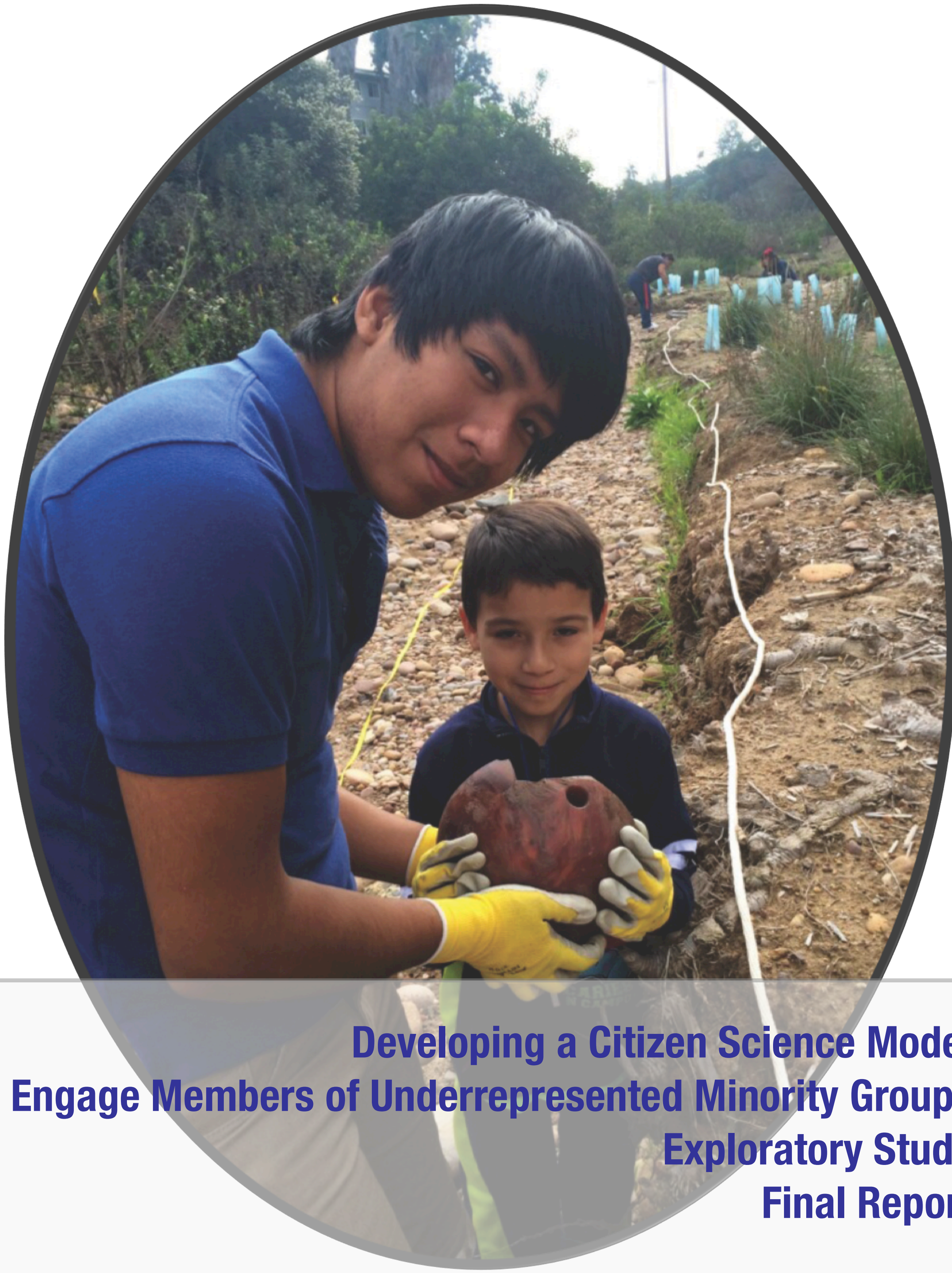

Developing a Citizen Science Model to Engage Members of Underrepresented Minority Groups Exploratory Study Final Report

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Executive Summary

While interest in citizen science as an avenue for increasing scientific engagement and literacy has been increasing, understanding how to effectively engage underrepresented minorities (URMs) in these projects remains a challenge. Based on the research literature on strategies for engaging URMs in STEM activities and the project team's extensive experience working with URMs, the project team developed a citizen science model tailored to URMs that included the following elements: 1) science that is relevant to participants' daily lives, 2) removal of barriers to participation, such as transportation, faced by URMs, 3) hands-on, authentic science, 4) work alongside a scientist, 5) opportunities for repeated and ongoing participation, 6) leaders who are reflective of the community, 7) experiences that are guided as opposed to self-guided.

A citizen science initiative based on this model was developed and piloted in a single, ethnically diverse, low socioeconomic status (SES) community in Southern California with high numbers of URMs between March 2014 and July 2015. The initiative was developed and refined between March 2014 and January 2015 and an exploratory pilot study was conducted to gather data on the potential effects of the initiative between January and July 2015. This report is a summary of findings from the exploratory study, which examined participation, retention, learning of STEM, and interest in STEM during the citizen science initiative.

Based on data from the exploratory study, the citizen science model was successful at increasing participation in science by URMs from the targeted community. Approximately 70% of participants in the initiative were from the local community, and the races and ethnicities of participants across the initiative were similar to those in the local community as a whole. A slightly larger percentage of individuals who self-identified as Hispanic/Latino or white, non-Hispanic and fewer individuals who self-identified as Asian attended more than one session of the initiative as compared with participants overall, a difference that is aligned with the race/ethnicity of the individuals who led the citizen science initiative and was therefore consistent with the model.

The model was very successful at engaging females and young people. Two-thirds of participants in the exploratory study were female; nearly half were under the age of eighteen. An even larger percentage of individuals who attended more than one session of the initiative were female and/or under the age of eighteen.

The majority of individuals reported first hearing about the initiative through their participation in an organization or through their school. More than half the individuals who attended more than one session reported first hearing about the initiative from a friend or family member. Participants in the initiative came with organized groups, with their school, with their families, and individually. Those who first attended with their families or as individuals made up a larger percentage of repeat participants than those who first came to the event with their school or with another organized group.

Interview data suggest that the majority of participants were drawn to the citizen science initiative in order to help or engage with the community or the environment or to have fun. All participants attended one or more of the weekend data collection days in the local canyons; no participant attended an afterschool data entry session in a local building. No participant mentioned doing science as a reason for attending, and those participants who had the opportunity to interact with a scientist during their first visit did not return for a second visit in larger numbers than those who did not have this opportunity.

On average, participants did not demonstrate increased understanding that water flows to the mouth of a watershed after participating in the citizen science initiative, and the majority of those interviewed reported learning about trash in the canyon and/or human impacts on animals or the environment but not scientific processes or methods. Similarly, the topics for which there were the largest increases in reported interest after participation in the initiative related to the focus of the citizen science experience, but through a community service or stewardship lens rather than a science lens. Analyses of interview and field data suggest at least two possible explanations for these findings: participants' ideas about science and interactions during the fieldwork.

In interviews, a number of participants defined science as learning, hearing, or being told facts or information, and only a quarter of those interviewed referred to an aspect of the hands-on, authentic citizen science activity and defined it as science. That 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 the community may partially explain why some participants did not conceive of the field activity as participation in a scientific study, why no participant mentioned science as a reason for attending, why no individual reported learning about scientific processes or methods, and why the largest increases in reported interest after participation related to the focus of the citizen science experience but through a conservation or stewardship lens rather than a science lens.

