

There is a movement in the field of science communication towards Inclusive Science Communication, which explicitly recognizes that science communication has historically promoted the White Supremacy Culture that exists in Western science (Callwood et al., 2022). The movement posits that ethical and effective science communication should be characterized by intentionality, reflexivity, and reciprocity in order to center inclusion, equity, and intersectionality (Canfield et al., 2020) – including both diversity of identities and diversity of disciplines necessary to solve socioscientific issues. Inclusive Science Communication focuses on multiple ways of knowing in science and co-creation by scientists and other stakeholders, in contrast to more traditional deficit approaches to science communication, which focus on the non-scientist public as an ignorant monolith (Simis et al., 2016). More inclusive and culturally-responsive forms of science communication focus on humanist approaches to science communication as opposed to the more traditional instrumental uses of science communication (Blue, 2019). Unfortunately, many deficit-based approaches persist in science communication (Suldovsky, 2016; Metcalfe, 2019; Nerghes et al., 2022).

We have recently analyzed published science communication trainings for STEM students, finding that most published trainings for undergraduate STEM students promote a more deficit-based rather than an inclusive approach to science communication (Vickery et al., 2023). This is problematic in two ways: one, students will not receive the inclusive worldview and skills necessary to engage in more Inclusive Science Communication practices, which are more effective than prior deficit-based approaches (Simis et al., 2016; Suldovsky, 2018); and two, students from marginalized backgrounds will not be trained how to capitalize on their own assets that they bring to science. Studies of participants from low-income and other minoritized backgrounds indicate that they have limited interaction with science communication, mainly consuming instead of producing science communication. They often feel misrepresented in these communications and powerless to actively participate (Dawson, 2018). There is a need for more expansive and inclusive approaches to science communication training for all students, but especially students from historically marginalized backgrounds.

Thus, in this study, we aimed to develop and evaluate an Inclusive Science Communication workshop for first-year STEM undergraduates. We assessed how the training helped them develop skills in Inclusive Science Communication as well as how it helped them trust their own perspectives and stories. There are multiple methods to evaluate the effects of educational interventions on students of diverse backgrounds in STEM. In this study we utilized mixed methods to assess student affective measures before and after the training as well as student perceptions about science communication assets and barriers.

## Quantitative analysis: theoretical foundation

Mindset and emotional state have a critical impact on student learning (National Research Council, 2000). For instance, motivation impacts cognition and learning (Schunk and DiBenedetto, 2020). Participating in values affirmation activities has been shown to promote the success of FGC students (Harackiewicz et al., 2014) and BIPOC students (Jordt et al., 2017). Specifically, student affective measures like science identity and science self-efficacy are shown to support STEM student success and are correlated with STEM retention (Estrada et al., 2011). Science identity describes the sense of feeling like a scientist and being perceived by others as a scientist, while science self-efficacy describes the sense of feeling confident in the ability to do the work of a scientist.

Abbreviations: TPB, Theory of planned behavior; CCW, Community cultural wealth; WSC, White supremacy culture.

Science communication training has been shown to increase factors like science identity (Cameron et al., 2015; Linvill et al., 2019) and support STEM career progression (Cameron et al., 2020). Being able to communicate like a scientist – such as by doing disciplinary science communication skills like poster presentations – increases students' sense that they are a scientist. Building upon this concept, inclusive science communication focuses on the value of contribution from diverse perspectives into conversations about science and thus affords a space for students of diverse backgrounds to further develop their sense of belonging (identity) and confidence (self-efficacy). Instead of having to simply develop the skills to assimilate to current science communication practices (Halsey et al., 2020; Massey et al., 2022), students of all backgrounds should be empowered to think critically about the assets their perspectives and the perspectives of students different than themselves bring to conversations about science. Inclusive science communication training thus may add a layer of science identity and self-efficacy development.

Methodologically, affective measures like science identity, science self-efficacy, and science communication skills are quantifiable with validated metrics (e.g., Chemers et al., 2011; Estrada et al., 2011; Hanauer and Hatfull, 2015). Since these factors correlate with STEM retention, they serve as a more immediate measure of the potential long-term impact of training in inclusive science communication. Thus, while we theorize that inclusive science communication training can impact retention and success in STEM in the long term for students from historically marginalized backgrounds, measuring these affective measures enables immediate evaluation of inclusive science communication training.

Thus, for this portion of the study we generated the following hypothesis:

> *H1:* Training in Inclusive Science Communication will increase student affective measures such as science identity and self-efficacy.

## Qualitative analysis: theoretical foundation

We also asked students open-ended survey questions in order to better explore their attitudes regarding science communication in general and Inclusive Science Communication training. We wanted to prompt reflexivity in our students. The concept of reflexivity – critically examining one's own feelings and motives – is critical for effective and inclusive science communication (Canfield et al., 2020; Callwood et al., 2022) but is a skill not often developed in STEM training programs (Salmon et al., 2014; Knoblauch, 2021; Jensen, 2022). Reflexivity is often connected to humanism in research paradigms (Gemignani, 2017).

Specifically, we prompted students to discuss their strengths and weaknesses in science communication before and after the workshop as well as reflect on their science communication practice after the workshop. These questions enabled us to assess what impacts undergraduate student science communication behavior.

### Theory of Planned Behavior

To contextualize our analysis of student behaviors and behavioral, intentions, we analyzed themes of these qualitative responses in terms of the Theory of Planned Behavior. For a student to engage in science communication, they need both positive attitudes towards science communication as well as confidence in their science communication skills. The Theory of Planned Behavior (TPB) is a model that integrates how perception of social norms about a behavior, attitudes towards a behavior, and self-efficacy in the behavior impact an individuals' behavioral intentions and behaviors (Ajzen, 1991). It is based on an expectancy-value framework, where an individual's behavior is based on how much they value the task as well as how much they expect to succeed in the task (French and Hankins, 2003). Strategic science communication has been conceptualized as a form of planned behavior (Besley and Dudo, 2022), and scientists' communication objectives have been framed in terms of TPB (Besley et al., 2018). Other studies have utilized the TPB to assess the efficacy of science communication trainings and graduate students' behavioral intents in science communication (Copple et al., 2020; Akin et al., 2021) and to investigate undergraduate students' motivations and behaviors in science communication (Murphy and Kelp, 2023). Beyond science communication, TPB has been used in science education research studies to conceptualize teachers' and students' behavioral intentions (Cooper et al., 2016; Archie et al., 2022). In this study, we mapped undergraduate students' perspectives about the influence of the training and other factors influencing their behavioral intentions in Inclusive Science Communication to the TPB constructs.

