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Using Community Science to Address Pollution in an Urban Watershed: Lessons about Trash, Diverse Engagement, and the Need for Science Mindsets

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Abstract: Community science projects offered in urban areas may be particularly effective at addressing environmental problems and engaging people in science, especially individuals whose identities have historically been underrepresented in the field. In this project, we worked with individuals from a racially diverse, low-income community in San Diego, California to conduct community science to: 1) test a conceptual program model aimed at engaging diverse communities in science, and 2) contribute to scientific knowledge about the inputs and accumulations of trash in an urban watershed. While the program model did well at bolstering environmental stewardship, recruitment, and short-term retention of community members as project participants, it was not as effective at building science understanding, interest in science, and awareness of doing science, indicating a need for a mindset approach. Despite this, the data collected by the community between 2014-2018 revealed in-depth information about the spatial and temporal distributions of trash, including the identification of three main debris inputs: encampments, illegal dumping, and storm drain flows, as well as the validation of global trends of a predominance of plastics across waterways and through time. In a few instances, community stewards became community scientists—the quantity and quality of data collected improved, and community members presented results to authorities who responded with concordant management actions (e.g., help with cleanups, outreach to unhoused communities). Based on project outcomes, our revised community science program model includes a focus on strengthening a science mindset, in which even short-term science interventions that improve the recognition of science, a sense of belonging, and access to mentorship may have meaningful long-lasting effects on increased participation in science.

Keywords: *citizen science, community engaged science, DEI, illegal dumping, marine debris, plastics pollution, STEM, stormwater flows*

Trash pollution is a ubiquitous, global problem with well-documented effects on coastal communities and marine ecosystems (UNEP 2014; Rochman et al. 2016). Most trash found throughout watersheds and in lakes and oceans around the world originates from land (Rochman 2013). California is no exception, with trash collected during coastal cleanups dominated by single-use and plastic food containers and wrappers, tableware, bottles, bags, straws, and cigarette butts (CCC 2019), reflecting global trends (Ocean Conservancy 2020; Reddy and Lau 2020). Trash, in particular plastic trash, is concerning because of its persistence in the environment and its potential to harm wildlife through entanglement, suffocation, malnutrition (when ingested), internal blockages, and increased exposure to environmental toxins (e.g., Teuten et al. 2009; Rochman et al. 2013a; 2013b; Kühn et al. 2015). With rapidly growing awareness of the ubiquity of trash and its detrimental effects on wildlife and humans, trash is increasingly being treated as a water pollutant (Moore 2008; Koch and Calafat 2009; Hollein et al. 2014;

Research Implications

- Community science practices that maximize accessibility and relevance to community members by tackling problems that are ubiquitous and important to the community (e.g., trash pollution, in the case of this project) will increase diverse participation in the activities and facilitate entry into science.
- Community science practices that provide impactful experiences, such as guided, hands-on, authentic science activities led by people from the community, will increase environmental awareness, enthusiasm, and stewardship; strengthening diversity in science will require the addition of practices that build science mindsets.
- Community science practices that build science mindsets, in particular activities that are impactful even with brief exposure such as inclusion of STEM role models, may heighten participants' recognition of doing science, valuing of science, and sense of belonging, which may in turn increase engagement and perseverance of a greater diversity of people in science.
- Guided research experiences with the community, in particular collaboration between scientists and key community members within and between project sessions, contributes to the generation of appropriate, high-quality data and community empowerment—both needed for effective communication with officials and crafting of locally-relevant solutions.
- Recording even basic data about trash during cleanups, such as location, counts, volumes, and/or weights, can reveal much about sources of inputs and serves as a powerful public education and action tool.

USEPA 2020). In California, a 2015 state permit amendment mandated that all municipalities eliminate trash from flows into receiving waters by 2030 through the installation of trash capture devices or alternative trash reduction innovations (CSWRCB 2015; USEPA 2020). In order to develop appropriate and effective trash solutions, better understanding is needed of both the trash dynamics within individual coastal watersheds, including sources of inputs, types of debris, and spatial and temporal distributions of trash, and how to engage people throughout the watershed in trash reduction practices.

Community science can strengthen the environmental awareness, stewardship, and literacy of non-scientist community members (Trumbull et al. 2000; Brossard et al. 2005; Evans et al. 2005; Ballard and Belsky 2010; Jordan et al. 2011; Bonney et. al 2009; 2016) and facilitate the inexpensive collection of data over large geographic areas, which can then advance scientific knowledge, practice, and policy (Cooper et al. 2007; Ballard and Belsky 2010; Conrad and Hilchey 2011; Miller-Rushing et al. 2012; Sauermann and Franzoni 2015; Theobald et al. 2015). Community science projects offered in urban regions may be particularly productive and important given the high densities of potential participants, and the need for studies of urban ecosystems which provide crucial services for many communities, in spite of their often-degraded states (Elmqvist et al. 2015). Further, urban populations tend to be diverse, with relatively high proportions of people from the very minority groups that are underrepresented in science, giving urban community science projects great potential for engaging and increasing representation of these groups in science (Evans et al. 2005; Pandya 2012; NSF 2015).

Effectively engaging people from diverse groups in science remains a challenge (Miller-Rushing 2013), so increasing participation in community science efforts may be an effective way to increase representation in science more generally. We developed and tested the effectiveness of a conceptual community science program model (Figure 1; Ruzic et al. 2016) aimed at engaging a diverse urban community in community science, specifically in the investigation of trash pollution in their neighborhood's waterways. The model was based on emerging best practices which we categorized as improving ***science entry*** (access to experiences and encouraging initial participation; Figure 1) and ***science intervention*** (impact, meaning, value, and/or inspirational power of initial and early experiences; Figure 1). We chose seven best practices, two practices aimed at facilitating science entry and five aimed at providing impactful science interventions

(Figure 1), that have been linked with increases in participants' ***understanding*** of (e.g., knowledge, skills, interest; Figure 1) and ***persistence*** in science (i.e., long-term, repeated participation including interest in science careers; Figure 1) (Bell et al. 2003; Dee 2004; Lauver et al. 2004; Bang and Medin 2010; Sadler et al. 2010; Wu and Van Egeren 2010; Harrison et al. 2011; Pandya 2012; Graham et al. 2013).

The causes and effects of trash pollution are issues that most people understand, and trash reduction is a priority for many communities, making trash a logical focus of community science projects (i.e., science relevant to participants' daily lives; Figure 1). As in many urban neighborhoods, the residents, community-based organizations, and civic leaders in City Heights, a neighborhood located in the middle of San Diego, California, USA (Figure 2), often work together to conduct trash cleanups and move toward sustainable solutions to improve and steward their urban waterways. We worked with members of City Heights because our project team had existing ties with community groups in City Heights. We chose trash as this project's subject matter because community members had been working together to reduce trash pollution in local waterways for more than five years before this project began (Ruzic et al. 2016), indicating that trash control was a priority for many in the community. No group had previously engaged the community in an organized, hands-on, authentic (not classroom science; Crawford 2015) science project (Figure 1) built around the community's trash reduction goals.

City Heights was also an ideal focus for this project because it is a highly urbanized, high-poverty, "disadvantaged" community (DWR 2015; Ruzic et al. 2016). It is highly diverse, with at least 40 languages and 80 dialects spoken by neighborhood residents (EHC 2011; Mento 2018). The community has been identified as having low engagement and performance in STEM and being "vulnerable to climate change impacts" (Cooley et al. 2012; CDE 2013; SANDAG 2015; Ruzic et al. 2016). All community science project activities took place in four canyons in City Heights (Figure 2). These canyons are seasonal waterways that serve as green spaces, wildlife and sensitive species habitat, and the city's stormwater system, and are part of the Chollas Creek sub-watershed, labeled one of the most impaired waterbodies in San Diego County (Anderson et al. 2012; San Diego Coastkeeper 2014). These facts combined indicate a need for strengthened stewardship and bolstered resilience of both the urban community and ecosystem.