In addition, while the scientist consistently engaged with others nearby during the fieldwork, the high school aged project leaders tended to work more silently and focus on the project task of collecting and sorting trash, meaning only small numbers of participants had consistent access to science mentoring during the event. In addition, individuals had a tendency to stay with the groups with which they came rather than integrate into a single group, which may have limited both their exposure to the scientist and the opportunity to feel culturally like a part of a science team. While the scientist engaged with the participants as equals in the task of collecting trash, the sharing of knowledge typically ran from scientist to participant, rather than between the two.

These findings suggest that following the model while recruiting through word-of-mouth within the community; focusing on locally familiar aspects of science initiatives such as the environmental and community-based aspects of this study; more explicitly establishing a process for integrating all individuals into a single group that works closely with scientist mentors in order to create a sense of belonging and science identity; and creating opportunities for the sharing of expertise among all participants, including from community members to science mentors, holds great promise for more fully engaging URMs in citizen science initiatives.

Introduction to the Study

Background

Citizen science is the engagement of non-professionals in scientific investigations (Miller-Rushing, Primack, & Bonney, 2012). Citizen science projects vary in the level and type of public engagement, from those where participants primarily contribute data to those where community members and scientists work together to drive the scientific process (Shirk et al., 2012).

Although research and evaluation of the effects of citizen science activity is in the early stages, existing evidence suggests citizen science projects can be productive for both the scientific community and non-scientist participants (Bonney et al., 2009). In the scientific community, such projects can advance scientific knowledge (Cannon, Chamberlain, Toms, Hatchwell, & Gaston, 2005; Cooper, Hochachka, Butler, & Dhondt, 2005; Theobald et al., 2015), allow data to be collected inexpensively and over large geographic areas (Boyle, 2012; Sauermann & Franzoni, 2015; Theobald et al., 2015), and provide data that can be used to influence practice and policy (Ballard & Belsky, 2010; Foster-Smith & Evans, 2003; Gregory et al., 2005; Shirk et al., 2012). In volunteer participants, such projects can build scientific literacy and decision-making skills (Ballard & Belsky, 2010; Butler & MacGregor, 2003; Evans, Abrams, Reitsma, Roux, Salmonson, & Marra, 2005; Trumbull, Bonney, Bascom, & Cabral, 2000), increase engagement in scientific activities (Brossard, Lewenstein, & Bonney, 2005; Cooper, Dickinson, Phillips, & Bonney, 2007; Evans et al., 2005), and develop capacities such as environmental awareness and stewardship (Butler & MacGregor, 2003; Evans & Birchenough, 2001; Evans et al., 2005; Jordan, Gray, Howe, Brooks, & Ehrenfeld, 2011).

While interest in citizen science as an avenue for increasing scientific engagement and literacy has been increasing (Bonney, Phillips, Ballard, & Enck, 2016; Conrad & Hilchey, 2011; Theobald et al., 2015), understanding how to effectively engage underrepresented minorities (URMs) – here defined as individuals of color and individuals from low socioeconomic status (SES) communities – in these projects remains a challenge (Miller-Rushing, 2013; Pandya, 2012).

Members of URM groups are less engaged in STEM broadly (Evans et al., 2005; Trumbull et al., 2000), less likely to demonstrate proficiency on standardized tests of science knowledge in school (National Center for Education Statistics, 2012), less likely to pursue and persist in STEM degrees (National Academy of Sciences, National Academy of Engineering, Institute of Medicine, 2010) and less likely to hold jobs in STEM fields (National Science Foundation, 2015). There have been repeated calls to find ways to better engage URMs in STEM fields in order to promote equity and sustain the position of the United States as a leader in innovation and in the global economy (Committee on Equal Opportunities in Science and Engineering, 2015; National Academy of Sciences, National Academy of Engineering, Institute of Medicine, 2010), including through citizen science initiatives (Evans et al., 2005; Miller-Rushing, 2013; Pandya, 2012).

Despite a lack of a robust understanding within the field of how to effectively engage URMs in citizen science, the literature on engaging URMs in STEM and on citizen science initiatives suggest a number of promising best practices for developing citizen science programs specifically tailored to URMs. Programs that combine hands-on authentic science experiences and work alongside scientists, that provide ongoing experiences, and that incorporate the priorities of high-need communities and program leaders that match the demographics of the community are associated with increases in participants' knowledge, skills, interest, and persistence in science and interest in science careers (Bang & Medin, 2010; Bell, Blair, Crawford, & Lederman, 2003; Dee, 2004; Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Harrison, Dunbar, Ratmansky, Boyd, & Lopatto, 2011; Lauver, Little, & Weiss, 2004; Sadler, Burgin, McKinney, & Ponjuan, 2009; Wu & Van Egeren, 2010).

Based on this research literature and past work with URMs in other science initiatives, the project team developed a citizen science model specifically tailored to URMs and implemented it in a community with high numbers of URMs.

Goals of the project

The goals of the project were threefold: 1) to provide opportunities for individuals in the targeted community to engage with science, 2) to contribute to the scientific knowledge about the accumulation and movement of trash into and through urban canyons (the topic of the citizen science study selected for the project), and 3) to better understand the citizen science model's impact on levels of participation, retention, learning, and interest in STEM for URMs.

This report is a summary of findings from 3), an exploratory pilot study of the citizen science model.

The Citizen Science Model

Model elements and theory of action

As seen in Figure 1, below, the citizen science model included the following elements derived from the research literature: 1) science that is relevant to participants' daily lives, 2) removal of barriers to participation, such as transportation, faced by URMs, 3) hands-on, authentic science, 4) work alongside a scientist, 5) opportunities for repeated and ongoing participation, 6) leaders who are reflective of the community, 7) experiences that are guided as opposed to self-guided.

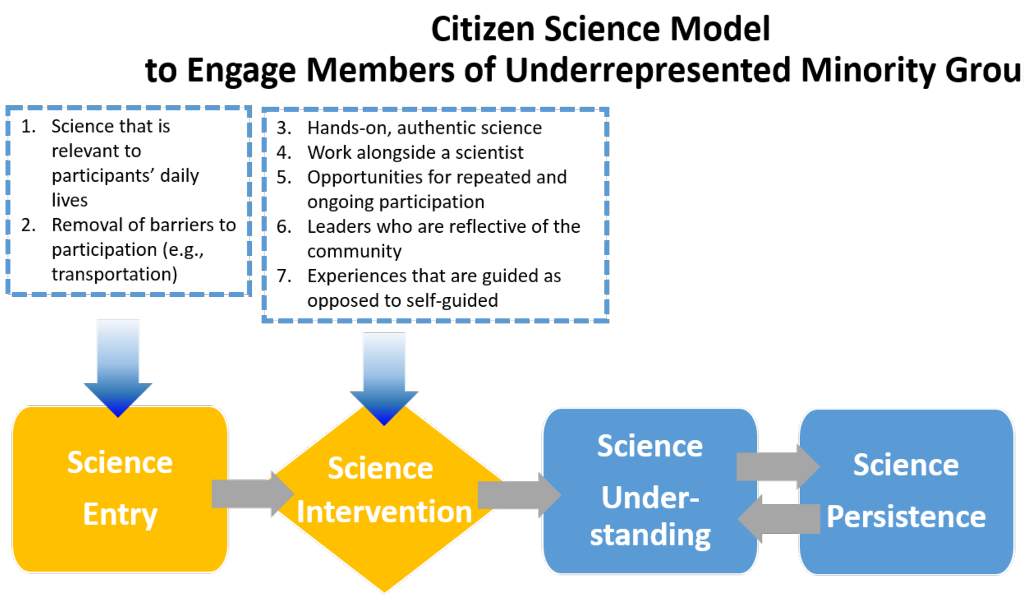

Figure 1. The citizen science model and associated theory of action.

