



Diversifying Large-Scale Participatory Science: The Efficacy of Engagement through Facilitator Organizations

RESEARCH PAPER

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ABSTRACT

Large-scale, scientist-led, participatory science (citizen science) projects often engage participants who are primarily white, wealthy, and well-educated. Calls to diversify contributory projects are increasingly common, but little research has evaluated the efficacy of suggested strategies for diversification. We engaged participants in Crowd the Tap through facilitator organizations like historically Black colleges and universities (HBCUs), predominantly white institutions, high school science classrooms, and corporate volunteer programs. Crowd the Tap is a contributory project focused on identifying and addressing lead (Pb) contamination in household drinking water in the United States. We investigated how participant diversity with respects to race, ethnicity, and homeownership (a proxy for income) differed between participation facilitated through a partner organization and unfacilitated participation in which participants came to the project independently. We were also interested in which facilitators were most effective at increasing participant diversity. White and wealthy participants were overrepresented in unfacilitated participation. Facilitation helped increase engagement of people of color, especially Black and lower-income households. High schools were particularly effective at engaging Hispanic or Latinx participants, and HBCUs were important for engaging Black households. Ultimately, our results suggest that engagement through facilitator organizations may be an effective means of engaging diverse participants in large-scale projects. Our results have important implications for the field of participatory science as we seek to identify evidence-based strategies for diversifying project participants.

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INTRODUCTION

Large-scale contributory projects may recruit thousands, or in some cases millions, of participants, but those recruited tend to be fairly homogenous. Most participants are white, wealthy, and well-educated (Allf et al. 2022; NASEM 2018; Pateman, Dyke, and West 2021). Some projects do not collect any data on participant demographics, complicating efforts to ensure representation (Moczek, Hecker, and Voigt-Heucke 2021). Nevertheless, the benefits of engaging in contributory projects are likely inequitably distributed across the population. Furthermore, in the United States, there is enduring spatial segregation of neighborhoods and rural communities based on race, ethnicity, and income. Therefore, the lack of racial and socioeconomic diversity in contributory participatory science produces data biased toward geographic areas that are more affluent and whiter, limiting the capacity of participant-generated databases to benefit communities of color and lower-income communities (Blake, Rhanor, and Pajic 2020; Mahmoudi et al. 2022). This not only hinders environmental justice efforts but can also have explicit disempowering outcomes like ostracizing those who participate from their communities and tokenizing certain stakeholders whose affiliations and identities may be helpful for acquiring funding but who may be less included after funding is obtained (Walker, Smigaj, and Tani 2021). Thus, the lack of diversity in contributory projects may contribute to pervading social inequities across the scientific enterprise (Graves et al. 2022).

The lack of diversity in contributory projects may be reinforced by historic exclusion from both scientific institutions and outdoor spaces. Racial and ethnic diversity in STEM graduate degrees (NCSES 2022) and careers (Pew Research Center 2021) are disproportionately lower than other disciplines, with stark disparities relative to the racial composition of the United States (NCSES 2021). Academia and other scientific institutions have legacies, policies, and practices that uphold and reinforce the lack of diversity in STEM (Bonilla-Silva and Ray 2009). Racial and ethnic disparities are extreme in ecological and environmental sciences (Cronin et al. 2021), likely due to a dual history of exclusion from both sciences and the outdoors (Whitesides 2016). For example, racism and segregation led to disproportionate access to interior lands and exclusion from parks and outdoor leisure areas by marginalized populations (Glave 2010), discouraging participation in mainstream outdoor activities. As many contributory projects have a focus on ecological or environmental topics and are run by scientific institutions, these appear to produce the same racial biases.

Efforts to address diversity issues in participatory science projects are increasingly common. The term “citizen science” is assumed exclusive to people who are not citizens,

leading many to rebrand projects with other terminology (Ellwood et al. 2023) without clarity on the plurality of participatory science design (Lin Hunter, Newman, and Balgopal, 2023; Cooper et al. 2021). Addressing diversity issues requires more than change in name alone (Cooper et al. 2021). Making participatory science projects more community-driven and better aligned with the goals of communities of color could aid in overcoming diversity issues (Paleco et al. 2021; Pandya 2012). Strategies for doing this include designing for reciprocity, ensuring the safety of participants when conducting project activities (Chesser, Porter, and Tuckett 2020), and partnering with pre-existing, community-embedded organizations and individuals (Bonney et al. 2016; Pandya 2012; Salmon et al. 2021). For example, partnerships with *promotoras*, or trusted community members who are trained to support local health initiatives, has increased diversity of participants in community-based participatory research projects (Davis, Ramirez-Andreotta, and Buxner 2020).

Minority-serving institutions like historically Black colleges and universities (HBCUs) have been effective at overcoming academic challenges related to student diversity. Unlike predominantly white institutions (PWIs) of higher education, HBCUs foster a sense of belonging among students of color (Winkle-Wagner and McCoy 2018). As a result, Black students who attend HBCUs for their bachelors are more likely to persist into science and engineering graduate degrees compared with their counterparts at PWIs (NCSES 2021; NSF 2020). Because HBCUs have been effective at addressing diversity challenges amongst scientific institutions, partnerships with these organizations may be effective at addressing the diversity challenges of contributory projects.

We refer to community-embedded organizations like HBCUs as facilitator organizations. For the purposes of this study, facilitator organizations are third party organizations that engage their members or audiences in participatory science to enrich their experience with the organization. Engagement through facilitators can help project leaders achieve certain goals. For example, a collaboration between SciStarter and the Girl Scouts of America (in this case, the facilitator organization) engaged troops in contributory projects and achieved science learning outcomes, civic science education, and community action among elementary school-aged girls (Smith et al. 2023). Thus, participatory science enriched scouts’ experiences, and engagement with scouts helped contributory projects achieve learning outcomes unlikely to be achieved without facilitation. We were interested in the role that various facilitator organizations, including HBCUs, could play in increasing participant diversity. Specifically, we were interested in the efficacy of partnering with facilitators to increase diversity in contributory projects that are large in scale, that is, not tied

to one location or community. In this study, we evaluated the extent to which facilitator organizations increased racial and socioeconomic diversity of participants in a contributory project focused on the built environment. Specifically, we evaluated the following research questions:

1. Is participant diversity greater (with regard to race and income) in partnership with facilitator organizations than carried out alone?
2. To what degree are various facilitator organizations effective at elevating participant diversity relative to unfacilitated participation?
3. Among university facilitators, how do HBCU and PWI facilitators compare in engaging diverse participants?