Project Goal and Objectives

The goal of our project was, therefore, to address the issue of trash pollution in a coastal urban watershed through community science, and engagement in science more generally, to lead to longer-term, sustainable solutions. We addressed this goal by using social science approaches to study the community as they participated in a community science project called the "Discoverers Program," which employed applied natural science approaches to study trash pollution. Specifically,

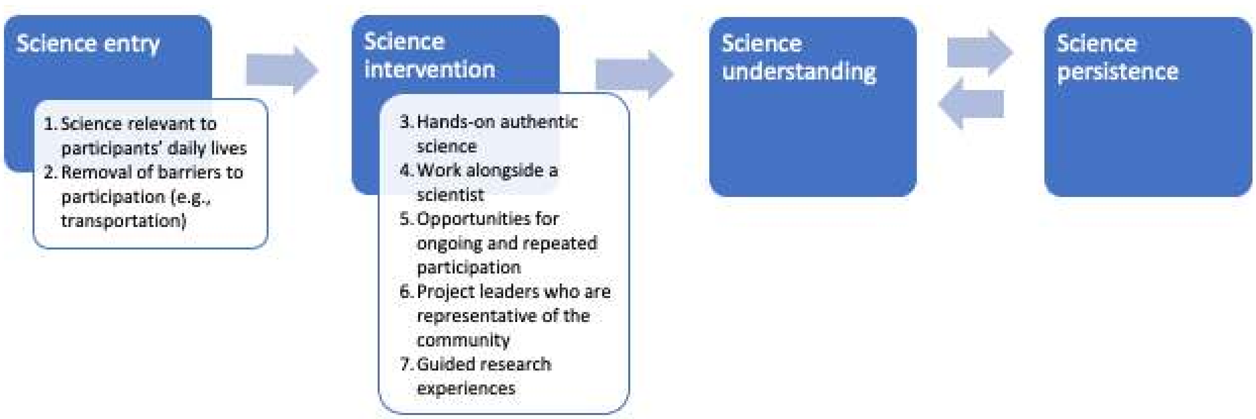

Figure 1. An initial conceptual community science program model used to recruit (entry) and engage (intervention) members of a diverse community in community science with hopes of ultimately increasing science understanding and persistence. Modifications were made based on project outcomes resulting in a more effective model.

we fulfilled the following two objectives by answering the associated research questions:

1. Assess our newly developed conceptual program model (Figure 1) aimed at engaging diverse communities in community science and, ultimately, increasing science understanding and participation in science, by piloting, evaluating, and subsequently modifying the initial model which was based on known best practices.
   a. To what extent did our science entry practices (Figure 1, Practices 1-2) contribute to the participation of people from all demographic variables?
   b. To what extent did our science intervention practices (Figure 1, Practices 3-7) influence science understanding and persistence in participants from all demographic variables?
2. Improve our understanding of trash pollution, specifically the types and abundances of trash inputs through space and time in an urban waterway.
   a. How do the types and abundances of trash inputs differ across canyons and with time (year and season)?

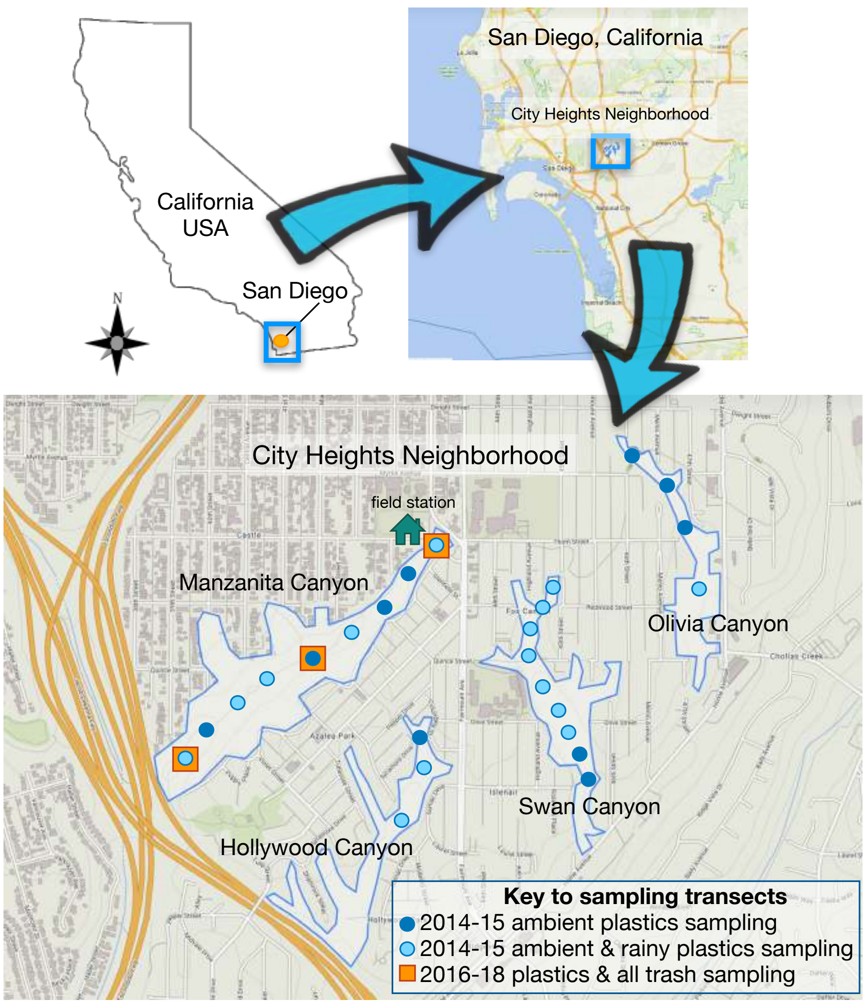

Figure 2. Location of canyons where community science efforts were conducted between 2014-2018 in the City Heights neighborhood of San Diego, California. In 2014-2015, all four canyons were used for both the Discoverers Program (the community science project) and the community science program model assessment. In 2016-2018, only the Discoverers Program was conducted and only in Manzanita Canyon; besides the transects (orange squares), the whole canyon was also studied for trash.

b. What is the total magnitude of inputs of all types of trash into these canyons, using Manzanita Canyon as an example?

Methods

Assessing Our New Community Science Program Model

The influence of our initial community science program model on levels of participation and persistence, indicated by retention, learning, and interest in science (Table 1) of participants eight years and older was tested between January and July 2015, in conjunction with the Discoverers Program (the community science project). Of the 215 individuals who participated in the project throughout this period, 208 met the minimum age requirements and 95% (198) chose to participate in the assessment. Up to five types of data were collected from each participant to answer research questions (Table 1):

1. Tracking data – the number of individuals who attended each session and attendance over time using a participant ID number assigned during each person's first visit.
2. Written surveys – administered at the beginning of each participant's first session. Surveys collected demographic information (zip code, age range, gender, race/ethnicity) and data about how the person heard about the initiative (n=198 individuals).
3. Written assessments – administered at the beginning and end of each participant's first session. Assessments asked a basic science question (specifically, an illustrated question about the direction that water (and, in turn, trash) flows in a watershed) and a question about the participant's interest in particular conservation and science topics (n=125 individuals who completed both the pre- and post-session written assessments).
4. Individual interviews – administered at the end of one session, in either English or Spanish. Interviews were composed of questions about the day's activity, the participant's experience and learning during the activity, and reasons for attending (n=32 individual (or family) interviews).
5. Field recordings – one- to two-hour long audio recordings from recorders voluntarily worn around the necks of 64 unique individuals over 10 sessions that captured all audible sounds, including conversations with consenting participants without recorders, to determine the type and frequency of science talk during the sessions. Of these, the recordings from the final three project sessions were selected for analysis because they were best suited (see Ruzic et al. 2016 for details) for comparisons of discussions with and without a scientist present (n=1 session with a scientist and n=2 sessions without a scientist present for a total of 16 recordings from 12 unique individuals).

During the 2016–2018 Manzanita Canyon project, the number of community participants, as well as participants' zip codes and age ranges (adult, minor) were recorded for all sessions. The names, contact information, and demographic information of high-frequency participants were voluntarily provided.