Our theory of action posited that designing citizen science initiatives with the seven elements would provide access and motivation for members of URM groups to engage in citizen science research in their communities in personally and culturally relevant ways. This access and motivation would lead to participation in citizen science initiatives based on the model, which in turn would build understanding of science concepts and processes in familiar contexts. This understanding of science concepts and processes, paired with consistent opportunities to participate in science research in the community, would lead to return visits and individuals' increased understanding of science concepts and processes over time.

Implementation of the Model

Audience

In order to conduct the exploratory pilot study, a citizen science initiative, developed based on the citizen science model, was implemented in a single, ethnically diverse, low SES community with high numbers of URMs.

The target community as a whole at the time of implementation was racially and ethnically diverse, with 59% of residents identifying as Hispanic/Latino; 17% as Asian/Pacific Islander; 11% as black; 10% as white, non-Hispanic; 2% as multi-race; and 1% as other.[1] On average, individuals in the target community experienced high levels of poverty and low levels of STEM engagement. More than 99% of students in the target community were eligible for federal free lunch programs.[2] Nearly 80% of high school students tested "below proficient" on state tests in science and nearly 90% tested below proficient in mathematics.[3]

The citizen science topic

The topic for the citizen science initiative was to understand the accumulation of trash in and movement of trash through a series of interconnected urban canyons in the community where the pilot took place, using protocols developed in partnership with the Southern California Coastal Water Research Project (SCCWRP).

The topic was selected because reducing trash in the canyons was an existing priority for the community. Residents, community-based organizations, and civic leaders had been working together to conduct cleanups and work toward sustainable solutions to improve and steward the canyons for more than five years, with more than 5,000 residents involved in these efforts, but no group had previously engaged the community in organized scientific activity toward this goal.

The citizen science initiative

The citizen science initiative took place during out-of-school time, two days a week, with each session designed to last between two and three hours. Sessions took place in one of four local canyons that were within walking distance from multiple sites within the community and in a vacant apartment, owned by a local informal science education (ISE) organization and converted into a modest field station that was centrally located in the community and adjacent to the canyon sites.

[1] Source: SANDAG, Current Estimates: January 1, 2015. Calculated at www.sandag.org.
[2] Source: Gary Petill, Food Service Director San Diego Unified School District, personal communication, February 13, 2012.
[3] Source: California Department of Education, STAR 2013 CST Summary, September 9, 2013.

Participants of all ages[4] were invited to attend as many or as few sessions of the citizen science initiative as they chose and to join the project at any time. The initiative was advertised through multiple channels including flyers posted in the neighborhood, articles in school newsletters, postings on social media, phone calls to local organizations and partners, presentations at local parent meetings, tables at community events, and notification of current and former members of the local ISE organization's other programs.

Each session of the program was led by an educator from the ISE organization, two members of a team of four high school project leaders from the community, and a project scientist when present. The educators from the ISE organization had extensive experience working with URMs from the local community. The project leaders were high school students from the community, were representative of the cultural/ethnic diversity in the community, and spoke the three most common languages in the community (English, Spanish, and Vietnamese). The project scientist, a coastal ecologist with more than a decade of experience working with URMs, participated in two sessions of the program per month.

Each session began in the apartment near the canyons with a brief (15-20 minute long) introduction to the day. This portion of the program included self-introductions by all program leaders and participants and a brief didactic introduction to the science research project, with visual aids, led by the project leaders. The introduction included what a watershed is, the impact of trash locally and downstream, and an overview of the science research project. This included a brief description of the goal of the research, results to date, specific questions that would be addressed in that session, methods, how the data would be analyzed, and what might be learned from the work.

Depending on the day, the group then walked to a local canyon and began data collection or stayed in the apartment and began data entry, with either option lasting for a period of one to two hours.

Data collection sessions were offered every Saturday morning[5] during the seven-month period of the exploratory study. These took place in one of four local canyons, all accessible by foot from the apartment where the introduction to the day took place. Participants worked in small groups, sometimes with a scientist, to collect and catalog trash in particular transects (designated sections) that were set up in the canyon. Project leaders assisted with logistics during the field days including leading the collection, sorting, and cataloging of trash with a particular small group each week.

Data entry sessions were offered every Wednesday afternoon[6] during a four-month period during the exploratory pilot study, from March through June 2015. In these sessions, participants were to enter the amount and type of trash collected from the field days into spreadsheets so these data could be analyzed, visualized, and shared.

[4] Individuals under the age of twelve were required to attend with an adult.
[5] Three Saturday sessions were canceled due to rain, holidays, or special events.
[6] One Wednesday session was canceled due to a special event.

Each session concluded with a brief (10-15 minute long) wrap-up in the apartment. This portion of the session included an opportunity for participants to ask questions about the day's activities and share their observations, and a didactic presentation of stewardship actions that could be taken, an overview of how the data collected would be used, and an invitation to attend a future session of the initiative.

Following each session, participants received a 'thank-you' email with a photo from the day and invitation to participate in a future session.

Training of the project leaders

Each of the four high-school aged project leaders completed a twelve-hour training program, consisting of one three-hour long session each week for four weeks. During the training program, the project leaders worked with different members of the project team to understand the citizen science research topic, develop leadership skills, and prepare for the exploratory pilot study. Activities included reviewing the citizen science research plan, practicing data collection and categorization methods in the field, becoming familiar with protocols for data analysis, practicing describing the research project to others for recruitment purposes, practicing leading groups of community members in conducting the research, and becoming familiar with the exploratory study research plan and associated logistics.

Following this initial training, the project leaders continued to meet weekly with one of the ISE educators throughout the exploratory study to build their leadership skills, gain experience with data analysis and dissemination of results, address concerns related to the implementation of protocols, and inform recruitment strategies.

Refinement of the citizen science initiative

The citizen science session format was piloted and refined three times prior to the exploratory study: through an in-house trial, through a "friends and family" day, and through a community trial.

In-house trial

An "in-house" trial was conducted with thirty-three middle school-aged young people from the target community who were already engaged in the ISE organization's programs. During the in-house trial, the middle school-aged individuals, led by high school-aged project leaders who were also involved in the organization's programs, participated in all aspects of the citizen science initiative over the course of nine three-hour long sessions.

In this trial, the majority of the trash found in the canyons was plastic. The data sheets for the citizen science initiative were found to be cumbersome and difficult to manage in the field because of the number of classification categories. The project leaders were effective in leading groups of three to five other individuals in data collection but struggled to facilitate logistics such as getting groups to the right location and assigning sectors of the transect for each group to work on.

Based on these findings, the data collection instruments were simplified and streamlined to focus only on plastic and the project leaders were assigned more clear and specific roles especially in terms of the project logistics.

Friends and family day

To test the modifications to the research tools and protocols made in response to the in-house trial, a single three-hour long "friends and family" data collection session in one of the local canyons was held with the friends and family of the ISE organization's program participants.

In this trial, it was determined that the newly refined research tools and protocols were successful at orienting new groups of individuals to the research methods without overwhelming them, enabling them to meet the daily research goal.

Community trial

To ensure the citizen science study would meet the needs of a wide range of members of the target community, three[7] data collection sessions were held in a local canyon using the revised tools and protocols after the completion of the friends and family day but before the start of the exploratory pilot study. These sessions were open to participants of all ages.

The recruitment strategy for the community trial was based on practices, such as targeting community-based high school clubs and service-oriented groups, that were successful in programs that engaged the same target audience but in large, periodic community restoration and cleanup events. These strategies were not as effective in recruiting individuals for smaller, more regular programming that did not specifically focus on community service. The project team also noted a lack of engagement by participants during the project introduction.

Based on these findings, a visual concept map showing the scientific process with diagrams and pictures of community members completing different stages of the process was created and integrated into the introduction as a way to describe the research process. A movable marker was included to allow the project team to indicate the specific area of focus for each day.