As we analyzed students' behavioral intentions, we were specifically interested in the factors that empowered or impeded these science communication behaviors. While multiple theoretical frameworks exist to examine what empowers or impedes students, with the topic of inclusive science communication and its impact on historically marginalized students, we specifically chose frameworks related to how historically marginalized students bring assets and strengths into STEM or are impeded by the exclusionary culture in STEM.

### Community Cultural Wealth model

For factors leading to student strengths in science communication and positive impacts on behavioral intentions, we utilized the Community Cultural Wealth model. It is critical for STEM departments to not just expect underrepresented students to assimilate into current culture, but rather to examine the departments' own exclusionary practices (McGee, 2020) so that marginalized students can succeed and contribute their prior funds of knowledge (McGee, 2016). Constructivist learning theory recognizes that students take their previous knowledge and experiences into their interactions with STEM (Ernest, 1994). This shift from a deficit-oriented perspective – focusing on what students of color and other marginalized students lack and trying to provide it – to an asset-oriented perspective – focusing on what these students bring to the table and enhancing their experience based on it – is known as the Community Cultural Wealth (CCW) model, as developed by Yosso (2005). This critical race theory-based approach provides a framework for highlighting the valuable perspectives and cultural funds of knowledge that marginalized students contribute to historically exclusionary fields like STEM (Denton et al., 2020). Highlighting these perspectives and teaching students about community cultural wealth has been shown to affect the science identity (Ortiz et al., 2020), science self-efficacy (Rocha et al., 2022), and persistence (Samuelson and Litzler, 2016; McGowan and Pérez, 2020) of students of color in STEM in particular. Similarly, other work has explored an anti-deficit framework to highlight how students of color succeed in STEM (Harper, 2010). CCW identifies six forms of capital that students bring: familial, aspirational, social, navigational, resistant, and linguistic. Others have thematically analyzed student perceptions about belonging in STEM and mapped them to these forms of capital (Stanton et al., 2022). Similarly, we focused on students' identified assets and motivators towards science communication in terms of CCW capital.

### White Supremacy Culture

For factors leading to student weaknesses in science communication and negative impacts on behavioral intentions, we utilized factors identified as characteristics of White Supremacy Culture. Grounded in a critical race theory framework, the concept of White Supremacy Culture (WSC) highlights that certain dominant cultural norms privilege Whiteness and maintain a power dynamic that harms marginalized individuals (Haynes, 2017). While WSC has been conceptualized in various ways, Callwood et al. connect science communication to WSC using the following list of characteristics of WSC: perfectionism, sense of urgency, defensiveness, quantity over quality, worship of the written word, paternalism, either-or thinking, power hoarding, fear of open conflict, individualism, progress is bigger/more, objectivity, and right to comfort (Callwood et al., 2022). This list was originally conceived in a workshop on dismantling racism by Jones and Okun (2001). Callwood et al. delineate how these characteristics of WSC are pervasive in STEM, with Inclusive Science Communication identified as means to dismantle the characteristics in STEM (Callwood et al., 2022). Specifically in our study's context of undergraduate STEM students and their intentions with science communication, we identified that power imbalance, fear of conflict, and perfectionism may be barriers to their empowerment as science communicators. Undergrad STEM students are developing their science identity and positionality, identifying more as a scientist than non-STEM peers and family but feeling less confident in science than they perceive their professors to be (Kim and Sinatra, 2018). As such, they may not recognize how to discuss science with these various stakeholders in their lives (Couch et al., 2022). Empowering students to recognize their experiential knowledge as valid is key in combatting these *power imbalances* that exist within academia and society (Saetermoe et al., 2017). *Fear of conflict* with the public has been noted as a barrier for scientists doing public outreach (Johnson et al., 2014). Finally, *perfectionism* has been noted to negatively impact self-efficacy in STEM for groups such as women in STEM (Lin and Deemer, 2021) and may similarly impact self-efficacy in science communication skills. Here, we analyzed how these factors of power imbalance, fear of conflict, and perfectionism may manifest as barriers noted by students in their reflection on science communication activities.

Overall, for this portion of the study, we generated the following research questions:

*RQ1:* What forms of cultural capital and Community Cultural Wealth promote students' behavioral intentions to do Inclusive Science Communication?

*RQ2:* How do the characteristics of White Supremacy Culture in STEM – specifically power imbalance, fear of conflict, and perfectionism impede – students' behavioral intentions to do Inclusive Science Communication?

CCW and WSC are common theoretical frames in education research that emphasizes social justice and equity, and TPB is a common theoretical frame in science communication training. By connecting DEI-focused education and science communication training in this study, we are providing a novel connection between these theoretical models that can be used as a framework for future studies in Inclusive Science Communication education.

## Materials and methods

### Inclusive Science Communication workshop

We created a 50-min workshop intended to be integrated into existing STEM courses. This workshop had four components:

1. Discussion about definitions and models of science communication, utilizing concepts of science communication previously outlined (Vickery et al., 2023).
2. Analysis of science communication case studies. We encouraged students to discuss both ineffective and deficit-based as well as effective and participatory components of science communication that occurred in these stories. These case studies were adapted to fit the discipline of the students:
    a. For biomedical science majors, we discussed communication about HPV versus HBV vaccines as outlined in Kahan and Landrum (2017), an example of how college students participated in a science communication activity regarding nutrition as described by (Clement et al., 2018), and a local example of health communication activities occurring with immigrant communities in our region. We purposefully chose case studies with topics relevant to the students' major as well as a mix of local stories and stories with science communicators to whom the students could relate.
    b. For neuroscience majors, we discussed the Flint water crisis with an emphasis on how lead affects neurodevelopment. We also included the vaccine communication and nutrition communication case studies described above.
    c. For chemical and biological engineering majors, we discussed the Flint water crisis with an emphasis on pipe corrosion and engineering systems failure. We also discussed the 2021 Houston winter storm crisis and how climate intersects with society.
3. Practice communicating across disciplines and differences using a role-playing activity. We assigned students to a diversity of "roles" such as microbiologist, journalist, teacher, physician, etc., and had them work in groups of three different "roles" to discuss and create a solution to a socioscientific issue such as food insecurity, clean energy, antibiotic resistance, and others. We encouraged students to be creative and recognize the need for diverse perspectives to solve complex issues.
4. Discussion with peers about making a plan to be a science communicator in the next month, such as talking to a friend about their views on a scientific topic.

Overall, the goal of the workshop was helping students recognize the value of diverse perspectives and backgrounds to co-create solutions to socioscientific issues. Via this training, we aimed for all students, especially those of marginalized backgrounds, to recognize the power of their own perspectives and backgrounds. We aimed for all students, especially those of non-marginalized backgrounds, to recognize the power of the perspectives and backgrounds of those who have been historically excluded from STEM.

We piloted this workshop in first-year seminar courses for biomedical science majors, neuroscience majors, and chemical and biological engineering majors. We ran the workshop in each course twice for different semesters' worth of students.