Model Assessment Data Analysis. For each type of data collected, analyses were performed to test for overall trends and differences by demographic variables such as race/ethnicity, age range, and gender. Paired t-tests were used to identify changes in science understanding and interests before and after participation in the project. The individual interviews and field recordings, which consisted of multiple, different recording perspectives of each conversation and session, were transcribed verbatim. Transcripts were imported into HyperRESEARCH™ qualitative analysis software. Both the transcripts and original audio recordings were used concurrently during coding to distinguish near, far, and inaudible conversations from each participant's vantage point during the field session. Data were analyzed using a modified grounded theory approach. We applied a set of *a-priori* coding categories while also allowing codes and themes to emerge from the data, all with consideration of each recorded participant's unique experience within the larger context of the field session. Transcripts were coded for participants' reasons for attending the project session, what they got out of or learned through the project, their understanding of the community

Table 1. The variables measured or assessed, and the methods used to fulfill this interdisciplinary project's two research objectives by answering corresponding research questions. The testing of science intervention practices (3-7) additionally assessed the effect of the presence/absence of a scientist on the variables listed.

Research Questions	Variables Measured	Data Collection Methods
Objective 1. Assess our new community science program model		
To what extent did our science entry practices (1-2) contribute to the participation of people from all demographic variables?		
Relevance of project to participants	participant motivations for participating	individual interviews
Removal of barriers (accessibility to the community)	participant zip code and demographics (vs. community demographics)	written surveys
	how participants heard about the event	written surveys
	participant return rates	tracking data
To what extent did our science intervention practices (3-7) influence science understanding and persistence in participants from all demographic variables?		
Changes in understanding: level, type, and drivers of	pre- and post-session ability to answer a basic science question	written assessment
	type and frequency of talk about science and related topics during the field session	field recordings
	understanding of the trash study during field sessions	field recordings
	understanding of science and/or the trash study after field sessions	individual interviews
Persistence in science: return rates, expressed interests, and drivers of	participant return rates (overall), participant return rates with and without a scientist present on first visit	tracking data
	repeat participant vs. leader demographics	tracking data and written assessment
	pre- vs. post-proportions of participants interested in various science and conservation topics	written assessment
	type and frequency of talk about science and related topics during the field session	field recordings and individual interviews
Objective 2. Improve our understanding of trash pollution (specifically the types and abundance of trash inputs through space and time)		
How do the types and abundance of trash input differ across canyons and with time (year and season)?		
Spatial and annual dynamics of plastics trash	annual proportional numeric abundances of each type of meso-plastic trash from each of the four canyons in 2014 and from 2015-2018 in Manzanita Canyon	2014 ambient plastics sampling, 2014-15 rainy plastics sampling, 2016-18 all trash sampling
Rainy season plastics trash inputs	average volume of the different types of meso-plastics trash collected from each canyon in the rainy season vs. pre-rainy season (ambient)	2014 ambient plastics sampling, 2014-15 rainy plastics sampling
What is the total magnitude of inputs of all types of trash into these canyons using Manzanita Canyon as an example?		
Magnitude of inputs of all trash	volume and weight of each type of meso-trash and large items totaled by location within Manzanita Canyon by year	2016-18 all trash sampling

science study, and their conceptions of science (Ruzic et al. 2016).

Community Science Project: The Discoverers Program

Session Access and Leadership. The Discoverers Program was conducted between January and July 2015 in four neighborhood canyons and between April 2016 and May 2018 in Manzanita Canyon only (i.e., Figure 1, Practices 1, 5: Relevant science, repeated opportunities; Figure 2). All canyons were within walking distance of multiple schools and residential areas within the community (i.e., Figure 1, Practice 2: Removal of barriers; Figure 2).

Each session of the Discoverers Program was advertised through multiple channels, including neighborhood and school newsletters, phone calls to local groups and partners, presentations at community events, and community group mailing lists and social media (i.e., Figure 1, Practice 2: Removal of barriers; Ruzic et al. 2016). Each 2015 session was led by a staff educator from a community-based science education organization and two members of a trained team of four project leaders. The project leaders were high school students from the community who were representative of the cultural/ethnic diversity in the community and spoke the three most common languages in the community (English, Spanish, and Vietnamese) (Figure 1, Practice 6: Leaders from the community). The project leaders, guided by the staff educator, provided participants with an introduction at the start of the day consisting of an overview of the science research project (methods, results to date) and basic underlying science concepts, including what a watershed is and the impact of trash locally and downstream (Figure 1, Practices 1, 3, 7: Relevant, hands-on and authentic, guided research). The project leaders and staff educator also oversaw the field activities, ensuring protocols were followed and providing participants with assistance and information about the activity and the underlying science as needed or as opportunities arose to share information (Figure 1, Practice 7: Guided research). The project scientist actively participated in half of all the sessions including the field activities because the study tested the influence of scientist presence (and absence) on participant engagement (Figure 1, Practice 4: Work alongside a scientist; Ruzic et al. 2016). While the project scientist—a white, middle-aged female PhD-level ecologist—was not representative of any of the underrepresented groups from the community (i.e., did not fulfill Figure 1, Practice 6: Leaders from the community), she had over a decade of experience working with diverse students in this community on science research projects.

The 2016-2018 Discoverers Program sessions were held in conjunction with semi-weekly stewardship events led by staff of a local environmental non-profit group, and five biannual (spring and fall) regionally organized stewardship events (e.g., California Coastal Cleanup Day; Figure 1, Practices 1, 2, 5, 6, 7). Key volunteers also frequently engaged in community science activities on their own, independent from organized events. The project scientist, the same scientist as in the 2015 program, and a mid-20s white, female scientist participated in all five of the biannual sessions from 2016-2018, with occasional participation in the semi-weekly events (Figure 1, Practice 4: Work alongside a scientist).

Plastics in Time and Space. Within each of the four canyons, three to nine 30-m long transects were established longitudinally and equidistantly along the canyon floor from the upstream head to the downstream drainage point (total number of transects across all canyons = 25). Each 30-m long transect included the adjacent reach of flood plain, or bank-full width. The average width of each transect ranged from 7.2±0.26 to 8.6±0.5 m, for a range of 216-258 m^2 of surveyed area.

Three types of surveys were conducted to address research questions (Table 1). "Ambient plastics sampling" consisted of surveys of meso-plastic trash (2-50 cm) that were performed in all four canyons during an initial 2014 dry season (n=25 transects; Figure 2). "Rainy plastics sampling" consisted of meso-plastic trash surveys conducted in Swan Canyon throughout the 2014-2015 rainy season (n=7 transects), and again in all canyons after the end of the 2014-2015 rainy season (n=15 transects; Figure 2). Rainy season data from Swan Canyon were summed for a cumulative rainy season total that was comparable to the end of rainy season surveys conducted in the other canyons.

During the 2014-2015 meso-plastics surveys in the four canyons, plastics were collected, sorted, and counted within general use categories (bags and packaging, construction and auto, food and kitchen, home and office, other unidentifiable pieces, outdoor and sports, personal care and health) following rapid trash assessment protocols (SWAMP 2007; Miller-Cassman et al. 2016). The total volume of each general use category was measured at the end of the survey. In the spring and fall of 2016-2018 in Manzanita Canyon, all other types of meso-trash were also collected and sorted by material type (e.g., plastic, metal, wood, natural fiber cloth, paper). Total weight and volume of each material type were measured.

Magnitude of Inputs of All Trash: Manzanita Canyon. "All trash sampling" consisted of surveys conducted in Manzanita Canyon throughout 2016 and 2018 to assess the abundances of all types of meso-trash (e.g., plastic, metal, wood, natural fiber cloth, paper) along three transects (Figure 2) and both meso-trash and large items (>50 cm long) from throughout the whole canyon. Large trash items (e.g., discarded furniture, whole bags of trash) and meso-trash litter were documented and removed from across the whole canyon area throughout 2016-2018 by the project team and community volunteers. Team members and neighbors reported the location, volume, and weight of all material removed, and often provided a general description or qualitative assessment of the types of trash removed during each visit to the canyon. These data were totaled to create assessments of the total amounts of trash removed from within regions of Manzanita Canyon and across the whole canyon over the course of two years.

Trash Data Analyses. Abundances and compositions of all the recorded sizes and categories of trash were summarized using descriptive statistics. All meso-trash abundances (density, volume) were standardized to 200 m^2. Abundance data were $\log_{10}(x+1)$ transformed before analysis, unless otherwise noted, to normalize data and homogenize variances.