METHODS

We investigated the efficacy of facilitator organizations to promote diversity in Crowd the Tap, a contributory project in the United States that addresses lead contamination in household drinking water.

STUDY CONTEXT

Across the globe, one hallmark of urbanization is infrastructure to treat and transport safe drinking water from sources to homes (McDonald et al. 2014). Yet, degrading infrastructure is a threat to drinking water quality (Levin et al. 2002). Lead-bearing infrastructure for transporting water is a common source of lead exposure and can detrimentally affect development, behavior, hearing, and speech, especially in children (Mayans 2019; Needleman 2004). Lead service lines were the primary type of pipes laid in the early 1900s because they were malleable and affordable. Furthermore, lead soldering of copper pipes and lead-lining of steel pipes were significant contributors to lead in water. In 1986, the Safe Drinking Water Act banned the incorporation of lead into any parts of water service lines (e.g., pipes, soldering, connectors; US EPA 1986). In 2016, the American Water Works Association surveyed utilities and estimated there are 6.1 million lead service lines present in the United States, which serve roughly between 15 and 22 million people (Cornwell, Brown, and Via 2016). Over the years, lead service lines have been replaced, but little attention has been given to sources of leaded plumbing remaining within homes. There have been no large-scale surveys or estimates of leaded plumbing within households, a data gap that impedes full understanding of the spatial patterns of the distribution of risk of lead in drinking water. Through Crowd the Tap, we crowdsourced data on drinking water infrastructure within households to obtain a better understanding of the spatial

distribution and social determinants of lead plumbing and contamination in drinking water.

Crowd the Tap provides participants with the resources needed to identify the material of their service line and in-home pipes that provide drinking water. We developed a screening process to prioritize households for laboratory testing based on previous drinking water quality models that have indicated which variables might predict the presence of lead (Fasaee et al. 2021, 2022). Crowd the Tap screening is based on pipe materials that people identify, the age of the home, and in some cases, the detection of iron or copper by the participant using water chemistry strips (Figure 1). Households that screened as high priority were eligible for free lab testing. We will report screening data and laboratory results in subsequent publications. This study focuses on our research questions related to household diversity. Prior to screening, all participants 18 years and older consent to share household data. Participants 13–17 years of age assent, and parents and/or caregivers consent to share household data.

RECRUITMENT OF PROJECT PARTICIPANTS

There is increasing recognition that communities of color and/or low-income communities are more likely to have lead-bearing infrastructure (Benfer 2017; Muller, Sampson, and Winter 2018; Sadler, LaChance, and Hanna-Attisha 2017), necessitating engagement in diverse communities. To address this need, we worked with several facilitator organizations to help engage households (Table 1). When engaging with facilitator organizations, we focused on reciprocity between the project leadership, members of the facilitator organization, and participants engaged through the facilitator organization (Receveur et al. 2022). In the context of participatory science projects like Crowd the Tap, reciprocal benefits are those that meet the participants' goals for engaging and provide them ownership over the project (Hetland 2020). We recruited households through PWI and HBCU internship programs, partnerships with university and high school classrooms, and a program administered by SciStarter.org with Verizon's corporate volunteers.

As part of the screening process in which participants identify their pipes and provide information on their water and household demographics, participants self-identified their affiliation with a facilitator organization. Some high school students did not identify their teacher as the facilitator, but their email and parental consent information made their affiliation status clear. Several hundred households participated without any self-identified affiliation to a facilitator (hereafter, "unfacilitated"). Participants from unfacilitated households may have been recruited to Crowd the Tap via a cooperative program between the National