## Data collection

We collected the pre-survey during the week before implementation of the workshop and the post-survey 1 month after the workshop. The survey contained both close-ended constructs and open-ended questions (see Supplementary material). For close-ended constructs, we used scales derived from published instruments to measure science self-efficacy (Baldwin et al., 1999; Chemers et al., 2011; Estrada et al., 2011), science identity/sense of belonging (Chemers et al., 2011; Estrada et al., 2011), science values (Estrada et al., 2011), motivation (Guay et al., 2000), and science communication (Hanauer and Hatfull, 2015). For open-ended questions, we asked students to identify their strengths in science communication and weaknesses and barriers in science communication in both the pre- and post-survey. In the post-survey only, we asked students about any experiences they had in engaging in science communication as a result of the workshop. Finally, the survey included questions about student identity as a study of color, first generation college student, or Pell grant recipient (a proxy for low socioeconomic class). This study was approved by the Institutional Review Board of Colorado State University, and students consented to their survey responses being used in the study.

## Quantitative data analysis

In order to test Hypothesis 1, we analyzed student affective measures before and after the Inclusive Science Communication training. For affective measures about science, we used constructs derived from published instruments to measure science self-efficacy (Baldwin et al., 1999; Chemers et al., 2011; Estrada et al., 2011), science identity/sense of belonging (Chemers et al., 2011; Estrada et al., 2011), science values (Estrada et al., 2011), and motivation (Guay et al., 2000). The scales list statements with Likert scale responses on a 5-point scale that has been used in these publications with ordinal values for further statistical analysis. These validated and published constructs were reliable in our sample as measured by Chronbach's alpha >0.7. To assess their attitudes towards science communication, we utilized metrics to assess science communication identity [based on (Lewenstein and Baram-Tsabari, 2022)], science communication self-efficacy (Hanauer and Hatfull, 2015), and science communication motivation (Guay et al., 2000). For science communication values, we modified the science values construct (Estrada et al., 2011) to match values involved in inclusive science communication (Canfield et al., 2020). Similarly, Chronbach's alpha for the published scales in our sample was >0.7. For science communication values, since we had substantially modified the scale from the published version for science values, we performed principal component analysis to confirm goodness of fit (results in Supplementary materials). While these several of these constructs have been combined to create a multi-factor scale to measure student persistence in the science (Hanauer et al., 2016), we assessed each construct individually to analyze how inclusive science communication training may impact each individual concept.

Only students who completed both the pre- and post-survey were included in the quantitative data analysis. After confirming that the published constructs were reliable in our sample (all Chronbach's alpha >0.7), we averaged the items for each scale to generate a value for each student for each construct. We then utilized paired t-tests to compare pre-intervention and post-intervention scores. We compared separately for students who identified as a member of a historically disadvantaged and marginalized group in STEM (low socioeconomic class, first generation college student, and/or a student of color; which we termed "marginalized students"), and for students who did not identify in any of these categories (which we termed "non-marginalized students").

## Qualitative data analysis

We utilized thematic analysis (Braun and Clarke, 2006) of open-ended survey questions about students' strengths and weaknesses in science communication, both before and after the workshop, as well as their description of participating in science communication activities after the workshop. We included all responses to these questions in the pre- and post-workshop surveys in our analysis. We inductively generated codes, then deductively grouped these codes into sub-themes related to three established theoretical models: the Theory of Planned Behavior (Armitage and Conner, 2001), Community Cultural Wealth model (Yosso, 2005), and the characteristics of White Supremacy Culture (Callwood et al., 2022). Each different model had several themes (the characteristics previously established in the models) and codes/sub-themes (how the themes manifested in our dataset).

# Results

## Implementation of Inclusive Science Communication workshop

The workshop appeared to be successful in all courses, with students engaging in rich discussion, inputting creative ideas about science communication in audience response systems, and developing creative solutions during the activities. Beyond the in-class experience, we recognize that the success of a science communication training relies upon students applying the mindsets and skills beyond that one-hour workshop. Based on students' responses in the post-workshop survey, we assessed students' response to questions about whether they practiced being a science communicator in the month following the workshop. Of the $n = 218$ responses to this prompt, the majority of students ($n = 177$) had positive experiences when practicing science communication, with only $n = 4$ reporting a negative experience. An additional $n = 37$ indicated that they did not practice science communication in the month following the workshop.

## Quantitative data: analysis of student affective measures

We found statistically significant increases from pre-workshop to post-workshop in many of the measures we quantified via validated survey metrics (H1; Table 1). In all classes regardless of sample size,

TABLE 1 Pre- and post-training means and $p$-values in student affective measures at a result of the workshop.

| Marginalized students | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Biomedical science majors ($n$ = 58 students) | | | Neuroscience majors ($n$ = 13 students) | | | Chemical and biological engineering majors ($n$ = 3 students) | | |
| Student affective measures about… | | Pre avg | Post avg | $p$-value | Pre avg | Post avg | $p$-value | Pre avg | Post avg | $p$-value |
| Science | Self-efficacy | 3.16 | 3.5 | <0.0001 | 3.34 | 3.77 | 0.0005 | 2.72 | 3.33 | 0.053 |
| | Identity | 3.54 | 3.84 | <0.0001 | 3.40 | 3.75 | 0.011 | 3.50 | 3.91 | 0.038 |
| | Values | 4.10 | 4.28 | 0.004 | 4.52 | 4.52 | 1.0 | 4.08 | 4.00 | 0.42 |
| | Intrinsic Motivation | 4.05 | 4.15 | 0.24 | 4.04 | 4.11 | 0.67 | 3.78 | 4.00 | 0.64 |
| | Extrinsic Motivation | 1.78 | 1.82 | 0.59 | 3.26 | 3.17 | 0.78 | 1.00 | 2.00 | 0.095 |
| Science communication | Self-efficacy | 3.46 | 3.76 | 0.0004 | 3.22 | 3.27 | 0.57 | 3.33 | 3.53 | 0.42 |
| | Identity | 3.82 | 4.17 | <0.0001 | 3.43 | 3.94 | 0.004 | 3.58 | 4.00 | 0.038 |
| | Values | 3.79 | 4.09 | <0.0001 | 4.48 | 4.42 | 0.81 | 4.58 | 4.17 | 0.038 |
| | Intrinsic Motivation | 3.84 | 4.06 | 0.012 | 3.70 | 4.26 | 0.18 | 4.33 | 4.11 | 0.053 |
| | Extrinsic Motivation | 1.84 | 2.14 | 0.03 | 3.47 | 2.61 | 0.08 | no data | no data | no data |
| Non-marginalized students | | | | | | | | | | |
| | | Biomedical science majors ($n$ =81 students) | | | Neuroscience majors ($n$ =13 students) | | | Chemical and biological engineering majors ($n$ =8 students) | | |
| Student affective measures about… | | Pre avg | Post avg | $p$-value | Pre avg | Post avg | $p$-value | Pre avg | Post avg | $p$-value |
| Science | Self-efficacy | 3.29 | 3.61 | <0.0001 | 3.31 | 3.63 | 0.056 | 3.17 | 3.52 | 0.01 |
| | Identity | 3.38 | 3.73 | <0.0001 | 3.26 | 3.80 | 0.008 | 3.56 | 3.78 | 0.13 |
| | Values | 4.19 | 4.30 | 0.11 | 4.24 | 4.51 | 0.03 | 4.59 | 4.56 | 0.60 |
| | Intrinsic Motivation | 4.10 | 4.15 | 0.40 | 3.92 | 3.48 | 0.025 | 4.41 | 4.21 | 0.14 |
| | Extrinsic Motivation | 1.94 | 2.06 | 0.16 | 2.93 | 2.94 | 0.94 | 1.55 | 1.85 | 0.17 |
| Science communication | Self-efficacy | 3.44 | 3.85 | <0.0001 | 3.24 | 3.65 | 0.016 | 3.28 | 3.04 | 0.50 |
| | Identity | 3.68 | 3.84 | <0.0001 | 3.32 | 3.77 | 0.04 | 3.50 | 3.13 | 0.50 |
| | Values | 4.03 | 4.09 | 0.21 | 4.36 | 4.37 | 0.83 | 4.31 | 3.88 | 0.056 |
| | Intrinsic Motivation | 4.00 | 4.01 | 0.9 | 4.00 | 4.09 | 0.60 | 3.96 | 3.83 | 0.71 |
| | Extrinsic Motivation | 1.90 | 2.10 | 0.93 | 3.11 | 2.08 | 0.011 | 1.52 | 1.50 | 0.20 |