The members of the project team from the ISE organization also held a meeting with their Family Advisory Committee, composed of individuals from the community, to get feedback and suggestions for additional recruitment strategies. Based on the Committee's suggestions, the recruitment strategy was adjusted to more strongly highlight the connection between the citizen science research and areas of existing interest in the community such as participation in cleanups, giving back to the community, spending time with family, and spending time in nature while maintaining clarity that this was a community science project. Recruitment efforts were broadened to include venues such as tables at community events and phone calls through school-based systems.

[7] A fourth session was scheduled but canceled due to rain.

Exploratory study

The citizen science initiative, with the changes outlined above incorporated, was piloted in a single, ethnically diverse, low SES community in Southern California for seven months, from January through July 2015. During this time, the exploratory pilot study was conducted to better understand the citizen science model's impact on levels of participation, retention, learning, and interest in STEM for URMs. The remainder of this report describes the methods employed and findings from that exploratory study.

Research Methodology

Study participants

All individuals ages eight and older who participated in the citizen science initiative during the seven-month period from January through July 2015 were invited to participate in an exploratory study of the impacts of the citizen science model on URMs. Of the 215 individuals who participated in the initiative during this period, 208 met the minimum age requirements. Of these 208, 95% (198) chose to participate in the exploratory study.

Research questions

The study was guided by the following research questions:

1. What are the levels of participation and retention of URMs in the citizen science initiative?
2. Is the citizen science initiative associated with URMs' learning of STEM principles?
3. Is the citizen science initiative associated with URMs' increased interest in STEM topics and activities?

   For each of the above questions, we asked:
   - Are these effects different for different individuals?
   - What factors contribute to these effects?

Data collection

In order to answer the research questions, the project team collected five forms of data from participants over a seven-month period, before, during, and after they engaged in sessions of the citizen science initiative: tracking data (RQ#1), written surveys (RQ#1), written assessments (RQ#2, RQ#3), individual interviews (RQ#1, RQ#2), and field data (RQ#1, RQ#2, RQ#3), as described in detail below:

Tracking data

The project team counted and recorded the number of individuals who attended each session for all individuals across all sessions. In addition, each participant in the exploratory study was assigned a study ID that was used to track attendance over time.

Written surveys

All individuals who consented to participate in the exploratory study were invited to complete a short (one-page) written survey at the beginning of the first session they attended. The survey asked the individual for demographic information (zip code or school, age range or grade level, gender, and race/ethnicity) as well as how he or she heard about the initiative. All 198 participants in the exploratory study completed this written survey.

Written assessments

All individuals who consented to participate in the exploratory study were invited to complete a short (two-page/four-question) written assessment at the beginning and conclusion of the first session of the initiative they attended. The assessment included an illustrated question about the direction water flows in a watershed, two text-based questions about science or the scientific method, and a survey question about the participant's interest in particular conservation and science topics. The assessment questions were similar but not identical in the pre- and post- condition to prevent participants from remembering their answers. The survey question was identical in both conditions. Of the 198 individuals in the exploratory study, 125 (63%) completed both the pre and post assessments.

Individual interviews

A subset of English- and Spanish-speaking individuals who consented to participate in the exploratory study were invited to complete a single, short (ten minute) individual interview[8] at the conclusion of one session of the initiative. Interviews were audio recorded with participants' knowledge and consent. Whenever possible, interview participants were chosen based on their residency in the local community or a socio-economically similar community. Interviews were conducted on nine different days over a five-month period, between March and July 2015. The interview included questions about the day's activity, the participant's experience and learning during the activity, and reasons for attending. The interviewer did not attend the session in order to reduce the likelihood that participants would develop differing levels of relationship with the interviewer or would give answers designed to please the interviewer. A Spanish interpreter was made available to those participants who were more comfortable speaking in Spanish. Thirty-two individuals and families completed individual interviews.

Field data

A subset of individuals who consented to participate in the exploratory study were invited to wear an audio recorder around their neck during one of the fieldwork sessions in which they participated. Whenever possible, these individuals were chosen based on their residency in the local community or a socio-economically similar community. Participants nearby but without recorders around their neck had also volunteered to participate in the exploratory study and were aware of and consented to the use of the recorders. The audio recorders picked up conversations involving the participant wearing the recorder as well as conversation and sounds that were audible nearby. Audio recordings were used to track patterns of interaction between participants and determine the type and frequency of science talk during the sessions. Sixty-four unique individuals, including the six project leaders, elected to wear a recorder.

[8] In three cases, multiple family members were interviewed together.

Data analysis

Members of the project team entered and analyzed the data collected using a variety of methods, as described below. For each type of data analyzed, we looked for trends overall and differences by factors such as race/ethnicity, age range, and gender.

Tracking data

We used the tracking data to calculate the percentage of individuals in the citizen science initiative who participated in the exploratory study.

Written surveys

We entered the data from the written surveys into an Excel spreadsheet and calculated descriptive statistics for the group overall and the group of individuals who participated in more than one session for each question on the survey.

Written assessments

We entered the data from the written assessments into an Excel spreadsheet and used descriptive and inferential statistics to identify differences associated with participation in the initiative for each question on the assessment using data for individuals for whom we had both pre and post data for that particular question. We did not use the two text-based pilot questions in the analysis because of concerns about reliability and validity.

Individual interviews

The individual interviews were transcribed verbatim and analyzed using both directed and conventional content analysis. Transcripts were coded for participants' reasons for attending the initiative; what they got out of or learned through the initiative; what surprised them during the initiative; their satisfaction with the experience; their understanding of various aspects of the citizen science study; and their conceptions of science. All interviews were used in the analysis.

Field data

We reviewed portions of all the field recordings and subsequently analyzed all audio files for three sessions, two with a scientist present and one without, using conventional content analysis. The three sessions included audio data from twelve unique participants on a total of sixteen different recordings. Field sessions and therefore audio recordings for those three sessions lasted between one and two hours each, for a total of twenty-two hours of audio. The twelve participants included one scientist; three program staff/project leaders; and nine adult, youth, and child participants from within and outside the community.

We chose the last three sessions of the initiative that did not include school groups in order to compare sessions with and without the scientist, and in order to examine "best possible" examples in which project leaders and program staff were experienced in leading the project activities and there were multiple audio recordings available within the same groups. We excluded school groups from consideration because sessions with school groups turned out to be atypical, and no participant who first attended with a school group returned for a second session.

Findings from these analyses are described in the pages that follow.

Findings

Findings related to the three research questions (participation and retention, learning of STEM, and interest in STEM) are presented below.

1. Where were the participants from?

✜ The majority of participants in the citizen science initiative were from the local community.

Of the individuals who participated in the exploratory study, 96% (190 of 198) told us their permanent zip code. As shown in Figure 2, below, 71% of participants (134 of 190) were from the local community. An additional 10% (19) came from the surrounding city, 17% (33) from the surrounding county, 1% (2) from elsewhere in the state, and 1% (2) from elsewhere in the United States.