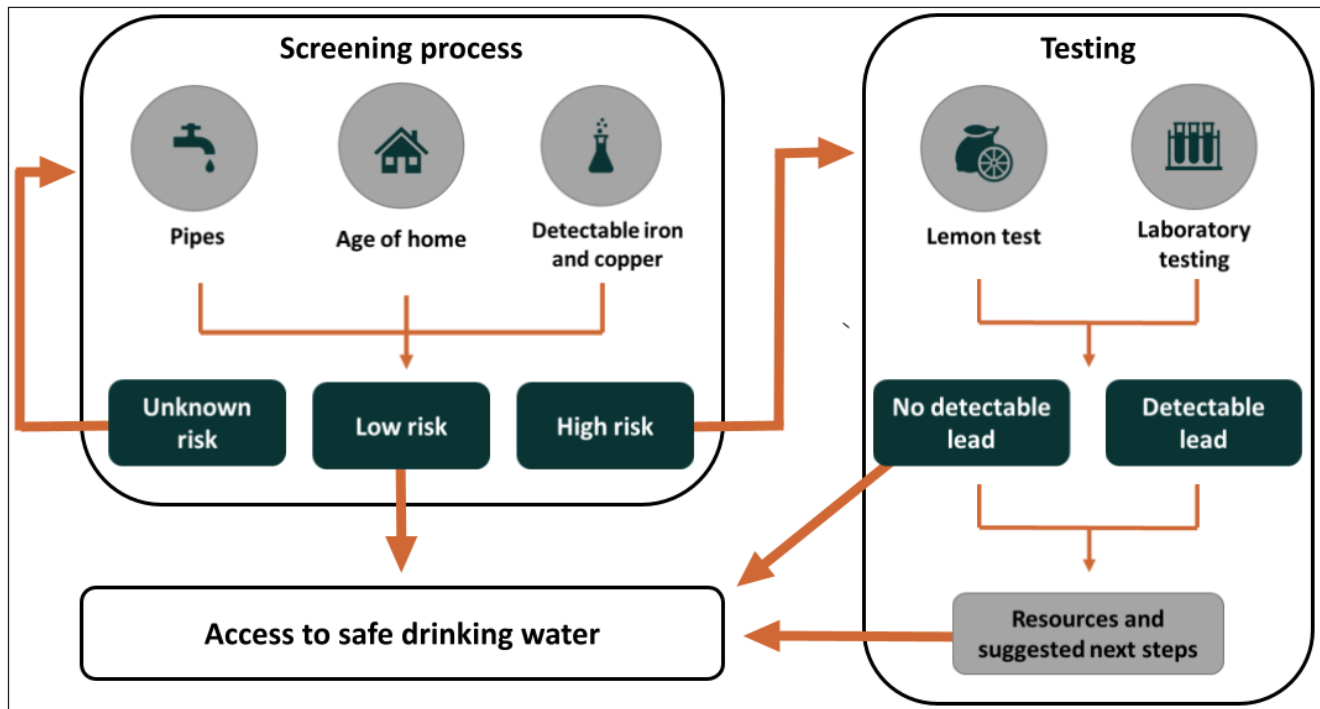


Figure 1 How the Crowd the Tap project works. Participants screen their homes by providing data on their pipes, on the age of their homes, and in some cases, on preliminary water chemistry data from a chemistry strip. This information is used to classify households' priority level for lab testing. Households that do not provide enough information to determine priority level are classified as unknown, and they are provided more resources on how to informatively re-screen. Households that are high priority are offered laboratory testing alone or the combination of a modified at-home lead test (Kriss et al. 2021) called the lemon test and a laboratory test. This testing determines whether or not household water has detectable lead. People receive resources on suggested next steps for addressing lead in water. Ultimately, be it through a low-priority risk designation, through confirmation of no detectable lead in the water, or through the resources a household is provided to address detectable lead, participants can be assured of the safety of their drinking water.

Libraries of Medicine and SciStarter to place water resource kits that included Crowd the Tap materials in a hundred or more public libraries throughout the United States (US); and through social media, Science Friday, various public webinars, announcements on listservs, and press releases. For this study, we use screening data from the 3,198 households that participated between May 2019 and August 2023.

Altogether, Crowd the Tap recruited 435 households from PWI intern programs, 57 from HBCU intern programs (27 from faith communities and 30 from a community-based health organization), 894 households from university students, 860 from high schools (461 level 1 students and 399 level 2 students), and 273 households through a corporate partnership with Verizon. Another 497 households participated in Crowd the Tap in an unfacilitated manner.

DATA COLLECTION AND ANALYSIS

Our screening survey was hosted on the Crowd the Tap webpage on SciStarter.org from May 2019 to October 2022 and then was linked from the webpage on SciStarter.org to a Qualtrics survey from November 2022 until August 2023. The surveys and an explanation of how they differed are available in Appendix A. Participants provided consent to participate

in research, and then provided information on the types of pipes in their homes, qualitative characteristics of their water, information about their home, demographic data, and in some cases quantitative water chemistry data provided from an at-home chemistry strip. Demographic data included the races represented by the households, the number of people in the household, household income level, and whether or not the participant had home or health insurance.

To assess our first research question related to the diversity of households reached, we compared household diversity from facilitated (from any organization) and unfacilitated engagement. We used chi-square tests to assess how race or ethnicity and homeownership differed by facilitation. When assessing race and ethnicity, American Indian or Alaska Native ($n = 6$) and Native Hawaiian or Other Pacific Islander ($n = 5$) households were excluded from chi-square tests due to low sample size. We use homeownership as a proxy for income because several students provided questionable income data (e.g., they would screen their parents' home, but then select their own income of $< \$10,000$). Homeownership is an effective proxy for income because higher-income individuals are more likely to own a home (US HUD 2005). Bonferroni

PWI internship program	We mentored 25 interns from North Carolina State University (NCSU) to engage their communities in Crowd the Tap. Interns received training on water systems engineering, science communication, and public engagement. They recruited members of their hometowns to screen and sample water. Reciprocal efforts with student facilitators included financial compensation, research credits, mentored research experiences, letters of recommendation, and workshops on drafting resumes and cover letters.
HBCU internship program	We (Cooper and Johnson) collaboratively obtained a grant with equitably distributed funds to support an internship program at Shaw University. We hired interns from HBCUs to engage households in Crowd the Tap through the North Carolina Council of Churches' (NCCC's) Program for Health and Wholeness and through the Southeastern Wake Adult Day Center (SEWADC). In total, we mentored eight Shaw University students, one North Carolina A&T (NC A&T) student, and one student who did not attend an HBCU but represented a community-based, nonprofit meant to improve Black livelihoods. Reciprocity with students in the HBCU internship program was similar to those in the PWI program. <i>Faith communities:</i> In the summer of 2022, six students worked with NCCC to engage members of faith communities across North Carolina. Students emailed and called contacts at various faith communities about the program and provided support for faith community leaders who engaged their members. Reciprocity with faith communities included stipends provided through NCCC's grant program to conduct health and wellness programs, in this case, Crowd the Tap. Another form of reciprocity involved data submission. We received feedback that the need for a login and the length of the survey made submitting data too complex for older members of faith communities. We completely revamped how we collected data, removing the need for a login and making questions related to water aesthetics and demographics optional. While the login information and the questions helped us fulfill our research objectives, they were a barrier to those most affected by the issue of lead contamination. We chose to prioritize people having access to information about their drinking water over our research questions. <i>A community-based health organization:</i> In the summer of 2023, four students worked with SEWADC, a day center run by Black employees for older adults and adults with disabilities that serves a primarily Black community in the Raleigh, NC area. Reciprocity with this facilitator organization involved providing water pitchers with filters to anyone found to have any amount of lead in their drinking water. With the permission of the people who participated, and within the scope of our IRB, we also provided non-anonymous data back to SEWADC, which they are using to apply for foundation grants.
University students	We engaged undergraduate students at NCSU and NC A&T through service learning projects in classrooms in which instructors had their students conduct the screening as an assignment. At NCSU, we also partnered with the Wicked Problem's Wolfpack Solutions summer course to engage incoming students in screening their homes prior to coming to campus. Instructors from other universities engaged their students in our project, but this was not through explicit partnerships set up between Crowd the Tap project leadership and the university. Reciprocity with university classrooms involved providing anonymized datasets for classroom use and guest lecturing about the project and findings.
High school students	We partnered with high school science teachers to engage their students in Crowd the Tap. We specifically recruited Advanced Placement Environmental Science (APES) teachers because of the flexibility that their curriculum offered and science teachers in areas of the state of North Carolina where the Department of Environmental Quality had reported the presence of utilities with lead plumbing. We had two levels of high school participation that involved differing classroom engagement and reciprocity: Level 1 teachers received curricular materials and lesson plans without any synchronous training, and they engaged their students in the screening process only. Level 2 teachers attended synchronous training sessions and engaged their students in both the screening and testing (Figure 1). Level 2 teachers also received a stipend. Curricular materials were specific to APES and Chemistry classes and were co-developed with paid teachers and contracted education experts.
Corporate volunteers	Verizon has a corporate volunteer program in which employees volunteer their time to engage in participatory science projects. This program is facilitated through SciStarter.org , an online hub for participatory science projects. As part of this program, Verizon employees received volunteer hours for screening their home, and if needed, sampling their water. Because SciStarter facilitates a suite of projects for Verizon employees to participate in, Crowd the Tap staff had very little interaction with corporate participants. As a result, efforts to foster reciprocity with Verizon is outside of the scope of our work with them, though we assume that given their longstanding partnership, there are reciprocal benefits between Verizon and SciStarter.