Comparisons of plastics abundance before and at the end of rainy season were made using paired t-tests in JMP Pro 12. Comparisons of plastics trash composition before and at the end of rainy season were carried out with multivariate analyses using Primer 7 (Clarke and Gorley 2015), specifically analysis of similarity (ANOSIM) on Bray Curtis similarity indices of standardized, 4^{th} root transformed data to reduce the dominant contributions of abundant items. Analyses of dissimilarities in trash composition found before and at the end of rainy season, and the particular items contributing to those dissimilarities, were carried out using SIMPER.

Results

Participant Zip Codes and Demographics

Of the 190 participants who provided their home zip codes for the 2015 community science program model assessment, most (71%) were from the local community, 10% were from the surrounding city, and 17% were from the surrounding county. Nearly 64% of the 2,589 participants in the 2016-2018 Discoverers Program were from the local community.

Self-identified females made up 67% (133 of 198) of participants in the 2015 community science program model assessment and the rest identified as male. While gender information was not collected from all participants in 2016-2018, 40% of the high-frequency participants identified as female and the rest as male. Adults over the age of 18 made up 28% of participants in 2015 and 42% of participants in 2016-2018.

The self-identified races and ethnicities of individuals who participated in the 2015 community science program model assessment were similar to those in the local community as a whole (Chi square=2.4, df=5, p=0.79; Figure 3). However, a slightly larger percentage of individuals who self-identified as Hispanic/Latino or white, and a smaller percentage of individuals who self-identified as African/African American and Asian/Pacific Islander, as compared with participants overall, attended more than one session (Chi square=14.7, df=5, p=0.01; Figure 3). The racial/ethnic composition of returning participants began to converge with that of the individuals who led the Discoverers Program, who were majority Hispanic/Latino and white (Figure 3). Information on race and ethnicity was only collected from the five 2016-2018 high-frequency participants, who self-identified as white (60%), Hispanic/Latino (20%) and Native American (20%).

Participant Return Rates

The majority of people who participated in the Discoverers Program attended only once (2015: 83%; 2016-2018: 83%). Over half of returning participants were from the local community (2015: 64%; 2016-2018: 58%). Only about 8% of 2015 participants and 4% of 2016-2018 participants attended more than two sessions of the Discoverers Program. In 2016-2018, 3.8% returned 3-5 times and <1% (5 people, all from the neighborhood) participated anywhere between 12-53 times. A total of 33 groups helped to organize volunteers to work in Manzanita Canyon in 2016-2018, including non-profits, community groups, faith-based groups, businesses, K-16 schools and clubs, and the Navy.

The chance to interact with a scientist on the first visit was not associated with increased rates of participation in future sessions. The proportion of returning participants who had the opportunity to interact with the project scientist on their first visit (27%) was similar to the proportion of individuals who returned and had not interacted with the scientist on their first visit (29%) (Chi Square=0.15, p=0.70, n=149).

Motivations for Participating

In response to the question "Why did you choose to come to the session today?" about one-third of participants (n=29) said that they came with a community service, faith-based, or school group, and 10% said they attended as part of a school or club project. Just over one-third of participants cited altruistic reasons for participating in the project, including wanting to help the community or the environment. Nearly half of the participants cited reasons related to personal growth and recreation, including to have fun, be outside or in nature, meet new people, learn about the environment, and get exercise (participants gave one or more responses so responses total >100%). No participant mentioned science or doing science as a reason they came to the initiative.

Motivations underlying participation were not explored in 2016-2018, but the highest volunteer turnout occurred when sessions coincided with organized regional cleanup efforts, such as the annual spring "Creek to Bay Cleanup" and fall "Coastal Cleanup Day," which stress the stewardship aspects of events. Similar to the 2015

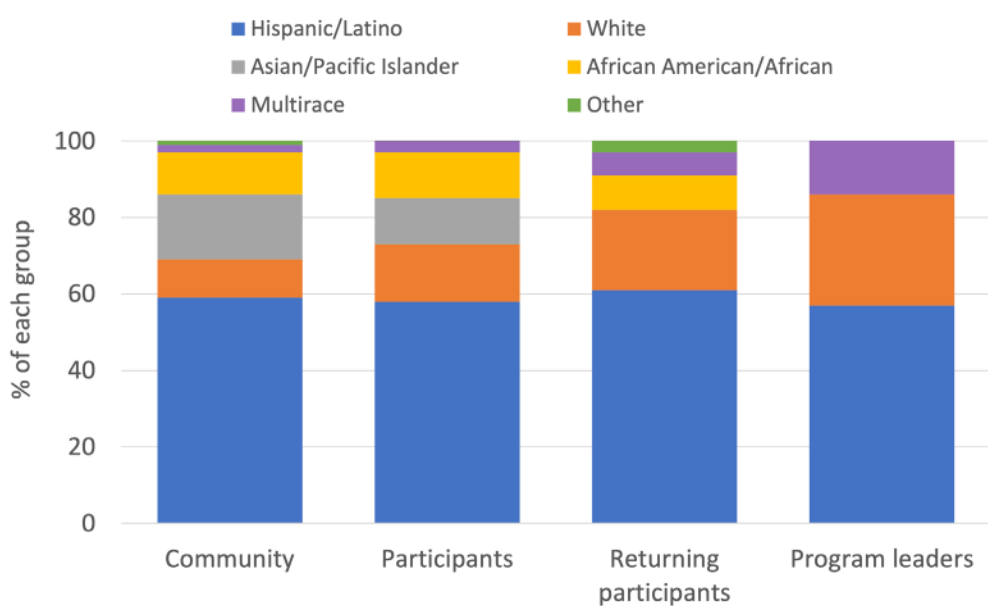

Figure 3. The percent of each self-identified racial and ethnic group comprising the whole community in which the Discoverers Program (the community science project) was conducted, the people who participated at least once, the people who participated two or more times, and the program leaders. N=77,697 people in the community (SANDAG 2015), 198 participants, 33 returning participants, and 7 leaders, respectively. Data are from 2015.

sessions, many attended as members of groups that have educational or philanthropic missions (e.g., K-16 schools, community service or faith-based groups, local businesses). These organizations tended to participate repeatedly even if many of the individual members came only once or twice. Local community activists (the five high-frequency participants and several other neighbors), although few, were effective at motivating and leading many other community volunteers throughout the year at informal events. The community activists participated repeatedly while the volunteers they recruited came once to a few times per year.

Changes in Scientific Understanding and Interest after Participation

There was no change observed in the performance of any age group, or the group as a whole, in correctly indicating on a watershed diagram the direction that water (and therefore trash) flows following participation in a community science session (four answer options with one being the mouth of a watershed; $P \geq 0.10$, paired t-test, $n=125$). When model assessment interviewees ($n=30$) were asked "What question were you investigating today?" just under half (46%) were not able to identify a purpose for the study.

When asked "Do you feel like you learned anything today? If so, what?" the majority (83%) of interviewees ($n=28$) reported that they learned while participating in the Discoverers Program. Over half said they learned about the sources or amounts of trash, water flows, and trash effects on wildlife, the canyon, and/or the ocean. A quarter said that they learned about actions that a person can take to prevent trash from flowing into the watershed and subsequently hurting the environment or animals (e.g., not littering). Just over a third of people reported learning about the impacts that they personally or humans generally have on the environment (participants could give more than one answer, so percentages add up to >100%). No individual reported learning about scientific processes or methods.

On written surveys, participants reported increased interest in conservation or stewardship topics related to the community science experience rather than increased interest in science or the scientific process (Table 2). These changes in interest were reported by individuals across all zip codes, race/ethnicities, genders, and ages.

Drivers of Science Understanding and Interests

Despite explicit and consistent marketing of the initiative as a community science opportunity, over a quarter of the 19 interviewees who were asked whether they felt like they were doing science said they were unsure (11%) or did not think so (16%). Of those who said they felt like they were or might be doing science and who gave a reason, 42% said it was because they were collecting data, one-third said it was because they learned, heard, or were told facts or information, and a quarter said they were or may have been doing science because they were collaborating, measuring, or using science tools (Figure 4).

Of the four individuals who said they were not or might not be doing science and gave a reason, two (50%) said they were picking up trash and/or doing community service, not science; one said that "bringing in the information" [collecting data] was helping science but not necessarily science itself; and one said, "*Because it's different than science. Usually in science I learn different things, like I usually do physical science like with chemicals*" (i.e., the day's activities did not match what the participant usually did in science in school).