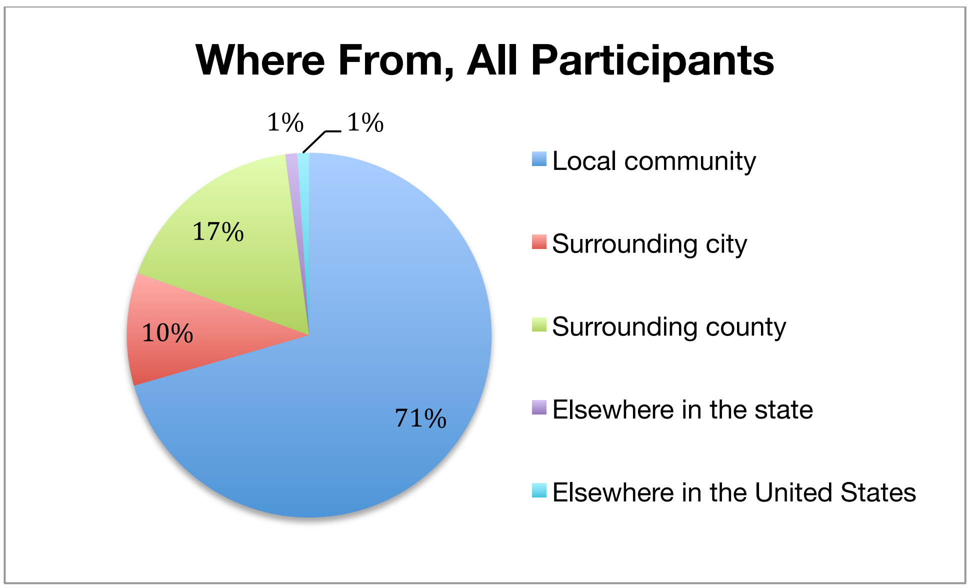

Figure 2. Origins of participants, all exploratory study participants (n=190).

Of those individuals who provided their permanent zip codes, 17% (33) came to more than one session of the citizen science initiative. As shown in Figure 2 on the following page, 64% of returning participants (21 of 33) were also from the local community. An additional 24% (8) came from the surrounding city, and 12% (4) came from the surrounding county. No returning participants came from elsewhere in the state or from elsewhere in the United States.

Of the thirty-three returning participants, just under half (15, or 45%) attended more than two sessions of the citizen science initiative. The origins of those who returned for more than two sessions were nearly identical to those displayed in Figure 3.

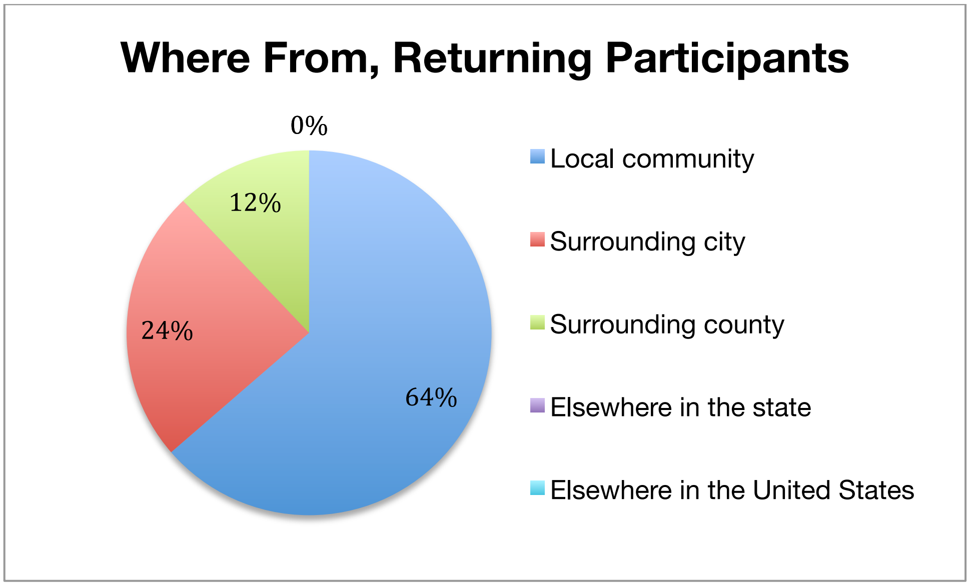

Figure 3. Origins of participants, returning participants (n=33).

2. What was the racial and ethnic background of the participants?

❖ The races and ethnicities of individuals who participated in the citizen science initiative were similar to those in the local community as a whole. A slightly larger percentage of individuals who self-identified as Hispanic/Latino or white, non-Hispanic and fewer individuals who self-identified as Asian attended more than one session of the initiative as compared with participants overall.

All individuals who participated in the exploratory study self-identified by race or ethnicity. As shown in Figure 4 on the following page, 58% of participants (114 of 198) self-identified as Hispanic/Latino or Mexican American, 15% (29) as white, non-Hispanic, 12% (23) as Asian/Pacific Islander[9], 7% (14) as African American, 5% (9) as African, 3% (6) as multi-race, and 2% (3) as other.

These percentages are similar to those in the local community as a whole at the time of the study, as shown in Figure 5 on the following page: 59% Hispanic/Latino, 10% white, non-Hispanic, 17% Asian/Pacific Islander, 11% black, 2% multi-race, and 1% other[10].

[9] This includes individuals who self-identified as Cambodian, Chinese, Hmong, Karen, Filipino, Lao, and Vietnamese.
[10] Source: SANDAG, Current Estimates: January 1, 2015. Calculated at www.sandag.org.

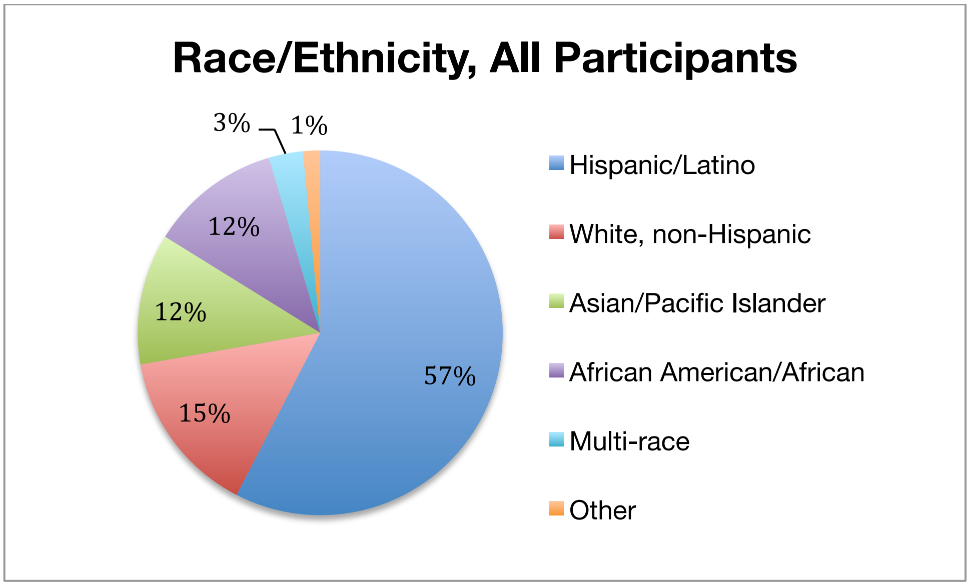

Figure 4. Race/ethnicity of participants, all exploratory study participants (n=198).