Table 1 Crowd the Tap recruitment through facilitator organizations.

post-hoc tests provided pairwise comparisons for race and ethnicity. Prior to selecting chi-square tests as our means of analysis, we conducted a Poisson regression that determined that the interactions between facilitators, race, and homeownership were insignificant for predicting the number of households. To better understand the degree to which we were able to reach a racially and ethnically diverse sample, we also compared facilitated and unfacilitated participation to national proportions of populations of different racial and ethnic groups (US Census Bureau 2021). We were not able to assess these differences statistically because we were comparing Crowd the Tap household-level data to individual-level data from the Census.

We were also interested in which facilitators encouraged diversity. To answer our second research question, we used chi-square tests with Bonferroni post-hoc tests to compare race and ethnicity with each of the facilitator groups as well as homeownership with each facilitator. Our third research question related to the role that HBCUs specifically could play as facilitators to engage diverse participants. We combined any household that participated through an HBCU, either a university student from an HBCU or someone from the faith communities or community-based health organization that partnered with HBCU interns, into a single variable. Similarly, we combined PWI students and those recruited through the

PWI intern program. Households that participated in an unfacilitated manner, through high schools, or through Verizon’s corporate volunteer program were grouped as “Other.” We used a chi-square test with a Bonferroni post-hoc test to assess how households engaged through HBCUs, PWIs, and other means differed by race and homeownership.

POSITIONALITY

The first author is an Asian American and white woman who works as a postdoctoral scholar at NCSU, a PWI. As part of her position, she manages several of the partnerships with various facilitator organizations including running both the PWI and HBCU intern program. The second author is a Black woman of Gullah/Geechee descent who works as the Dean of Arts, Sciences, and Humanities at Shaw University, an HBCU. She recruits interns for the HBCU internship program. The third author is a Jewish, white woman who works as a Professor at NCSU in the Department of Forestry and Environmental Resources. All three authors are homeowners in the state of North Carolina. Two of us have participated in Crowd the Tap’s water testing and have lead in our drinking water to some degree. One of us has higher than average levels of lead.

RESULTS

Facilitated Crowd the Tap households were generally more racially and ethnically diverse than unfacilitated households ($X^2(4) = 47.562, p < 0.005$; Figure 2a). Specifically, white households were overrepresented in unfacilitated participation and underrepresented in facilitated participation. Black households were overrepresented in facilitated participation and underrepresented in unfacilitated participation. There were no significant differences for Hispanic or Latinx, Asian, or multiracial households. Similarly, homeowners were overrepresented in unfacilitated households, while people that did not own their home were overrepresented in facilitated participation ($X^2(1) = 138.13, p < 0.05$; Figure 2b).

Furthermore, the percentages of racial and ethnic diversity for facilitated households were more similar to nationwide percentages for race and ethnicity from US Census data. Facilitated white households (55.4% of facilitated households) were approximately on par with the percent of white households in the US (58.9%), but unfacilitated white households were overrepresented (67.4% of unfacilitated households). Facilitated Black households (11.4% of facilitated households) were also on par with the percent of Black households in the US