Data from the field recordings revealed inconsistency in participants' access to science mentoring during any one session. The project scientist consistently engaged with participants as an equal in the task of collecting trash while simultaneously discussing the logistics of the scientific activity, modeling comfort with the natural environment, and sharing context-related scientific concepts in response to others' experiences or questions. However, the participants in the "scientist groups" had varying exposure to the scientist depending upon physical proximity and levels of sociability, and thus, science mentorship was not consistent across all participants. Further, others outside the scientist group were sometimes exposed to the scientist's knowledge before the day began, during breaks, or while moving around the canyon. Field recordings also revealed that, while the high school-aged project leaders clearly explained the logistical tasks associated with the project to the participants, they tended not to put

Table 2. Changes in individual interest in science and stewardship topics before and after participating in the community science project. Data are number of responses (and percent of all participants who answered that question) from 2015, n=84 surveys/participants. * = P≤0.05, paired t-test. Participants completed the sentence "I am interested in learning more about (please check all that apply):"

Topic	Pre	Post	Change
How the local watershed affects my community	26 (31%)	37 (44%)	+11*
How my community affects the local canyons	30 (36%)	39 (46%)	+9*
How I can help take care of our local canyons	24 (29%)	33 (39%)	+9*
How I can help take better care of the Earth	41 (49%)	49 (58%)	+8
How a watershed works	20 (24%)	28 (33%)	+8
Plants and animals	58 (69%)	64 (76%)	+6
What scientists do in their jobs	23 (27%)	29 (35%)	+6
How science works	29 (35%)	34 (40%)	+5
Science facts	42 (50%)	44 (52%)	+2
Nature	60 (71%)	60 (71%)	---
How I can get involved in community science projects	28 (33%)	28 (33%)	---
How to become a scientist	25 (30%)	20 (24%)	-5
What a watershed is	20 (24%)	14 (17%)	-6

the tasks in the context of the study or science more generally. The project leaders also tended to focus on the project task of collecting and sorting trash and work silently, only occasionally sharing a science fact with participants. This excerpt from a field recording between one of the high school-aged project leaders and a Discoverers Program participant illustrates a general lack of both scientific context and interactive approach in communications that took place during field logistical tasks and, therefore, a lack of an engaged response from the participant.

> Project leader: *Would someone like to help me take the picture? [long pause] Come on over here. [long pause] ... Okay, could you hold this and stand right here. [pause] Hold on. Yeah, that's good. All right, so now we head back. Thank you.*
>
> Participant: *Mm-hmm.*

Recordings further revealed that participants, in general, tended to stay with the groups with which they came, rather than integrating into one single "fieldwork" group. Many individuals, both youth and adults, spoke almost exclusively to members of their own group throughout the day, even when the scientist or educator staff member tried to engage members of the group. The talk among members of these groups was usually non-science related. All of these factors served to limit the numbers of participants who had consistent access to science mentoring during any one session.

Urban Watershed Trash Pollution Dynamics

While the Discoverers Program more strongly fostered environmental stewardship than science understanding and interest in participants, the scientific data collected by participants from 2014-2018 constituted an in-depth look at the inputs and the spatial and temporal distributions of trash pollution in these urban waterways.

Spatial and Annual Dynamics of Plastics Trash in Urban Waterways. Combining the plastic meso-trash data from community science sessions

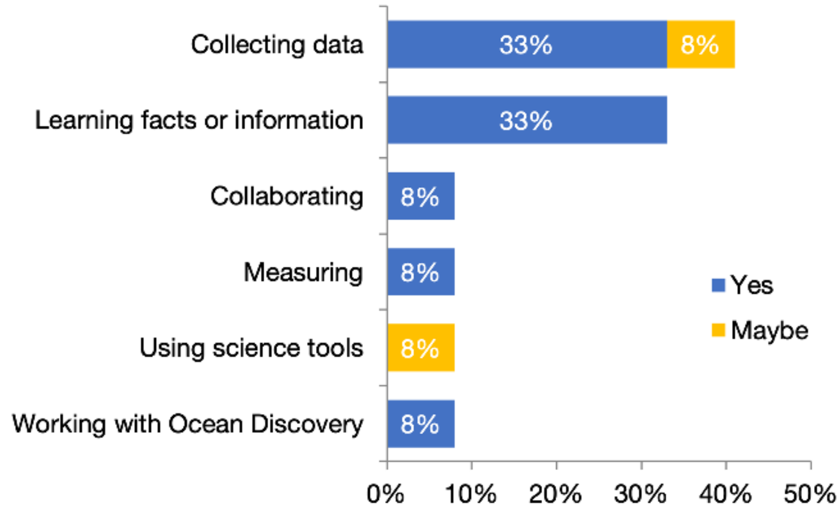

Figure 4. Reasons given by participants who answered "yes" or "maybe" to the question "Did you feel like you were doing science today?" for why they felt that way. Data are from 2015, n=12 interviewees; each person could give more than one reason, so the total is greater than 100%. Ocean Discovery = the community-based science education organization that partnered on this project.

between 2014-2018 revealed that plastic bags, packaging, and wrappers consistently dominated plastics trash across all four neighborhood canyons (Figure 2) and through time, with additional consistent proportions of plastics from food and kitchen items (e.g., single-use cups, plates), and home and office items (e.g., pieces of duct tape, small toys, pens/markers) (Figure 5). Small pieces and fragments also consistently made up 10-25% of all plastic items found across the four canyons (Figure 5).

Rainy Season Plastic Trash Inputs. Ambient plastic meso-trash collected at the start of the study, before rainy season began, represented amounts influenced by dry season inputs (e.g., wind, flows from irrigation runoff), directly deposited litter, and items left behind after previous community trash cleanups. The greatest volumes (and densities) of plastic meso-trash collected pre-rainy season were found at the head region of each of the four canyons. Amounts of trash per 200 m^2 ranged from 95±56 pieces (or 2.4±0.5 L) in Hollywood Canyon to 267±97 pieces (or 31±23 L) in Olivia Canyon (Figure 2).

Roughly 9-10 times greater densities and volumes of plastics flowed into all canyons during the rainy season than were found at ambient levels before the rainy season (Average±1SE across four canyons: 1607±713 vs. 187±36 pieces per 200 m^2 and 106±49 vs. 10±2 L per 200 m^2; paired t-tests $p \leq 0.001$, $t_{14} \geq 6.11$; Figure 6). Total amounts (volume and density) of every category of plastics trash were greater at the end of the rainy season than they were at ambient levels (paired t-tests, $p \leq 0.005$, $t_{14} \geq 3.35$; Figure 6) except for amounts of unidentifiable plastic pieces, which remained similar across time (paired t-test for density and volume both: $p=0.075$, $t_{14}=1.5$).

Composition of plastics in the ambient surveys and at the end of the rainy season remained broadly dominated by bags and packaging across all four canyons (Figure 6), but the individual items differed (ANOSIM Global P=0.001). Trash that flowed in with the rainy season, as compared to ambient trash, contained higher abundances of many items from across the trash categories, including bags and packaging (e.g., single-use grocery bags, trash bags), food and kitchen items (e.g., polystyrene foam pieces and take-out containers, single-use cups and plates, drinking straws and lids, utensils, bottles, caps), household items (e.g., pieces of electrical and duct tape, small plastic toys, ribbons, CDs/DVDs, pens/pencils/markers), personal care items (e.g., cotton swabs, bandages), electronic parts (e.g., cords, phones), synthetic cloth, cigarette butts, and soft and hard plastic pieces. The ambient trash contained higher abundances of take-out and retail bags (whole and pieces),