Statistically significant increases are listed in black and others in gray. Data pooled for students who completed both pre- and post-survey across two semesters for each course. Marginalized = first generation college student, student of color, and/or low socioeconomic class); Non-marginalized = not identifying as any of those categories.

self-efficacy and identity – both for science more generally and for science communication – tended to be the measures most impacted by the workshop. Additionally, where significant increases were seen, all students or students from marginalized backgrounds were the most likely to be positively impacted. This was important to ensure that we were not only supporting the students who historically already had support from the STEM culture. When we pooled the data from all three courses together for science and science communication self-efficacy as well as science and science communication identity, we found statistically significant increases for both marginalized and non-marginalized students (Figure 1). There were slight variations between classes in how students responded to the workshop in terms of quantifying their affective measures. A potential limitation of the data is the low student numbers who completed both the pre- and post-workshop surveys, especially in the chemical and biological engineering course. For example, some changes in science and science communication values as well as science communication motivation constructs were seen in the biomedical science majors, which was the largest class, and such changes may have been seen in the other classes if they had had larger sample sizes.

## Qualitative data: analysis of student comments related to themes in Theory Of Planned Behavior, Community Cultural Wealth, and White Supremacy Culture

We analyzed student comments related to their strengths, barriers, and practice of science communication (see Supplementary material)

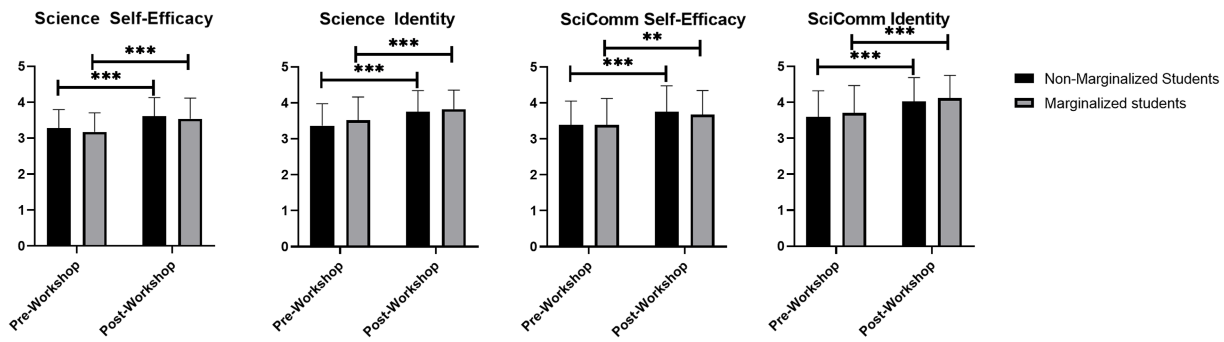


FIGURE 1
Increases in science self-efficacy and identity and science communication self-efficacy and identity seen in response to the Inclusive Science Communication workshop. Y-axis indicates value for ordinal usage of Likert-scale data, with 5 being "strongly agree" with survey items regarding those constructs and 1 being "strongly disagree." Data pooled from 3 first year intro courses in biomedical sciences, neuroscience, and chemical and biological engineering, with 2 iterations of the workshop in each course across different semesters. A total of $n = 108$ non-marginalized students and $n = 74$ marginalized students (identifying as a student of color, a first-generation college student, and/or a student of low socioeconomic status, as defined by being a Pell grant recipient). * Indicates $p < 0.05$, ** Indicates $p < 0.001$, *** Indicates $p < 0.0001$ by paired t-test between pre- and post-training means within student group.

utilizing thematic analysis. For the question regarding strengths in science communication, we had $n = 133$ responses in the pre-workshop survey and $n = 80$ responses in the post-workshop survey (pooled across courses and semesters). For the question regarding barriers for science communication, we had $n = 133$ responses in the pre-workshop survey and $n = 61$ responses in the post-workshop survey. Finally, for the open-ended question about students' experience practicing science communication after the workshop, we had $n = 181$ responses.

We inductively coded the data and then organized the codes/sub-themes deductively into themes for the three different theoretical models – Theory of Planned Behavior, Community Cultural Wealth, and White Supremacy Culture. Each different model had several themes (the characteristics previously established in the models) and codes/sub-themes (how the themes manifested in our dataset; see Tables 2–4). In our thematic analysis process, we identified that some students referred to multiple themes within a particular model and/or referred to themes from multiple models within an answer. Some students did not mention concepts related to these three theoretical models.

Below, we list quotes from various students to reflect how these themes and sub-themes manifested in student self-reflections.

## Theory of Planned Behavior

The first theoretical model we utilized in the thematic analysis was the Theory of Planned Behavior (TPB), an expectancy-value framework which outlines that an individuals' attitudes, social/subjective norms, and self-efficacy/perceived behavioral control impact their behavioral intentions as well as behaviors (Armitage and Conner, 2001). The TPB has been previously utilized in examination of disciplinary science communication training for graduate students (Copple et al., 2020; Akin et al., 2021), but we wanted to examine this theory in terms of Inclusive science Communication Training for first-year undergraduate students. Students indicated aspects of the TPB both when describing their strengths and weaknesses and when explaining their science communication experiences after the workshop (Table 2).