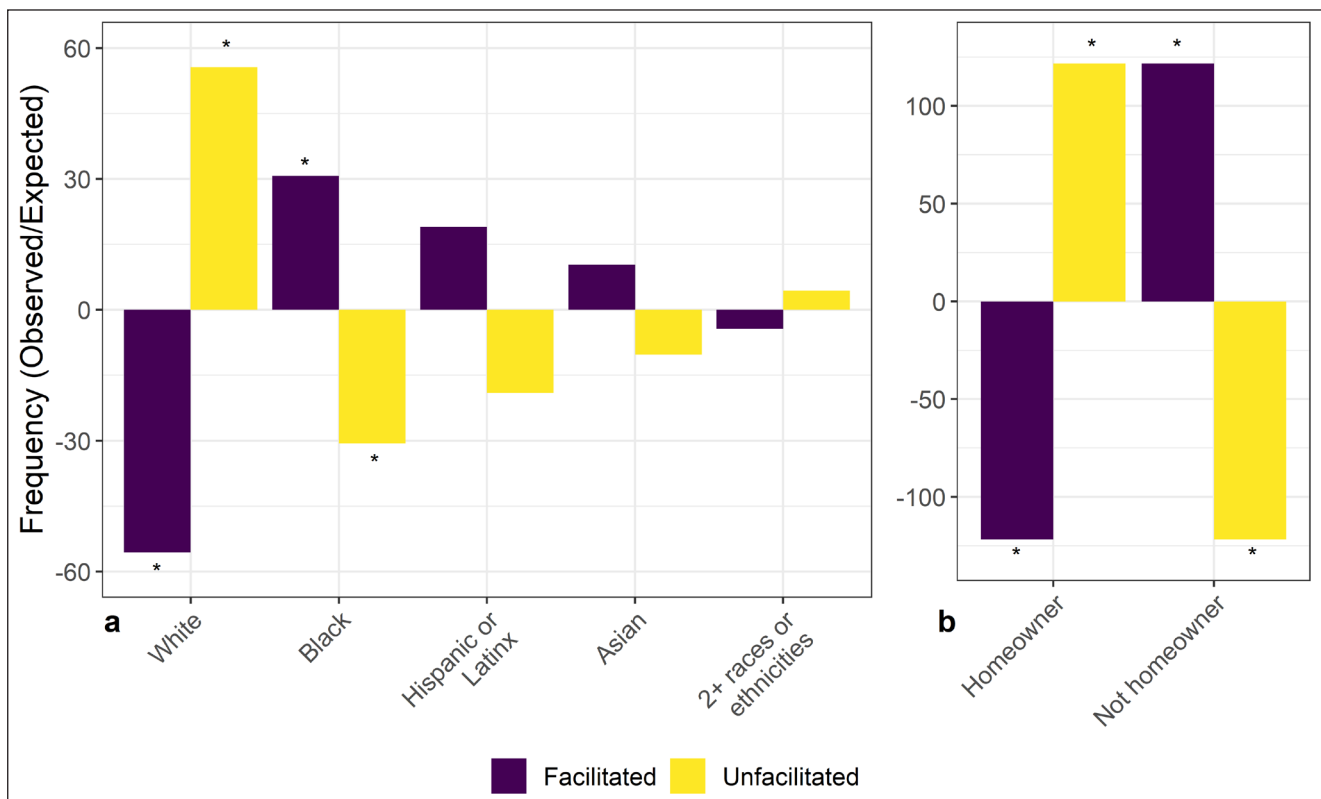


Figure 2 Breakdown of race (a) and homeownership (b) by whether or not their participation was facilitated. * indicates significance, either with an adjusted p-value based on a Bonferroni post-hoc test (a: $p < 0.005$) or b: 0.05).

(13.6%) but were underrepresented amongst unfacilitated households (5.1% of unfacilitated households). Both facilitated and unfacilitated Hispanic or Latinx households were underrepresented (11.5% of facilitated households and 5.1% of unfacilitated households) relative to national proportions (19.1%). Asian households, regardless of facilitation (7.2% of facilitated households and 4.6% of unfacilitated households), were similar to the national percentages (6.3%). American Indian or Alaska Native households made up 0.2% of facilitated households and 0.4% of unfacilitated households relative to making up 1.3% of the US population. Native Hawaiian and Other Pacific Islanders accounted for 0.1% of facilitated households and 0.2% of unfacilitated households in Crowd the Tap, while they make up 0.3% of the population nationwide. Finally, multiracial households (14.3% of facilitated households and 17.2% of unfacilitated households) were overrepresented relative to the percent of multiracial households nationwide (3.0%) regardless of facilitation.

Of the multiracial households, 401 had at least one person who was white, 204 had at least one person who was Hispanic or Latinx, 152 had at least one person who was Black, 173 had at least one person who was Asian, 54 had at least one person who was American Indian, and 11 had at least one Pacific Islander.

People of color more frequently screened their homes through facilitator groups like HBCU intern programs in partnership with faith communities and community-based health organizations as well as through high school classrooms ($\chi^2(20) = 624.74, p < 0.00167$; [Figure 3a](#)). White households were overrepresented in unfacilitated participation and PWI intern programs where university students recruited their communities. They were underrepresented in HBCU intern programs and high schools. Black households were overrepresented in HBCU intern programs and underrepresented in unfacilitated participation. Despite only recruiting 57 total households, HBCU intern programs with faith communities and a community-based health organization helped recruit 14.6% of all Black participants ([Table 2](#)). Faith community households were 81.5% Black, and the households recruited by the community-based health organization were 96.7% Black. Hispanic or Latinx households were overrepresented in high school classrooms but underrepresented in PWI intern programs and amongst university students ([Figure 3a](#)). Altogether, high school students accounted for 70.5% of Hispanic or Latinx households ([Table 2](#)). Level 1 high schools were important for recruiting Hispanic or Latinx households, while level 2 households recruited more Black and multiracial