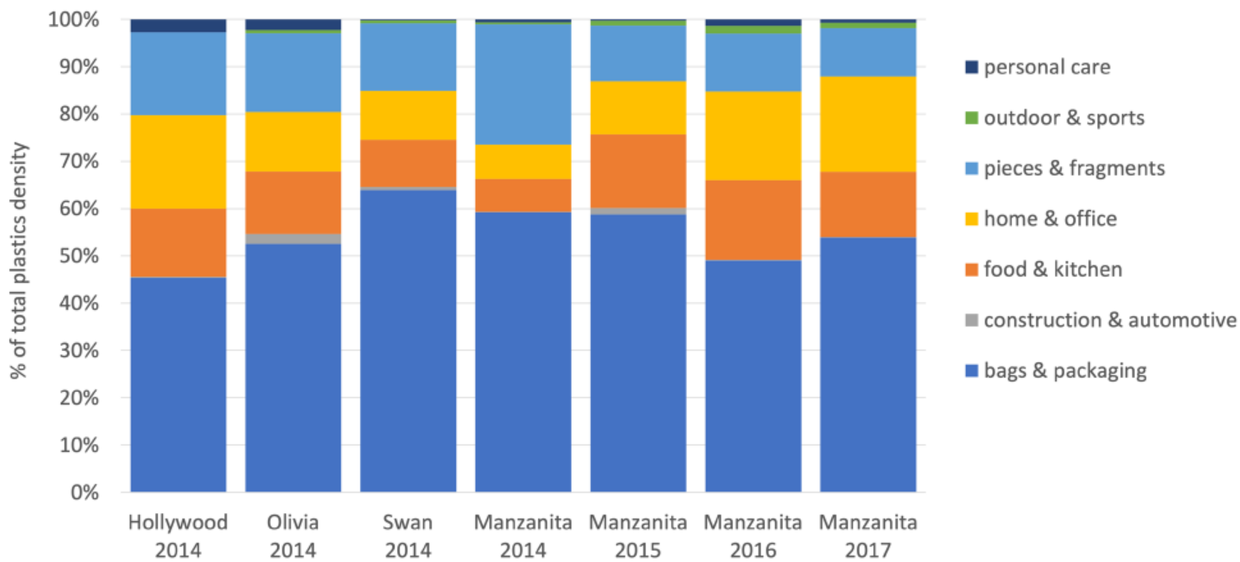

Figure 5. Composition of plastics found in each of the four City Heights canyons in 2014 and through time in Manzanita Canyon, San Diego, California. Data are calculated from total density (# per 200 m^2) of meso-plastics found in each canyon for each year shown.

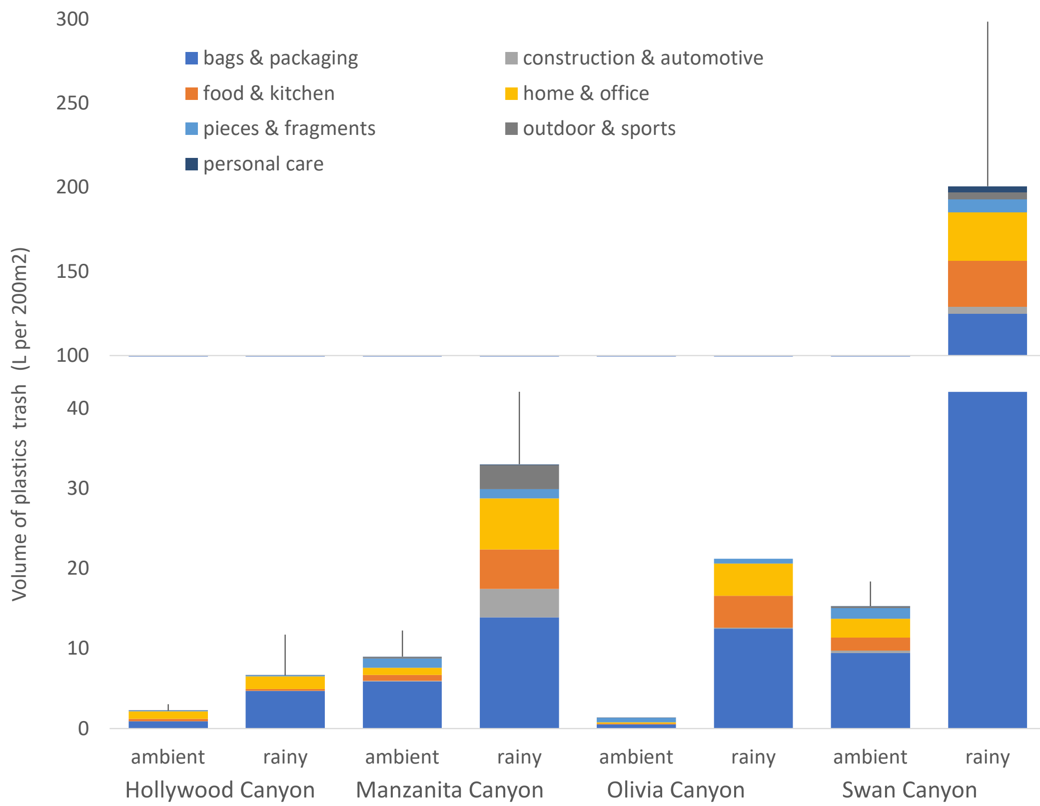

Figure 6. Average volume of plastics trash collected before the start of the 2014-2015 rainy season (ambient) and at the end of rainy season from the four City Heights canyons, San Diego, California, USA. Patterns were similar for trash density so only volume is shown. N=2 transects (200m^2) in Hollywood, 5 in Manzanita, and 1 in Olivia that were sampled before and at the end of rainy season, as well as 7 transects in Swan Canyon that were sampled before and throughout rainy season (average cumulative rainy season totals shown). Error bars are 1 standard error.

six-pack rings, and straw and utensil wrappers (SIMPER, items contributing to 65% of variation between seasons) indicating greater dry season inputs of these items, or lack of removal during cleanup efforts. Abundances of snack wrappers remained similarly high in the ambient and end of rainy season surveys, indicating consistent inputs throughout the year and/or lack of removal during cleanup efforts.

The Magnitude of Inputs of All Trash. Between April 2016 and May 2018, the community recorded and removed a total of 138 m^3 of trash from Manzanita Canyon. This trash weighed a total of 13 mt and included meso-trash items, furniture, engines, tires, camping gear, and whole bags of trash. The community data revealed that the head of Manzanita Canyon and major access trails that run through small side canyons were areas of most frequent and/or highest trash inputs. Data received from the community on the locations, amounts, and types of trash collected from around Manzanita Canyon throughout this time indicated three main inputs of trash to the canyon—encampments of unhoused individuals (e.g., abandoned camping and cooking gear in obscured areas off the canyon floor and in side canyons), illegal dumping (e.g., broken furniture at the canyon ridge and in side canyons where roads and alleys abut the canyon), and storm drain flows (e.g., assortments of meso-trash along the canyon floor downstream of storm pipes).

Despite the variety of items found in Manzanita Canyon, plastics generally dominated the meso-trash and large items that were removed (Figure 7). Fragments of illegally dumped wood and wood-composite furniture and construction materials, as well as metal construction and automotive materials, were also common, especially in the upper reach of Manzanita Canyon (Figure 7). Cloth (e.g., clothing, blankets) was common in spring 2016 in association with recently abandoned camps (Figure 7).

Discussion

Participation in Community Science Does Not Mean Science Understanding or Persistence

The seven practices that made up the initial community science program model (Figure 1) were successful at bolstering environmental stewardship and were somewhat successful at increasing participation and short-term retention of members of the targeted community in the science project, but did not lead to increased learning of science concepts or interest in science.