Students' valuing of inclusive science communication centered on their perception of the social norms of the activities – that is, whether they believe that others value the behavior and think they should do it. Students tended to believe that others in science perceived science communication to be important, but that these others might doubt the individual student's abilities in science communication based on how much the student knows about science. For instance, one student indicated that they feel unable to do science communication because *"I feel like I might not be smart enough"* and another noted that *"I am a woman and sometimes it is discouraging to be a woman in STEM because it is a male dominated field."*

Students' expectation that they could perform science communication, which is operationalized in TPB as self-efficacy or perceived behavioral control, was similarly dependent on how strong they felt as science students. For example, one student noted that *"I tend to do research on things even when I do not always have to and this really helps add to my background knowledge."* Thus, their scientific literacy skills in interpreting science information helped them feel confident to talk about science with others. Additionally, students noted that technical skills in the lab, having background knowledge in science fields, or the fact they are STEM majors increased confidence in science communication. This highlights a key connection between self-efficacy in science and self-efficacy in science communication. Conversely, some students felt they lacked adequate knowledge and confidence to engage in science communication or communication skills. For example, another student noted that *"I do not feel confident in my ability to explain a topic thoroughly being able to include all the important facts."*

Overall, when analyzing how students considered their planned behavior in science communication before and after the workshop (Table 2), we found that students had a slight increase in perceived behavioral control and a slight decrease in lack of perceived behavioral control.

When students engaged in science communication after the workshops, they noted in their reflections that they gained new understanding and included new perspectives or disciplines. They focused on themes related to subjective norms and interactions with others, rather than focusing on themes related to their personal perceived behavioral control and self-efficacy. This highlights their growing understanding and appreciation of Inclusive Science

TABLE 2 Thematic Analysis of student comments related to science communication utilizing Theory of Planned Behavior as a theoretical framework.

| Theory of Planned Behavior | | | | |
|---|---|---|---|---|
| **Main theme** | **Sub theme** | **Examples** | **Main theme frequency %** | |
| **Strengths** | | | **Pre ($n$ = 228)** | **Post ($n$ = 133)** |
| Subjective norms | Aptitude for Science | "I'm able to understand most material in science classes." | 10.96 | 7.52 |
| | Different Perspectives | "I have a really different perspective from my friends. I'm the only racial minority in my friend group and only STEM major." | | |
| Perceived behavioral control (self-efficacy) | Prior Classes | "I have taken various classes in high school that have exposed me to science, such as advanced chemistry, biology, and biomedical science classes." | 38.16 | 42.11 |
| | Science Knowledge | "I have gotten the opportunity to use different lab tools in these classes." | | |
| | Independent Research | "I tend to do research on things even when I do not always have to and this really helps add to my background knowledge." | | |
| | Current News | "I read a lot about new science advancements and I follow a lot of scientists on social media." | | |
| **Barriers** | | | **Pre ($n$ = 184)** | **Post ($n$ = 71)** |
| Subjective norms | Lack of Aptitude for Science | "I am not the best at the sciences. I am better at history and English." | 13.04 | 5.63 |
| | Identity | "My appearance often leads to an attitude of disrespect from my fellow scientific peers, because I do not appear to be someone who belongs in a STEM field." | | |
| Perceived behavioral control (self-efficacy) | Lack of Knowledge | "Not being very knowledgeable in the subject." | 25.53 | 18.31 |
| | Lack of Communication Skills | "I do not feel confident in my ability to explain a topic thoroughly being able to include all the important facts." | | |
| **Practice** | | | **Post ($n$ = 220)** | |
| Subjective norms | Gained New Perspective | "It felt really eye-opening to see and hear others' perspective on issues in science and think about how all of ideas are equally valid in solving modern medicinal issues." | 14.55 | |
| | Included Multiple Perspectives | "Though we had different understandings of the topic, we all discussed the implications for our individual fields and our own personal interests." | | |

The $n$ value was calculated by taking all Main Theme appearances (e.g., mentions of a theme related to that model) and adding them together for all models (TPB, CCW, and WSC). Students could have mentioned several Main Themes from each model. For the strengths related question, the pre-survey had $n$ = 228 themes mentioned across $n$ = 133 responses, and the post-survey had $n$ = 133 themes mentioned across $n$ = 80 responses. For the question about barriers, the pre-survey had $n$ = 184 themes mentioned across $n$ = 133 responses and the post-survey had $n$ = 71 themes mentioned across $n$ = 61 responses. The practice related question in the post-survey had $n$ = 220 themes mentioned across $n$ = 181 responses. The frequency of each Main Theme was calculated by taking the appearance of that theme/$n$.

Communication and co-creation with others. One student noted that *"I also got to listen to classmates' perspectives, which made me think differently than before."* Another student *"felt like it was valuable because we all have different backgrounds and knowledge basis, so it is nice to see others point of view in order to gain my understanding."*

## Community Cultural Wealth

The next theoretical framework utilized was the Community Cultural Wealth (CCW) model, which lists six forms of capital that students of color utilize for success in college: aspirational, linguistic, familial, social, navigational, and resistance (Yosso, 2005). To our knowledge, CCW has not been explicitly used as a framework to examine students' interactions with science communication. In our study, students indicated aspects of CCW – specifically aspirational capital, family capital, social capital, navigational capital, and resistant capital – both when describing their strengths and weaknesses and additionally when asked how their Science Communication experiences went after the workshop (Table 3).

Many students identified a connection between their aspirations for science and their confidence in science communication skills. One student noted that their *"curiosity and passion for science"* drove their desire to communicate about science. Synergistically, engaging in science communication activities made students increase their aspirations for science, such as the student who reflected on practicing science communication by stating, *"It was good outcome, I felt excited that I was able to talk about something I am passionate about."* While some students had a passion for science and intrinsic desire to learn, others also expressed aspirational capital as a personal connection or making a difference in their community, for example a student who explained that *"my grandfather has Parkinson's disease and I want to dedicate my life to finding a cure for that disease. I have pain and first-hand experience and I feel that I have the power to make a difference."*

Another strength was family in the field or family encouragement. Students who had family in STEM felt more confident to engage in science communication, for example the student who said that *"one of my close family members is studying for their doctorate and I've had* *many conversations with them about science."* And even if family members were not in a STEM field, their encouragement and support of science was a strength. Simply having family believing in science increased their confidence, such as for the student who narrated that *"I was born and raised on my family ranch, so I am very conscientious of all the new technology and scientific innovations to revolutionize the production of agricultural products."*