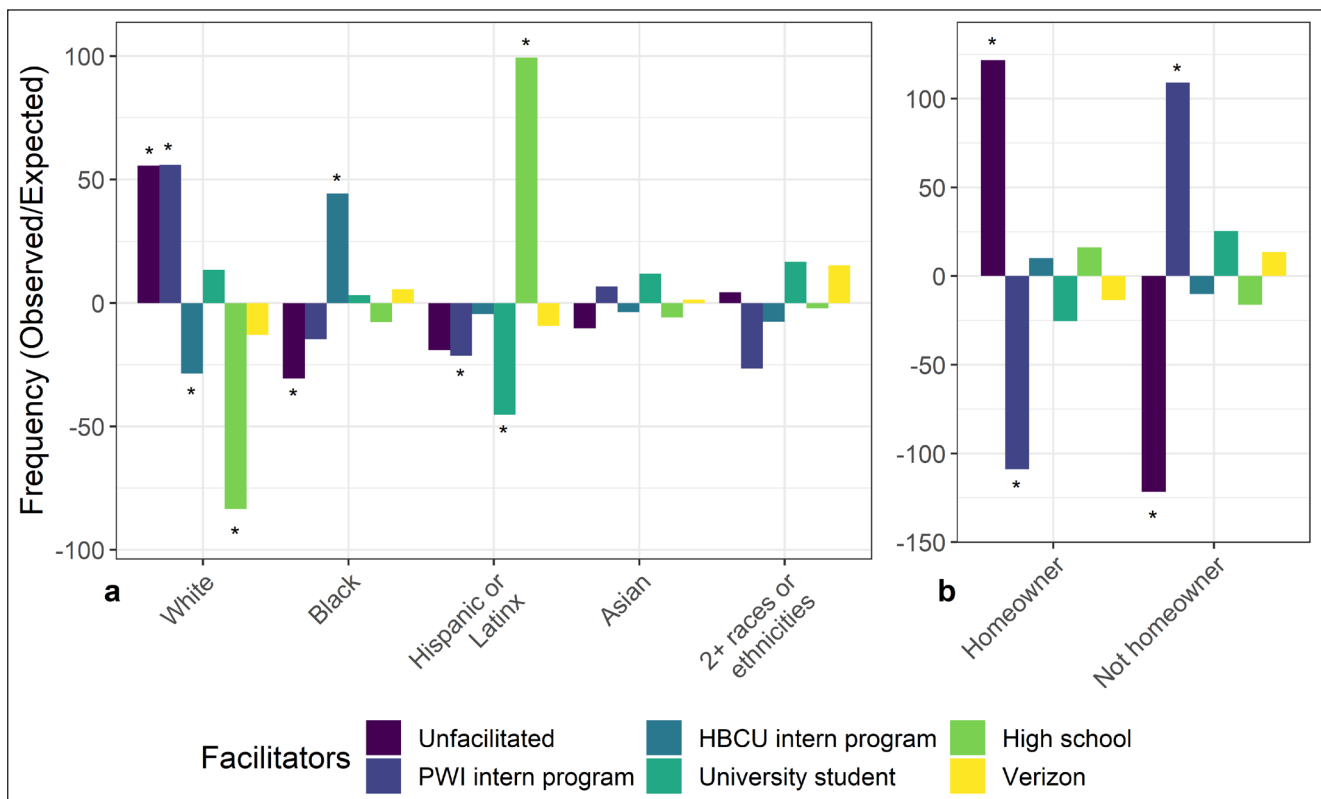


Figure 3 Breakdown of race (a) and homeownership (b) by facilitator organizations. * Indicates adjusted significance levels based on Bonferroni post-hoc tests (a: $p < 0.00167$; b: $p < 0.00417$). HBCU: historically Black college/university, PWI: predominantly white institutions.

households. There were no significant differences in race between facilitator groups for Asian and multiracial households (Figure 3a).

Homeowners were overrepresented in unfacilitated participation and underrepresented in PWI intern programs where students recruited their communities ($X^2(5) = 230.27, p < 0.00417$; Figure 3b). Homeownership was not significant for any of the other facilitator groups.

Because so many of our facilitators involved partnerships with HBCUs or their students directly, we wanted to investigate the specific effects of HBCUs on diverse recruitment. We found that recruiting households through partnerships with HBCUs was particularly helpful for engaging Black participants ($X^2(8) = 452.1, p < 0.00333$; Figure 4a). White households were overrepresented at PWIs, where Hispanic or Latinx

	UNFACILITATED	PWI INTERN PROGRAM	FAITH COMMUNITIES (HBCU INTERN PROGRAM)	COMMUNITY-BASED HEALTH ORGANIZATION (HBCU INTERN PROGRAM)	UNIVERSITY STUDENT	LEVEL 1 HIGH SCHOOL	LEVEL 2 HIGH SCHOOL	VERIZON
White	19.6%	17.6%	0.2%	0.1%	30.4%	11.1%	12.7%	8.3%
Black	7.7%	10.3%	6.3%	8.3%	30.6%	9.1%	17.1%	10.6%
Hispanic or Latinx	8.4%	5.5%	0.0%	0.0%	10.5%	59.1%	11.4%	5.1%
Asian	11.2%	17.9%	0.0%	0.0%	35.7%	17.9%	7.7%	9.7%
American Indian	16.7%	0.0%	0.0%	0.0%	16.7%	33.3%	0.0%	33.3%
Pacific Islander	20.0%	0.0%	0.0%	0.0%	40.0%	0.0%	20.0%	20.0%
Multiracial	17.4%	8.6%	0.2%	0.0%	33.3%	12.1%	15.9%	12.4%
Homeowner	23.9%	8.0%	1.3%	1.0%	26.9%	13.8%	16.4%	8.6%
Not homeowner	8.2%	21.9%	0.3%	0.8%	30.2%	17.9%	10.3%	10.5%

Table 2 Makeup of race/ethnicity and homeowner status by facilitators.