Effectiveness of Practices for Facilitating Science Entry and Intervention. Well over half of the participants (64-71%) in the Discoverers Program were from the local community, and the races and ethnicities of participants involved in the 2015 sessions were similar to those in the local community as a whole, indicating that the

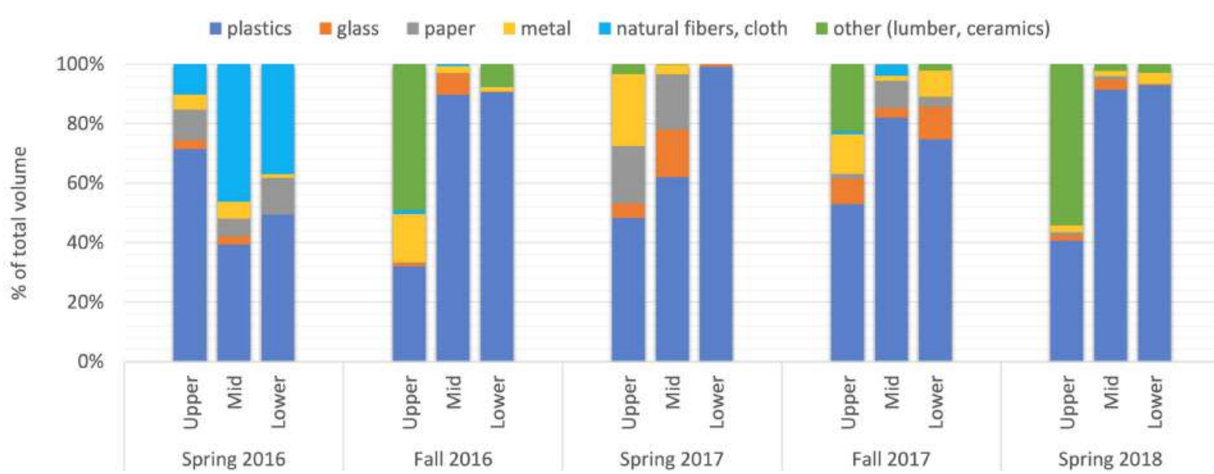

Figure 7. Composition of all meso-trash (by volume) collected biannually along three transects located at the head (upper), mid-reach (mid), and downstream end (lower) of Manzanita Canyon in San Diego, California between April 2016-May 2018. N=1 200 m^2 transect per season and location.

neighborhood-based project likely had equitable accessibility (e.g., the advertising was widespread, the meeting location was walkable; Practice 2). Repeated and ongoing guided opportunities (i.e., staff-guided sessions) helped to engage people (Practices 5 and 7), with nearly one-fifth of people participating two or more times and a few people in 2016-2018 continuing to work on their own between 12-53 times.

The integration of a trash cleanup activity (i.e., a hands-on stewardship activity) with scientific data collection (Practices 1 and 3) may have made the project more meaningful to community members and may have increased community participation and retention as a result. Many project participants surveyed in 2015 reported that they had attended sessions to help the community and/or the environment. Participants' explicit acknowledgment of and interest in affecting positive change in their community and environment indicate that connections to 'bigger picture' science may be more meaningful to potential community scientists (National Research Council 2015) and may be a way to increase participation and investment in STEM activities. Trash pollution may serve as especially poignant subject matter for community science, as it is ubiquitous, generally well understood by the public, and mitigated via relatively accessible actions like cleanups and waste reduction (Sheavly and Register 2007).

Contrary to what was expected based on community science literature (Bell et al. 2003; Sadler et al. 2010), working alongside a scientist (Practice 4) did not influence retention in our project. While the project scientist consistently engaged with participants throughout community science activities, only those nearby or willing to engage were reached and, even then, the sharing of knowledge typically ran unidirectionally from scientist to participant, rather than between the two parties. Further, the high school-aged project leaders from the community (Practice 6) tended to interact with participants infrequently; when leaders did interact with participants, they spent time explaining project logistics, rather than the scientific context and objectives of the project. Because of these dynamics, even participants who worked alongside each other may have had very different science experiences, from no science talk to short amounts of science talk to frequent and rich science-related conversations. This may have limited both the exposure to science concepts and the opportunity to integrate and feel culturally like a part of a science team.

The lack of effect of scientist presence on participant retention may also be partially explained by the fact that the project scientist was not reflective of any underrepresented minority group (Practice 6), which may have limited the meaningfulness and value of the experience of interacting with a scientist for participants (e.g., Bang and Medin 2010; Pandya 2012). The 2015 project leaders reflected the diversity of the community (Practice 6) and may have influenced repeated visits, though this was not directly tested. Integrating project scientists and other STEM professionals who also reflect the diversity of the community into projects as mentors has been shown to improve participation and retention (Pandya 2012). Mentoring by individuals who have received mentorship training, are at varying science career levels, and/or are from within the community have been associated with higher performance, higher grades, and persistence in college and STEM fields, particularly for members of high-need groups (Myers et al. 2010; Stolle-McAllister et al. 2011; Wilson et al. 2012; National Research Council 2015; Pfund et al. 2015).

Strengthening the Science in Community Science. Despite the project's relative success in the engagement and short-term retention of individuals from diverse backgrounds in project activities, it was not as effective at increasing participants' awareness of doing science or science understanding. Participants' understanding of how water (and trash) flows through a watershed did not improve after they had participated in the 2015 sessions, and only about half of those same participants were able to correctly identify an aspect of the project's purpose when they were surveyed following the day's activities. Furthermore, none of the participants who were interviewed in 2015 mentioned science as a motivation for participating in the trash study, and no interviewees reported learning about scientific processes or methods during the project. Some participants did not conceive of the day's activities as participation in a scientific study, despite recruitment materials clearly stating that fact. The largest increases in reported interests after participation in the project related to the focus of the community science experience, but through a conservation or stewardship lens rather than a science lens.

This disconnect between the Discoverers Program and science itself may be related to the participants' ideas about what activities constitute science, and participants' interactions (or lack thereof) with the science team throughout the project. Many of the participants who were interviewed in 2015 defined science as learning, hearing, or being told facts or information, and only a quarter of participants defined science using an aspect of the hands-on, authentic community science activity they had participated in (measuring, collecting data, and/or collaborating with others). Science other than "classroom" science—narrowly defined as learning facts, being told information, or doing experiments—is not a common or core experience in the local schools or community of City Heights, as has long been the case in urban centers (Day and George 1970; Lippman et al. 1996; Barton 2001). Exposure to different types of science, other STEM fields, and the careers and opportunities that are associated with those fields may increase enthusiasm, self-efficacy, and persistence of underrepresented individuals in science (Blotnicky et al. 2018).

The Need for a Science Mindset

Project outcomes revealed that our initial community science program model was lacking elements that made participants want to do science, aware that they were doing science, and/or aware that they were able to do science. Based on these findings, we modified our initial community science program model by creating and adding a new "science mindset" component to the model. The "science mindset" adopts the tenets of the "academic mindset" concept from the fields of psychology and education that emphasizes valuing, recognizing, belonging, and self-efficacy, and has been shown to support and retain underrepresented youth in academia (Farrington et al. 2012). This new science mindset component consists of five elements aimed at strengthening the understanding, participation, and persistence of people from underrepresented groups in science: 1) **recognizing** scientific activity as science, 2) **valuing** scientific activity, 3) feeling a sense of **belonging** within the science community, 4) believing in one's capacity to do science (**self-efficacy**), and 5) **growth mentality** (Figure 8).

Even brief, one-time interventions that emphasize social belonging and both the valuing and recognition of science can have persistent, long-lasting effects on individuals' engagement and perseverance in education (Aronson et al. 2002; Cohen et al. 2006; Hulleman and Harackiewicz 2009; Walton and Cohen 2011; Yeager and Walton 2011). Such interventions or experiences that cultivate a science mindset may similarly lead to increased participation in scientific activities, increased understanding of science, and increased persistence in science which, in turn, may further bolster all five elements of the science mindset through a positive, reinforcing cycle (e.g., Cohen et al. 2006; Oyserman et al. 2006; Yeager and Walton 2011). This project's updated community science program model (Figure 8) incorporates four additional practices shown to contribute to academic mindset growth (explained below). The updated model is meant to serve as a framework for increasing participation and retention of individuals, especially youth, from diverse communities with low levels of science exposure and engagement, in informal STEM activities.

The four specific practices added to the model to bolster science mindsets (Figure 8, Practices 8-11) include designing community science projects that are not only locally based but that have larger-scale or bigger-picture connections ("globally-connected"; Practice 8) to motivate and strengthen participants' sense of belonging and valuing of the activity (Figure 8; National Research Council 2015; Briggs 2016). Being able to use science to make a difference, such as contributing to a discovery or a solution to a problem as occurred in this project, may strengthen people's understanding, self-efficacy, growth mentality, and value of science (e.g., National Research Council 2015; Briggs 2016). For example, throughout 2016-2018, high-frequency participants exhibited growing enthusiasm for and depth of understanding of the science they were contributing to, as evidenced by vast increases in the quantity and quality of data they provided to the project scientists. Although these improvements in data quality and quantity may have been due in part to longer-term communication and relationship building with the project scientists, they were often accompanied by enthusiastic communications about the project results, which pointed to the community's pride and investment in the project. Participants frequently released results about trash abundances and inputs via neighborhood newsletters and Nextdoor.com and gave a presentation to City Council. These actions led to acknowledgments and further action by neighbors, and responses by City officials, including assistance with canyon trash removal and contributing to the creation of the San Diego Homeless Outreach Team.