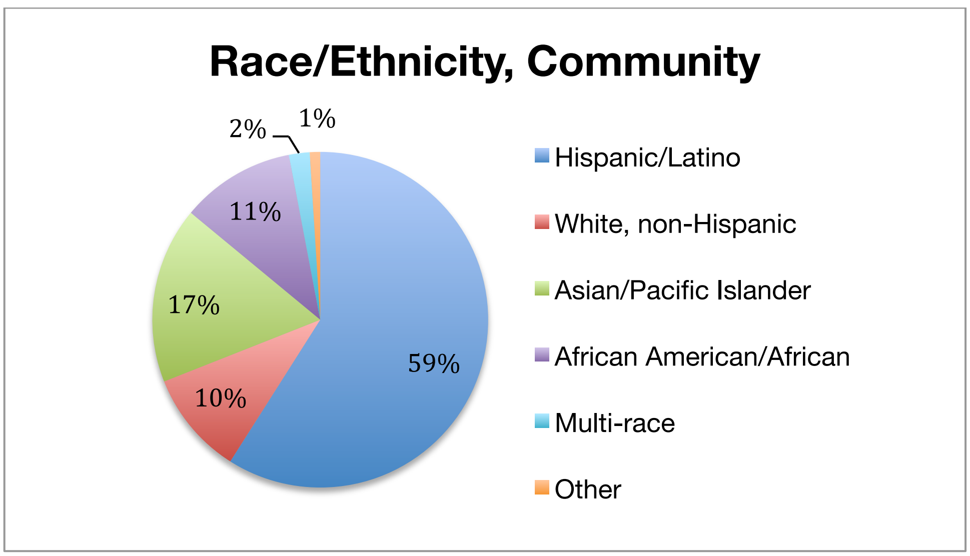

Figure 5. Race/ethnicity estimates for the target community, 2015 (n=77,697).[11]

The individuals who came to more that one session included higher percentages of individuals who self-identified as Hispanic/Latino or white, non-Hispanic and lower percentages of individuals who self-identified as Asian as compared with the participants in the exploratory study overall. As shown in Figure 6 on the following page, 61% of returning participants (20 of 33) self-identified as Hispanic/Latino or Mexican American, 21% (7) as white, non-Hispanic, 9% (3) as African, 6% (2) as multi-race, and 3% (1) as other. No returning participant self-identified as Asian/Pacific Islander or African American.

[11] Source: SANDAG, Current Estimates: January 1, 2015. Calculated at www.sandag.org.

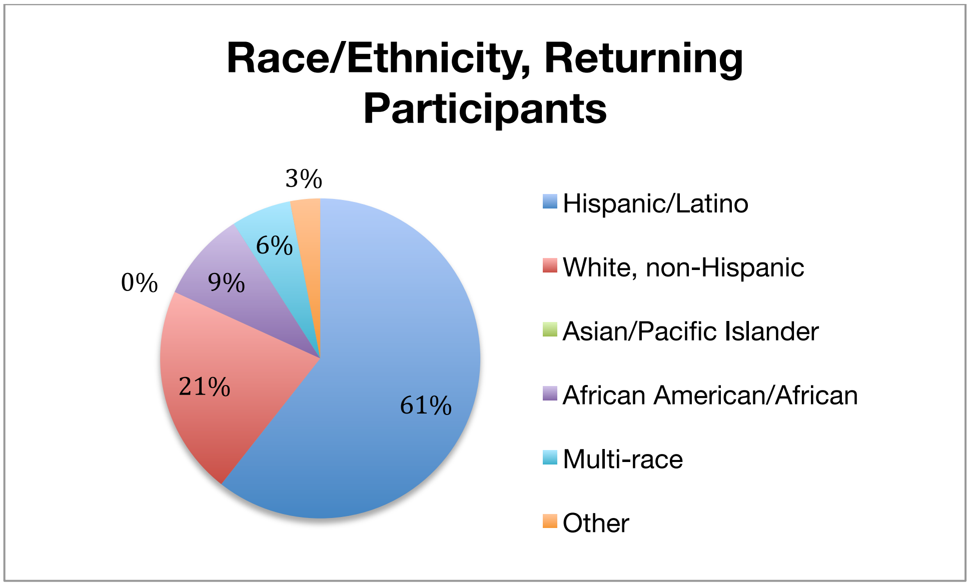

Figure 6. Race/ethnicity of participants, returning participants (n=33).

The differences between the individuals who came to more than one session as compared to those who came to a single session – the group of returning participants had higher percentages of individuals who self-identified as Hispanic/Latino or white, non-Hispanic and no individuals who self-identified as Asian– were aligned with the race/ethnicity of the individuals who led the citizen science initiative and who interacted with participants in the field, as shown in Figure 7, below.

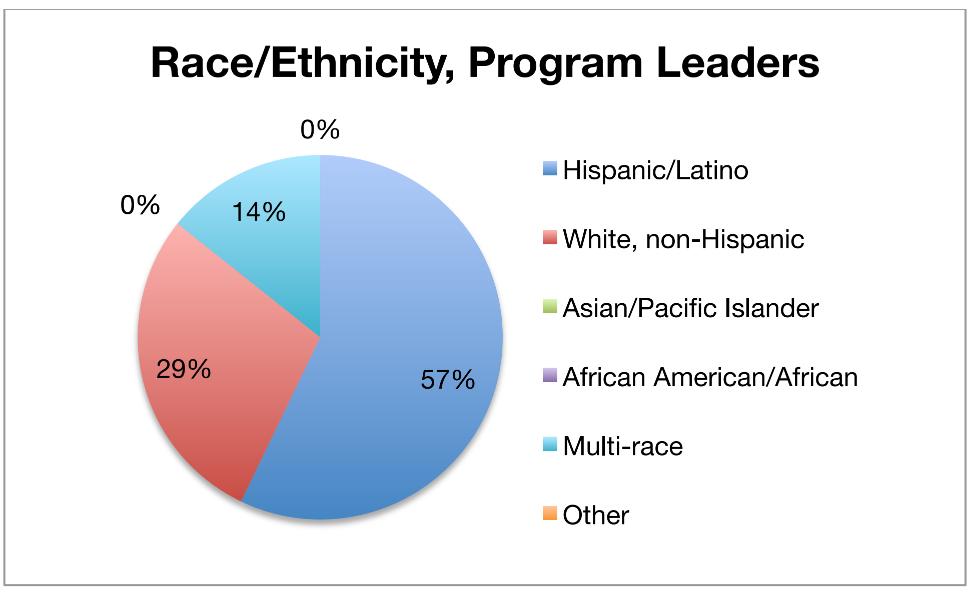

Figure 7. Race/ethnicity of citizen science initiative program leaders (n=7).

3. What were the genders and ages of the participants?

✜ The majority of participants in the exploratory study were female, and nearly half of participants were under the age of eighteen. A larger percentage of females than males attended more than one session of the initiative.

All individuals who participated in the exploratory study self-identified by gender and age range. Thirty-three percent of study participants (65 of 198) were male and 67% (133 of 198) were female, with participating members of both genders across age groups.

As shown in Figure 8, below, adults over the age of 18 made up 28% of participants overall, with 12 males (6%) and 44 females (22%). Youth ages 13-17 made up 25% of participants overall, with 21 males (11%) and 29 females (15%). Children ages 12 and under made up 46% of participants overall, with 32 males (16%) and 60 females (30%).

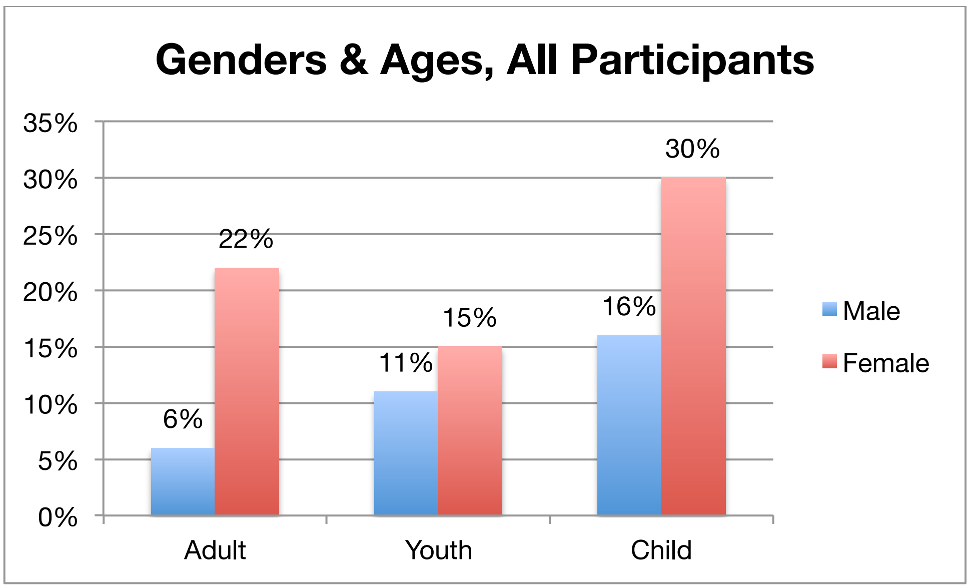

Figure 8. Genders and ages of participants, all exploratory study participants (n=198).