Students also enforced their social capital through discussing with different groups of people, increasing their networks. For example, students talked with family members, friends, peers, and professors. One student narrated that *"I was able to speak with a friend about basic cell anatomy and what we both knew about it. The friend does not have a science background, so it felt good to spread what I do know with my background and raises my confidence in speaking about science."* Another student reflected that *"It was nice to know they listened and heard me and added to something I thought was interesting."*

Navigational capital, or their ability to maneuver through institutions, contributed to students' perceived strengths in science communication. For example, a student explained that *"I am very passionate about engaging in scientific discussions with my peers and I believe it is very important to share scientific findings."* One way the students had navigational capital was through extracurricular activities or work experiences also gave students technical skills and opportunities to practice their science communication skills. One student gave the example that *"I've worked for 5 years at a veterinary clinic, so I've learned a lot about science by talking with my coworkers."*

The last strength connected to CCW was resistant capital. One form of resistant capital is recognizing one's strength to identify and combat stereotypes. Examples include students labeling themselves as a *leader, outgoing,* and *hardworking.* In contrast, some student barriers included perceived personal limitations. They lacked resistant capital and could not recognize their own strengths. For example, some students were less confident because they reported they were *shy, easily spoken over,* and *lack self-confidence.*

While many forms of capital are strengths, they can also present as barriers to students when they feel like they are lacking certain types of capital. An example includes lacking navigational capital in the form of lacking experience – *"I am not technically medical trained"* – or comparing their experience to their peers – "*They have taken more classes and have had more involved opportunities than I've had."*

Overall, when analyzing how students considered their various forms of capital in science communication before and after the workshop (Table 3), we found that students had a notable increase in resistant capital.

We also saw connections between CCW and TPB. For example, students were empowered by their aspirational capital coupled with their value for the social norms of science communication as well as their behavioral control in science communication. One student noted that engaging in science communication *"made feel proud and excited that I can talk about that I am interested and see that other people see it interesting as well."* Another reflected that *"I never thought about how great a feeling you could get from initiating a conversation yourself about something you are passionate about."*

Finally, as students considered their strengths compared to others' strengths, student conversations demonstrated reciprocity, where students would share but also learn from others. Reciprocity is a key component of Inclusive Science Communication (Canfield et al., 2020). This highlights the overlap between CCW and Inclusive Science Communication. One student reflected that *"We talked for a few hours about the relation of science and social issues and how important they both are, how we can try to solve them and how important it is to work together and consider how there's science in social problems and social issues in science problems. It was pretty cool."* Another shared that *"We have differing views on it, so I approached it in a way that would make sense to her, and we both ended up learning from the other."*

## White Supremacy Culture

The next theoretical framework utilized was the characteristics of White Supremacy Culture (WSC): perfectionism, sense of urgency, defensiveness, quantity over quality, worship of the written word, paternalism, either-or thinking, power hoarding, fear of open conflict, individualism, progress is bigger/more, objectivity, and right to comfort (Jones and Okun, 2001; Callwood et al., 2022). WSC has been previously examined in relation to science communication (Callwood et al., 2022), but our study is specifically analyzing this connection for undergraduate students learning science communication. In particular, we focused on power imbalance, fear of conflict, and perfectionism as likely barriers for science communication and marginalized students in science classrooms. In our study, students did not indicate any aspects of WSC as contributing to their strengths in science communication; rather, the characteristics of WSC acted as barriers and appeared in student responses describing their science communication practice (Table 4).

Students expressed perfectionism when they noted that *"I feel like I do not know everything I'm supposed to in a conversation"* and thus cannot engage in science communication. Others were afraid of perpetrating misinformation by speaking incorrectly. However, participating in the inclusive science communication training helped students combat perfectionism. One student reflected that *"I felt like there was a lot of pressures that came with scientific communication but the workshop alleviated some of that pressure and let me speak more freely."*

Fear of conflict manifest as being afraid of judgment from others, worried about anti-science sentiment from others, or negative past experiences when trying to talk about science. Some students felt qualified to speak about science but were afraid about anti-science rhetoric and conflict, as *"anything political is kind of scary and can cause me anxiety."* Other students were afraid of *"being told I'm wrong/not qualified and being shut down."* However, participating in the inclusive science communication training helped students combat fear of conflict. One student shared that *"I talked to my boyfriend about it a bit and we both disagreed on some things, but we ultimately just got a deeper understanding of the viewpoint of the other person."*

Lastly, a perceived power imbalance acted as a barrier for students. Students faced this barrier with people who they perceived have more knowledge and experience than they do. One student expressed that *"I worry that I am not qualified to participate in dialogue about science due to the fact that there are other who have more experience than me or know more about particular fields than I do."* This perceived lack of knowledge kept them from engaging in science communication activities. When students felt that their audience was also uneducated, this was further barrier: *"I tried to initiate science communication over the last month, but it is difficult when all parties are uneducated about the matter."*

Overall, when analyzing student responses about their science communication experiences before and after the workshop (Table 4),

TABLE 3 Thematic Analysis of student comments about science communication utilizing Community Cultural Wealth model as a theoretical framework.

| Community Cultural Wealth | | | | |
|---|---|---|---|---|
| Main theme | Sub theme | Examples | Main theme frequency % | |
| **Strengths** | | | **Pre ($n$ = 228)** | **Post ($n$ = 133)** |
| Aspirational capital | Passion for Science | "I really find science fascinating" | 17.54 | 15.79 |
| | Making a Difference | "The idea of making tangible changes in the real world." | | |
| Familial and social capital | Family in the Field | "My mom is an epidemiologist in diabetes and heart disease." | 12.72 | 11.28 |
| | Family Encouragement | "I have always been motivated to talk about science with [my mother]." | | |
| | Teacher/Professional Influences | "I have taken many classes with teachers who stressed the importance of being able to communicate the science I am learning." | | |
| Navigational capital | Extracurricular Participation | "I have taken and participated in many scientific opportunities at the state level with my 4-H extracurricular activity." | 18.86 | 16.54 |
| | Work Experience | "I worked in a doctors office for 3 years." | | |
| | Desire for Conversation | "I am very passionate about engaging in scientific discussions with my peers and I believe it is very important to share scientific findings." | | |
| Resistant capital | Personal Strengths | "Leadership, boldness, confidence." | 1.75 | 6.77 |
| **Barriers** | | | **Pre ($n$ = 184)** | **Post ($n$ = 71)** |
| Lack of navigational capital | Lack of Experience | "Never done laboratory experiments alone." | 11.96 | 11.27 |
| Lack of resistant capital | Personal Strengths | "Self-critical." | 13.04 | 7.04 |
| **Practice** | | | **Post ($n$ = 220)** | |
| Enforces aspirational culture | Enjoyment from Discussion | "I felt excited about this experience and the outcome was nice and all people contributed. " | 31.36 | |
| | Empowered | "This experience made me feel mature and important" | | |
| Enforces social capital | Conversations with Family, Friends, Peers, or Professors | "I talked to my mom about the COVID vaccine." | 40.91 | |
| | Respect | "It was a civil conversation that both of us were engaged and listening in." | | |
| | Reciprocity | "I was able to make connections and learn more about others." | | |