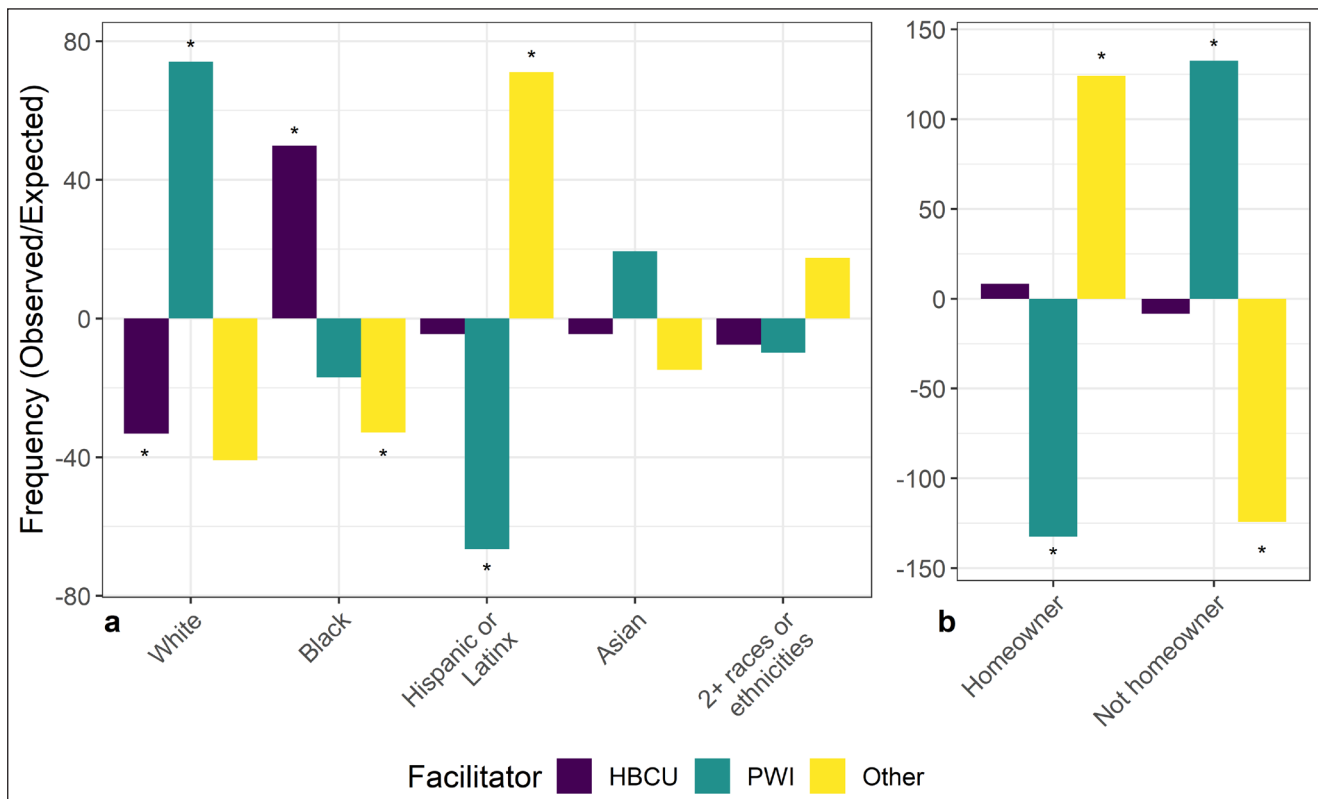


Figure 4 Breakdown of race (a) and homeownership (b) by HBCU, PWI, and other facilitators. * Indicates adjusted significance levels based on Bonferroni post-hoc tests (a: $p < 0.00333$; b: $p < 0.00833$). HBCU: historically Black college/university, PWI: predominantly white institutions.

households were underrepresented. Black households were underrepresented in other facilitator organizations, but these groups favored engagement of Hispanic or Latinx participants. Furthermore, homeowners were overrepresented in other facilitators and underrepresented at PWIs ($\chi^2(2) = 92.928, p < 0.00833$; [Figure 4b](#)).

DISCUSSION

For Crowd the Tap, facilitator organizations were an effective means of increasing participant diversity in a large-scale, contributory project. In general, facilitation increased diverse participation, especially for Black and lower-income households. Facilitated participation was generally aligned with proportional data for race and ethnicity from the US Census. Without facilitators, Crowd the Tap engaged a higher proportion of white and higher-income households, a pattern similar to other large-scale, contributory projects ([Alf et al. 2022](#); [Blake, Rhanor, and Pajic 2020](#); [NASEM 2018](#); [Rutter et al. 2021](#)). Partnerships with high school teachers helped engage Hispanic or Latinx participants, while internship programs with HBCUs helped recruit Black participants. Project managers seeking to broaden participation in their projects should consider engaging participants through facilitator organizations like K–12 classrooms, minority-serving institutions like HBCUs, community-based health organizations, and faith communities.

THE EFFICACY OF FACILITATOR ORGANIZATIONS FOR ENGAGING DIVERSE PARTICIPANTS

Partnerships with HBCUs were helpful for engaging Black households through the universities themselves and for partnering with community organizations that engaged Black households. Faith facilitators were important for engaging Black households. Black Americans are more likely to be Christian relative to the general population ([Pew Research Center 2014](#)), and churches have previously been effective for co-creating and disseminating public health information to Black communities ([McDonnell and Idler 2020](#)). In the United States, churches are often racially segregated, with about 90% of churches having congregations that are at least 90% a single racial group ([Emerson and Kim 2003](#)). In partnership with the North Carolina Council of Churches, our study recruited households through primarily Black churches. As a result, in our study, churches were largely made up of Black households. This engagement was also important for our project because lead piping and contamination have previously been found to be more common in Black communities ([Benfer 2017](#); [Muller, Sampson, and Winter 2018](#); [Sadler, LaChance and Hanna-Attisha 2017](#)).

The community-based health organization that we partnered with through the HBCU intern program was also helpful for engaging Black households. As the majority of employees at the organization were Black, and the elderly people served by the organization were Black, it is unsurprising that the facilitator was helpful for engaging Black households. Previous research on the importance of representation in the medical field has shown that Black men have higher trust in Black doctors, and as a result, are willing to agree to more preventative care and more invasive treatment ([Alsan, Garrick, and Graziani 2019](#)). It is possible that the dual representation in facilitator staff and project staff (the HBCU intern program) was integral in recruiting the high proportion of Black participants from this group specifically.

Partnerships that engaged HBCU students also helped engage Black households. In 2018, 23.2% of all Black graduate students who earned science and engineering doctorates attended HBCUs for their undergraduate degrees ([NCSES 2021](#)) even though only 8.5% of Black undergraduates attend HBCUs ([NSF 2020](#)). As HBCUs continue to help diversify science and engineering fields, our results suggest that partnerships with HBCUs and other minority-serving institutions may effectively diversify larger-scale, contributory projects as well.