As shown in Figure 9 on the following page, the individuals who came to more than one session included higher percentages of female youth and lower percentages of male adults and male youth when compared with the participants in the exploratory study overall. Among returning participants, 21% (7 of 33) were male and 79% (26 of 33) were female. Adults over the age of 18 made up 21% of returning participants overall, with no males (0%) and 7 females (21%). Youth ages 13-17 made up 33% of returning participants overall, with 2 males (6%) and 9 females (27%). Children ages 12 and under made up 45% of returning participants overall, with 5 males (15%) and 10 females (30%).

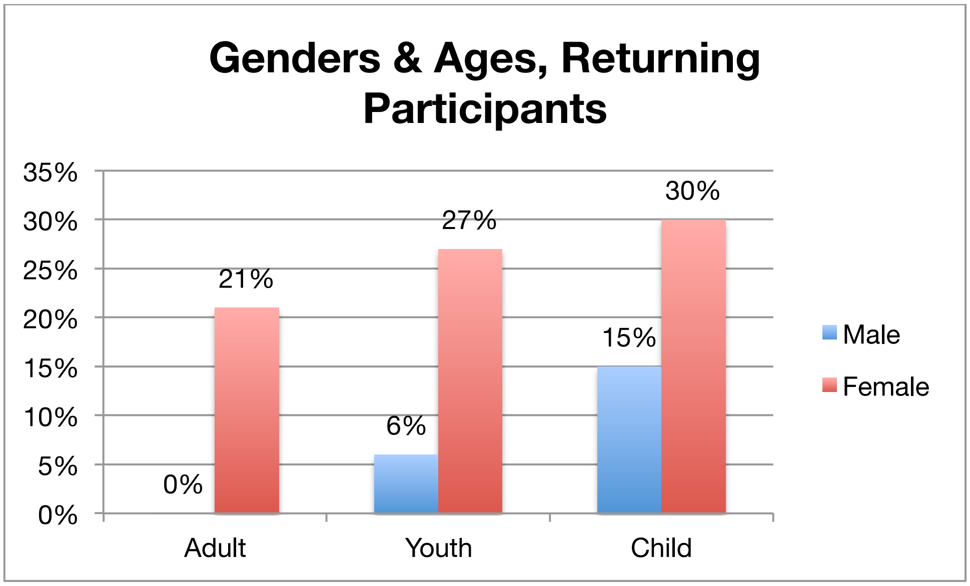

Figure 9. Genders and ages of participants, returning participants (n=33).

4. How did participants first learn about the initiative?

✜ The majority of individuals reported first hearing about the initiative through their participation in an organization or through their school. More than half the individuals who attended more than one session reported first hearing about the initiative from a friend or family member.

We had data on how participants first heard about the initiative for all but two individuals in the exploratory study. As shown in Figure 10 on the following page, 33% of participants (64 of 196) learned about the initiative from a local school — 28% (55) came on an organized trip with their class, while 5% (9) learned about the initiative through a teacher, phone tree, newsletter, website, poster, or parent meeting at school. An additional 16% (32) heard about the initiative from the sponsoring ISE organization, 26% (51) from an outside organization, 1% (2) from a community partner, 18% (35) from a family member, 4% (8) from a friend, and 2% (4) from social media.

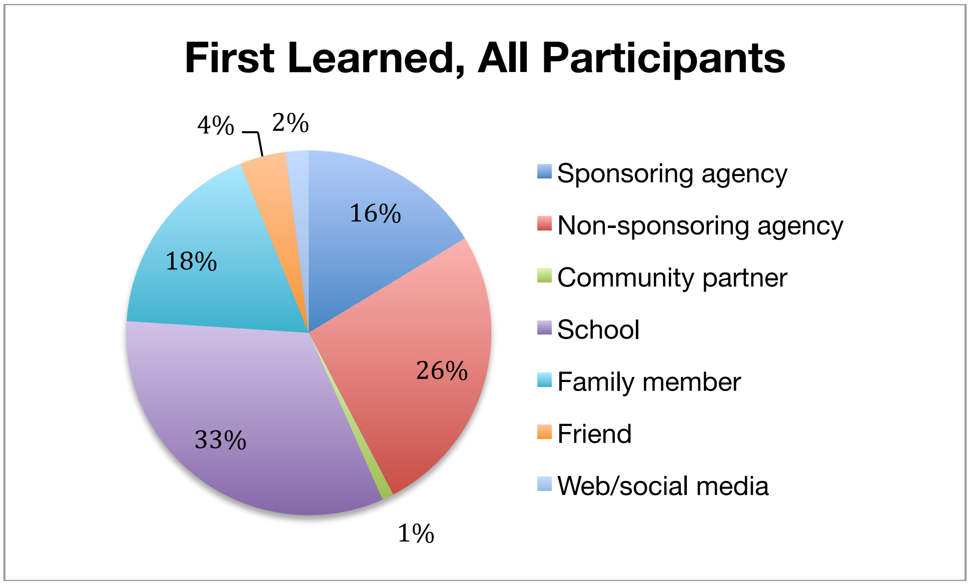

Figure 10. How heard about the program, all exploratory study participants (n=196).

As shown in Figure 11, below, of the individuals who came to more than one session, 24% of participants (8 of 33) first heard about the initiative from the sponsoring ISE organization, 9% (3) from an outside organization, 6% (2) from a local school, 40% (13) from a family member, 15% (5) from a friend, and 6% (2) from social media. No returning participant first attended with their class at school or first heard about the initiative from a community partner.

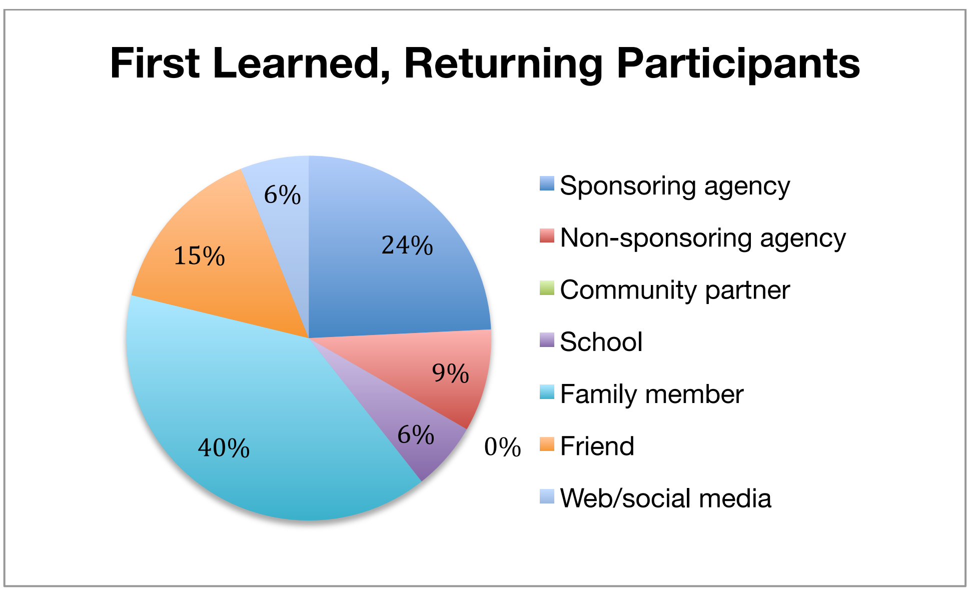

Figure 11. How heard about the initiative, returning participants (n=33).