The $n$ value was calculated by taking all Main Theme appearances and adding them together for all models. Students could have mentioned several Main Themes from each model. For the strengths related question, the pre-survey had an $n = 228$ and the post-survey has $n = 133$. For the strengths related question, the pre-survey had $n = 228$ themes mentioned across $n = 133$ responses and the post-survey had $n = 133$ themes mentioned across $n = 80$ responses. The barriers related question in the pre-survey $n = 184$ themes mentioned across $n = 133$ responses and the post-survey had $n = 71$ themes mentioned across $n = 61$ responses. The practice related question in the post-survey had $n = 220$ themes mentioned across $n = 181$ responses. The frequency of each Main Theme was calculated by taking the appearance of that theme/n.

we found that students were articulating characteristics of WSC as a barrier more after the workshop. It is possible that students were better able to identify and articulate the characteristics of WSC – so often otherwise historically glorified in STEM culture – as barriers to Inclusive Science Communication as a result of the workshop.

## Comparison of themes between models, students, and intervention

We analyzed the frequency of themes and any unique comparisons and overlaps between the three theoretical models, how themes differed between marginalized (students who identified as a student color, first generation college student, and/or a Pell grant recipient) and non-marginalized students, and how themes differed before and after the workshop. In particular, we were interested in how CCW capital (RQ1) and WSC barriers (RQ2) may interact with students' behavioral intents in inclusive science communication.

To answer RQ1, we assessed how students relied on CCW for their strengths in behavioral intention towards science communication. We noted a difference between how marginalized and non-marginalized students interacted with these themes and ideas. In the pre-survey, marginalized students mentioned more aspects of TPB (55%) than CCW (45%). Non-marginalized students mentioned more aspects of CCW (54%) than TPB (46%). Non-marginalized students may have been feeling more empowered by their familial and social connections than marginalized students when considering their strengths in science communication. However, these frequencies are somewhat similar – overall, about half of students are relying on various forms of capital to provide a sense of strength in science

TABLE 4 Thematic Analysis of student comments about science communication utilizing characteristics of White Supremacy Culture as a theoretical framework.

| White Supremacy Culture | | | | |
|---|---|---|---|---|
| Main theme | Sub theme | Examples | Main theme frequency % | |
| **Barriers** | | | **Pre (*n* = 184)** | **Post (*n* = 71)** |
| White supremacy culture | Perfectionism | "I cannot always remember everything about a topic." | 36.41 | 57.75 |
| | Fear of conflict | "Someone will judge me." | | |
| | Power imbalance | "There are many people who are much more knowledgeable than I am -- they have taken more classes and have had more involved opportunities than I've had." | | |
| **Practice** | | | **Post (*n* = 220)** | |
| Challenges white supremacy culture | Not pressured to be perfect | "Knowing that I did not have to have all of the answers and could rely on others to help inform me." | 8.18 | |
| | Reached mutual understanding | "We have differing views on it, so I approached it in a way that would make sense to her, and we both ended up learning from the other." | | |
| Enforces white supremacy culture | Fear of conflict | "I've been trying to get my boyfriend's family over vaccine hesitancy and it's hard. While they begin to understand the science more it seems like they come up with more social conspiracies and that people will be "sick in 6 months" it just feels very hopeless." | 5.00 | |
| | Power imbalance | "I tried to initiate science communication over the last month, but it is difficult when all parties are uneducated about the matter." | | |
| | Perfectionism | "My fear of saying the wrong thing and my lack of communication skills." | | |

The *n* value was calculated by taking all Main Theme appearances and adding them together for all models (TPB, CCW, and WSC). Students could have mentioned several Main Themes from each model. For the strengths related question, the pre-survey had *n* = 228 themes mentioned across *n* = 133 responses and the post-survey had *n* = 133 themes mentioned across *n* = 80 responses. For the barriers related question, the pre-survey had *n* = 184 themes mentioned across *n* = 133 responses and the post-survey had *n* = 71 themes mentioned across *n* = 61 responses. The practice related question in the post-survey had *n* = 220 themes mentioned across *n* = 181 responses. The frequency of each Main Theme was calculated by taking the appearance of that theme/*n*.

communication. After the workshop, both marginalized and non-marginalized students had less barriers related to TPB (such as lack of perceived behavioral control), with both groups mentioning these barriers ~40% of the time in the pre-survey and only ~20% of the time in the post-survey. This suggests that the workshop was able to provide students with a sense of self-efficacy in science communication. When putting science communication into practice, both non-marginalized (75%) and marginalized students (71%) could apply and recognize aspects of Community Cultural Wealth at a high frequency. Additionally, the frequency of resistant capital increased after the workshop and the frequency of lacking resistant capital decreased (Table 3). Social and community capital is clearly empowering for students in their science communication. Along these lines, students noted themes of social norms rather than personal behavioral control when discussing their science communication practice after the workshop.

To answer RQ2, we assessed how students noted barriers related to WSC that impeded their behavioral intents in science communication. Students especially mentioned that their inability to know everything and communicate perfectly made them hesitant to communicate about science; here, the perfectionism of WSC was impacting their perceived behavioral control and thus decreasing their behavioral intentions in science communication. Again, we noted a difference between marginalized and non-marginalized students. In the pre-survey, marginalized students were more affected by WSC (41% mentioning one of the characteristics as a barrier) than non-marginalized students (34% mentioning one of the characteristics as a barrier) in the pre-survey. In the post-survey, both groups of students increasingly noted that their barriers in science communication were due to these factors. Although we did not explicitly mention characteristics of WSC in the workshop, students were still growing in their ability to identify and articulate the reasons they may struggle with science communication. Further work to help students recognize and combat these characteristics is merited.