Facilitation by high school teachers increased the racial diversity of participating households, especially for Hispanics or Latinxes. While some minority-serving K–12 institutions often have fewer Advanced Placement course offerings, and these do not always attract a diverse audience ([The Education Trust 2013](#)), we still found that facilitation by high school teachers increased racial diversity. It is possible that high schools were a successful means of engaging Hispanic or Latinx participants because, as [Bonney et al. \(2016\)](#) suggested, schools can be an effective means of encouraging diversity because students are required to participate. However, this argument has been criticized because it requires students to assimilate into projects that may otherwise not be inclusive and absolves project leaders of the challenges of restructuring projects to address inclusion, equity, and accessibility challenges that hinder diversity ([Hawn et al. 2019](#)).

There were no significant differences between expected and observed numbers for each race for Verizon's corporate volunteer program. This suggests that relative to the rest of the sample, Verizon's program recruited a proportional number of households of each race, potentially reflecting the company's demographics. It is possible that this is because there was less of an emphasis on employee diversity and more of a focus on providing a volunteer opportunity.

Internship programs run through PWIs were not effective at engaging racially or ethnically diverse participants but did help the project reach participants who were not

homeowners, a proxy for lower-income households. It is possible that this is because PWI interns may have recruited their friends who were renting off-campus housing to participate in the project. However, this is unlikely to be the case because there was not an elevated number of non-homeowners amongst university students themselves.

LIMITATIONS RELATED TO DIVERSITY, EQUITY, INCLUSION, AND ACCESSIBILITY

One limitation of our analysis is that we compared household-level diversity in Crowd the Tap to individual-level data in the Census, meaning our units of analysis were not aligned. As a result, we were unable to conduct statistical tests comparing data from the US Census with our Crowd the Tap sample. This likely made our comparisons conservative for single-race households and might account for what appeared to be an overrepresentation of multiracial households. Alternatively, the overrepresentation of multiracial households may reflect national trends of interracial marriages, which increased by 14% between 1967, when the Supreme Court ruled that it was unconstitutional for states to outlaw them, and 2015 (Pew Research Center 2017). In the US, 42% of interracial marriages were between a white and Hispanic spouses (Pew Research Center 2017). Similarly, in Crowd the Tap, 48.5% of multiracial households included at least one person who was white and Hispanic.

Our assessment of diverse participation in Crowd the Tap does not equate to equitable or inclusive participation. Given that communities of color and low-income communities are more likely to have lead piping and leaded water (Benfer 2017; Muller, Sampson, and Winter 2018; Sadler, LaChance, and Hanna-Attisha 2017), equitable participation would have resulted in an overrepresentation from households with people of color. Furthermore, our assessment provides no indication of inclusion. In projects with the potential for repeated participation over time, retention could be an indicator of inclusivity, but Crowd the Tap participation is limited to once per household. We did not collect information about disability status within Crowd the Tap households and thus can make no inferences about accessibility.

IMPLICATIONS

Project leaders in large-scale, contributory projects looking to engage diverse participants should consider partnering with facilitator organizations like high schools, faith communities, and universities. Developing partnerships with minority-serving institutions like HBCUs may be especially effective at encouraging diverse participation. Furthermore, faculty at minority-serving institutions may also have connections to community organizations that serve similar demographics to their institutions. That said, project staff looking to

partner with minority-serving institutions should invest time and financial resources into establishing partnerships with faculty at minority-serving institutions. As we did between NCSU and Shaw University, we encourage scientists leading projects to establish partnerships prior to fully developing proposals and to ensure that an equitable amount of grant funding is allotted for minority-serving institutions.

Our results also suggest that partnering with facilitators that have diverse staff and/or a mission to service diverse communities may also be key in engaging diverse participants. We were unable to specifically tease apart whether we engaged diverse participants through the community-based health organization because of representation in project staff through HBCU interns and faculty, facilitator staff, and the facilitator's mission to serve diverse participants, or some combination of the three. However, selecting to work with facilitator organizations that have diverse staff and/or a goal of serving diverse communities may help diversify the people who ultimately participate in a project.

Finally, we urge our colleagues to prioritize reciprocity and inclusion. In Table 1, we detail the ways that we sought to engage in reciprocal relationships with each of the facilitators with which we partnered. We tailored reciprocity strategies to the specifics of the organizations with which we worked, and we suggest that those seeking to partner with various facilitators do the same. Reciprocal relationships are more feasible when there is grant funding set aside to pay a facilitator for efforts expended and purchase the supplies that are needed. While engaging diverse participants is an important goal, prioritizing inclusion in projects will ensure that the diverse participants who do come to your project will experience a sense of belonging and are more likely to continue participating.

CONCLUSIONS

Our results ultimately point to the efficacy of partnering with facilitator organizations to increase participant engagement, and especially engagement of people with diverse racial and ethnic backgrounds, in contributory projects. Without facilitation, Crowd the Tap, like many other contributory projects, engaged mostly white households. Yet, by partnering with faith communities, a community-based health organization, high schools, universities, especially minority-serving institutions, and a corporate volunteer program with Verizon, facilitation increased the racial and ethnic diversity of participants. Internship programs run through a PWI helped us reach lower-income households but were less effective at recruiting racially and ethnically diverse households. These results are a promising start as the field of participatory science seeks to continue to engage more diverse participants.

DATA ACCESSIBILITY STATEMENT

The data for this project are available in the Dryad data repository. The data can be accessed at <https://doi.org/10.5061/dryad.v15dv422h>.

SUPPLEMENTARY FILE

The Supplementary file for this article can be found as follows:

- **Supplemental File 1.** Appendix A, Crowd the Tap screening survey. DOI: <https://doi.org/10.5334/cstp.627.s1>

ETHICS AND CONSENT

These procedures in this study were approved by North Carolina State University's Institutional Review Board protocol #16549. Participants 18 and older provided informed consent, and participants 13–17 years old assented and provided parental consent.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

DLH helped manage relationships with facilitators, conducted analyses, and wrote the draft of the paper. VAJ recruits and provides oversight on the HBCU internship, initiated the community-based health organization partnership, and aided in writing the manuscript. CC conceptualized and started the Crowd the Tap participatory science project, initiated the faith community partnership, and university and high school facilitator programs, and aided in analyses and writing of the paper.

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