Adding structured reflections about both personal and scientific experiences in community science activities (Practice 11) may improve participants' recognition that they are doing science while building a growth mentality and sense of self-efficacy through self-reinforcing cycles of belief and behavior (Figure 8; Lew and Schmidt 2011; Yeager and Walton 2011; Wilson et al. 2012; Briggs 2016). More structured interactions over the short- and long-term, among participants and science role models (Practice 10) who are reflective of the diversity of the community, may help to strengthen a sense of belonging, recognition that one is doing science, and self-efficacy (Figure 8). In any one community science session, this may be as simple as integrating all individuals into a single group that works closely with scientists and/or science role models (Practices 9 and 10) to accomplish tasks that require the sharing of expertise among all participants.

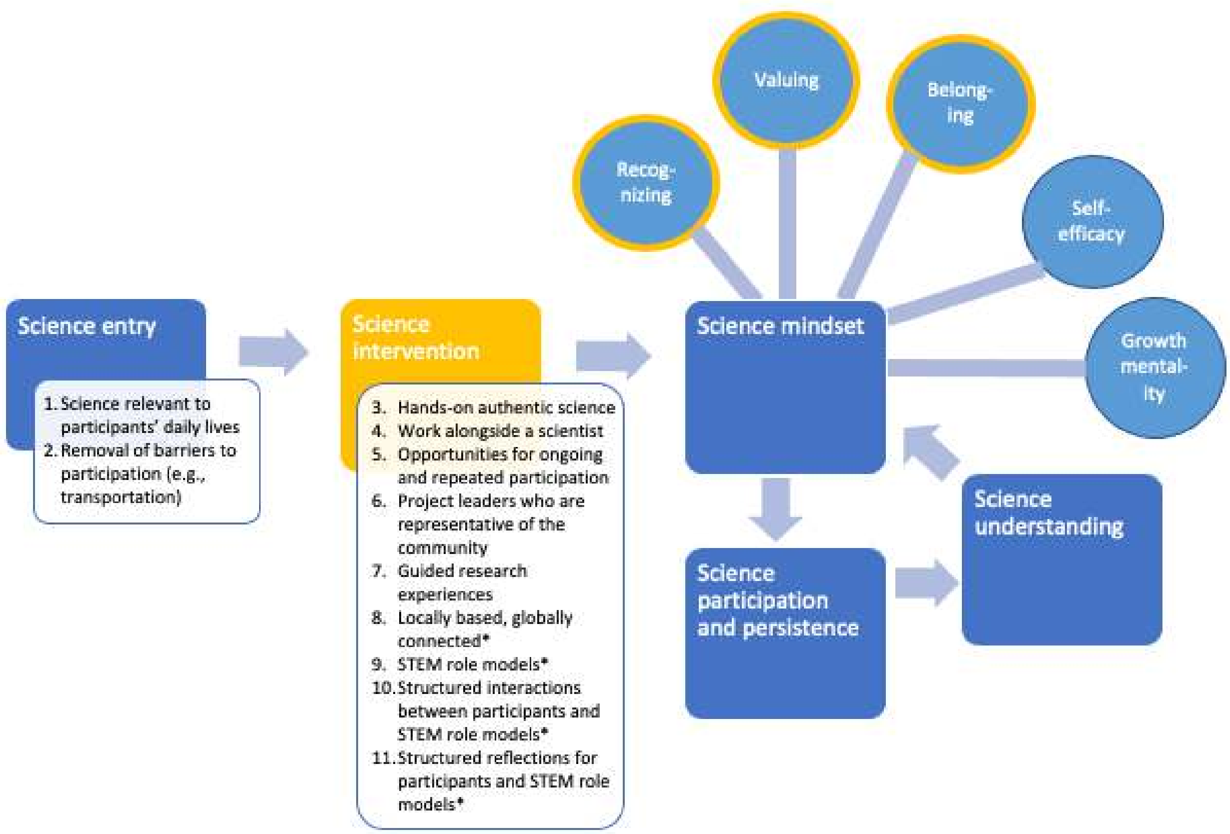

Figure 8. The new community science program model, which maintains all elements of the initial community science program model and adds practices aimed at building a science mindset. *= Practices added to the original conceptual model based on the lessons learned from this study to create this new model. The first three elements of the new science mindset component, which could potentially be achieved in as little as one community science session or intervention, are outlined in yellow.

Limitations of the Community Science Program Model Assessment

While the rate of participation in the model assessment study was very high (95%), not all data were collected from all participants—not all participants completed both the pre- and post-activity written assessments, answered all questions on surveys and assessments, or were selected for interviews. While the data collected across instruments and individuals tell a coherent story, it is possible that the experiences of individuals who were less engaged in the project activity or who were less comfortable speaking or writing in English or Spanish were underrepresented in the data and findings. Further, this study took place in a single community. While the community was selected because of its high levels of cultural, ethnic, and racial diversity, the implementation of the model and its effects may be different in other communities.

Conclusions: From Community Discovery to Environmental Solutions

A diverse STEM workforce holds our best hope of developing innovative, sustainable, scientific, social, and technological solutions to trash pollution and other environmental challenges (Østergaard et al. 2011; Hofstra et al. 2020). Achieving diverse participation in science relies on the widespread use of practices that provide entry points (access) to science and impactful interventions that set into motion the positive feedback loop of scientific learning, engagement, and belonging (i.e., science mindsets) (This study; Yeager and Walton 2011). Community science projects provide both science entry points and meaningful interventions to engage people of all ages in science while addressing environmental challenges. Through the Discoverers Program (the community science project), we were able to gain a better understanding of the trash pollution problem in San Diego's urban canyons that not only serve as green space for the community, but also as the city's stormwater system, channeling street runoff and other trash inputs from mid-city to San Diego Bay. Community members had long been engaged in stewardship activities in City Heights and, before this study, their frequent stewardship and cleanup efforts had kept the canyons clean to some degree, but had not contributed the quantitative information surrounding the magnitude and sources of the problem that often forms the foundation of solutions (e.g., CAW 2017; Reddy and Lau 2020). Through cooperation and collaboration, the community revealed that 138 m^3 of trash weighing 13 mt entered the 1-km long Manzanita Canyon over two years. This volume is equivalent to nearly 50 trash cans (32 gal or 121 L) of trash being removed from the canyon every month for two years. Further, the community data revealed the three main inputs of trash to the canyon—encampments of unhoused individuals, including trash generated from active camps and gear from abandoned camps, illegal dumping of large items and whole bags of trash, and storm drain flows, with the highest abundances of all sorts of items from around the house pulsing into waterways with rains. The community also revealed that plastics, especially small plastic fragments (which are often overlooked during cleanups), and single-use wrappers, bags, and packaging, dominated the trash pollution across locations and through time, a trend mirrored in many ecosystems throughout the region and around the world (Miller-Cassman et al. 2016; SCCWRP 2016; Lebreton et al. 2018; CCC 2019; Ocean Conservancy 2020; Parker 2020; Reddy and Lau 2020; Tiseo 2020).

Despite ongoing trash management efforts (e.g., street sweeping; CSD 2021), the community's data on trash inputs revealed that the amounts of trash entering these canyons still far exceeded the State's goal of eliminating trash flows into state surface waters (CSWRCB 2015). Further, the data provided insights into solutions to trash pollution, including the need to address the sources of trash flows into stormwater (e.g., reduce leakage from waste receptacles, educate the public on use reduction, and better control of wrappers), and reduce illegal dumping (e.g., through improved enforcement, more frequent and better-advertised free furniture and mattress pick-ups, education on the hazards of dumping/benefits of recycling). The prevalence of large trash items revealed by community data, coupled with an emerging awareness of the threats of small plastics that result from the break-down of large items (nanoplastics, microplastics; Moore 2008; Barnes et al. 2009; Rochman et al. 2015) highlight the ultimate solution—keeping trash out of waterways in the first place. By pairing science projects with a social science-based strategy for facilitating diverse participation, such as the model developed in this project, we can empower diverse community members to contribute to, affect, use, and become a part of science, and drive solutions.

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