# Discussion

## Summary of results

In this study, we found that a 50-min Inclusive Science Communication workshop increased students' science and science communication identity as well as their science and science communication self-efficacy (H1). Science/science communication values and motivation did not tend to be impacted by the workshop. The potential limitations of these data are sample size as well as the survey scales used to measure these constructs. For example, different ways of operationalizing science communication values or motivation with a focus on Inclusive Science Communication could have led to different results. We have previously identified the need for more evaluative frameworks for Inclusive Science Communication trainings (Vickery et al., 2023), and further exploration, development, and validation of survey scales to measure factors related to Inclusive Science Communication is warranted in the field. However, for the scales that do exist in the literature and that we applied to this study, it is interesting that the most consistent increases were seen in identity and self-efficacy for both science and science communication. Students are seeing a connection between "I feel like a scientist," "I feel like a science communicator," "I can do science," and "I can communicate science." We also saw a similar connection between identity and self-efficacy in science as well as identity and self-efficacy in science communication in our qualitative data. The positive correlations between science identity and science self-efficacy and their influence on science communication have been shown (Murphy and Kelp, 2023). The fact that this workshop increases these factors highlights the importance of training in Inclusive Science Communication not only for the sake of student science communication skills but also their empowerment and persistence in STEM (Estrada et al., 2011).

Another potential limitation of our quantitative measures is that many students were already reporting relatively high levels of science identity and other factors in the pre-survey; this is potentially due to the fact that these students had previously developed some sense of science identity and self-efficacy previously, which drove their decision to pursue a STEM major in the first place (Alhadabi, 2021). Additionally, a single short workshop may have not had as much influence on changes in these affective measures as other factors in their lives and education. Further scaffolding of other Inclusive Science Communication trainings may lead to larger and longer-lasting changes in these factors.

Science identity has been identified as a key factor for the development and persistence of students from low socioeconomic backgrounds (Langin, 2022), first generation college students (Longwell-Grice et al., 2016), and minority students (Estrada et al., 2011). In this study we combined these three groups of students for analysis since there were many overlaps of students identifying with more than one category. However, further parsing the differences in how Inclusive Science Communication training impacts students holding different combinations of these identities would be important, as intersectionality impacts the development of science identity (Avraamidou, 2020).

In this study, we assessed how students articulated their interactions with science communication in terms of the Theory of Planned Behavior, Community Cultural Wealth model, and the characteristics of White Supremacy Culture. For TPB, students' sense of self-efficacy in science communication behaviors was increased by how much they read and knew about science. This connection between science literacy (consuming and interpreting science information) and science communication (producing science information) is important for science education (Kelp et al., 2023) and offers an advancement to the literature on TPB as it relates to science communication behaviors. For WSC, we specifically noted that students are in a unique positionality – feeling less power than their professors and thus unwilling to communicate about science for fear of not communicating perfectly, but feeling more knowledge about science than some friends or family and unwilling to communicate about science for fear of conflict with audiences who doubt science. How students navigate this unique positionality in order to develop as boundary spanners between the scientific community and other communities (Shah et al., 2022) warrants further exploration, especially for students of marginalized backgrounds who can feel pulled between academia and family (Hehakaya, 2022). While TPB and WSC have been used in connection with science communication studies before (Copple et al., 2020; Akin et al., 2021; Callwood et al., 2022), this study is a novel application of the CCW model. Helping students rely on their forms of cultural capital, especially students from marginalized backgrounds, will help them succeed in science and science communication. Many students mentioned feeling impeded by their background; describing science communication in inclusive ways that values diverse experiences and perspectives can help these students feel empowered by their background.

## Implications for Inclusive Science Communication Research

Our utilization of a variety of theoretical models related to diversity/equity/inclusion studies as well as to skills/behavior highlights potential areas for new theoretical model development in the field of Inclusive Science Communication. We did not prompt students to discuss forms of capital from Community Cultural Wealth, but many students discussed how factors like familial/social capital and their aspirations were critical in their science communication. Similarly, we did not prompt students to discuss the characteristics of White Supremacy Culture, but many of them mentioned characteristics like perfectionism and fear of conflict as barriers to their science communication. Further research to assess students' interactions with these factors would provide insight for both science education research and science communication research. Overall, applying models from ethnic studies, science education research, communication research, and similar fields is critical to truly exploring Inclusive Science Communication.

## Implications for Inclusive Science Communication Training

It is important to highlight that the quantitative construct most consistently increased by the workshop in different groups of students was science identity (as well as science communication identity). Additionally, when asked about their strengths and weaknesses in science communication, students reflectively analyzed their diverse forms of capital, experiences, and psychosocial barriers. Our workshop included opportunities for personal reflection about what perspectives the student brings as a science communicator as well as what other perspectives they should be listening to and learning from. However, further explicit prompting and reflexive exercises would be important for students. We are developing scaffolded Inclusive Science Communication trainings and, as a result of this analysis from an introductory workshop, are including more reflexive exercises for students. Additionally, we are further analyzing students' sense of identity and their reflection upon their motives for science communication in focus groups after the Inclusive Science Communication trainings. Overall, when training students in science communication, focusing on mindset and identity is critical, and we cannot just focus on skill development.

Previous research has demonstrated that underrepresented graduate students can find science communication to be a place of belonging (Bennett et al., 2022). In this study, we identified that first-year undergraduate students similarly find science communication to increase their sense of identity and belonging as a scientist. Therefore, promoting training and opportunities for students of varied backgrounds to grow in their ability to connect with the scientific community as well as their communities of origin as boundary spanners (Couch et al., 2022) may be a powerful point of empowerment for these students to reconcile their varied life experiences (Longwell-Grice et al., 2016). However, we do not want to put the onus on students from underrepresented backgrounds to do all of the work in teaching and outreach (Thiry et al., 2007), and institutions should provide support for students engaging in STEM community engagement (Murphy and Kelp, 2023). This is a delicate balance and must be explored further.

Engaging in Inclusive Science Communication involves students both having a mindset and worldview towards co-production of science with society, as well as the skills necessary to engage in these conversations (Lewenstein and Baram-Tsabari, 2022). This workshop promotes development in both of those areas. However, spiraling and scaffolding further trainings would support a progression of learning in Inclusive Science Communication (Lewenstein and Baram-Tsabari, 2022). Additional trainings and training modalities for undergraduate STEM students to develop Inclusive Science Communication worldviews and skills are critical in developing the next generation of scientists.

Overall, training in an inclusive approach to science communication offers a valuable strategy for both supporting diversity, equity, inclusion, and justice in STEM education as well as helping STEM students develop the skills to communicate and collaborate with diverse groups in their future lives and careers.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by Institutional Review Board, Colorado State University. The participants provided their written informed consent to participate in this study.

## Author contributions

SA and NK conceived of the study. RM performed the quantitative data analysis. KM performed the qualitative data analysis. NK, SA, and KM taught the workshops. NK guided the data analysis. All authors contributed to the article and approved the submitted version.

## Funding

This work was funded by a Colorado State University College of Veterinary Medicine and Biomedical Sciences science pedagogy grant to NK as well as National Science Foundation grant #2225095 to NK.

## Acknowledgments

We thank the instructors of the three courses in which we ran the workshops. We thank Caley Valdez, Alycia Pisano, and Amanda Otamendi for their logistical assistance.

## Conflict of interest

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

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## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1173661/full#supplementary-material

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