5. Who did the participants come with?

✜ The majority of participants in the citizen science exploratory study came with a group or their school, while the majority of repeat participants came with their families or individually.

We had data on who individuals arrived with for all participants in the exploratory study. As shown in Figure 12, below, 35% (70 of 198) came with a group, 28% (55) came with their class at school, 17% (34) came with their family, and 11% (21) were either participants or family members of participants in existing programs at the ISE organization. Eighteen people (9%) came individually.

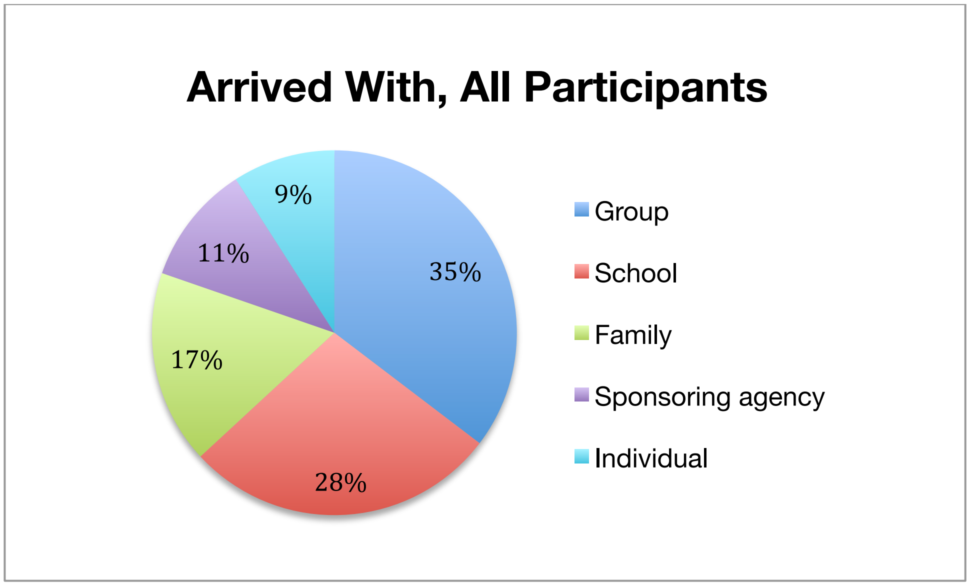

Figure 12. Who participants arrived with, all study participants (n=198).

All participants except one who reported living outside the surrounding city came with a group. The one exception came individually.

The participants who came with their school or who were either participants or family members of participants at the ISE organization all reported living in the community.

As shown in Figure 13 on the following page, of the individuals who came to more than one session, 39% (13 of 33) came with their family, 27% (9) came individually, 21% (7) came with a group, and 12% (4) were either participants or family members of participants at the ISE organization. No individual who came with his or her school returned for a second visit.

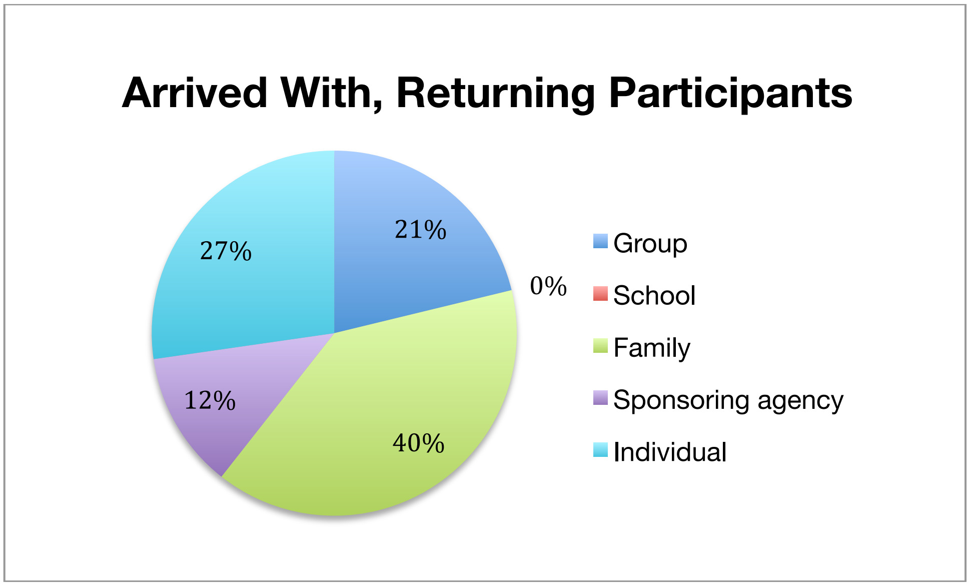

Figure 13. Who participants arrived with, returning participants (n=33).

6. What drew participants to the initiative?

✜ Interview data suggest that the majority of participants were drawn to the citizen science initiative in order to help or engage with the community or the environment or to have fun. No participant mentioned doing science as a reason for attending.

We had data on why participants came to the initiative for 29 of 32 individuals (91%) who were interviewed. As shown in Figure 14 on the following page, ten (34%) came with a group or were brought to the initiative with a class from school. Seven (24%) stated they came to help the community and four (14%) to help the environment. Five (17%) came to have fun, three (10%) to be outside or in nature, three (10%) to meet new people, three (10%) to get credit for a project for school or another organization, two (7%) to learn about the environment, and one (3%) to get exercise. In interviews, no participant mentioned science or doing science as a reason they came to the initiative.

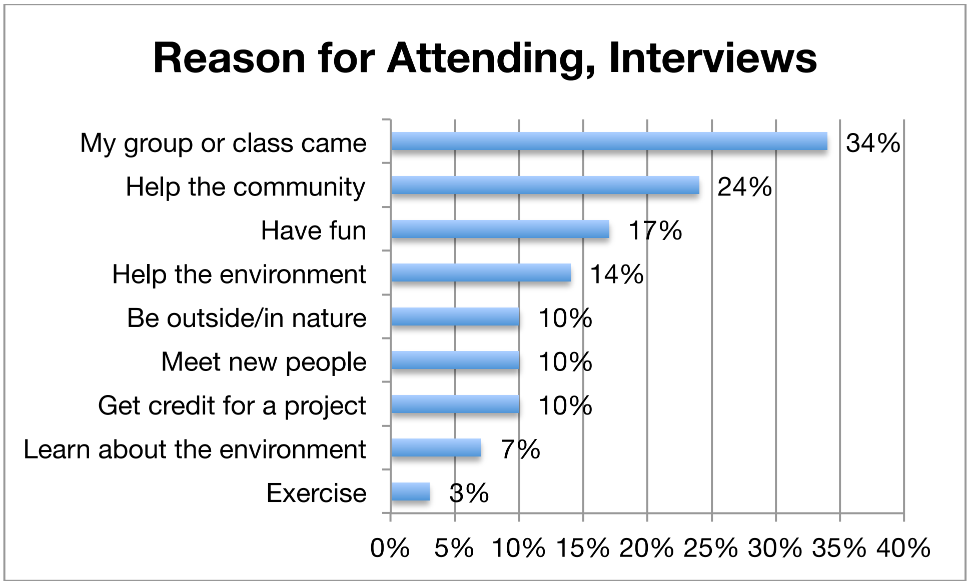

Figure 14. Reason for attending, interview participants (n=29).[12]

7. What activities did individuals participate in?

✜ One hundred percent of participants attended one or more data collection sessions. No participant attended a data entry session.

All participants attended one or more of the data collection sessions offered weekly on Saturday mornings in one of a rotating series of local canyons. No participant attended any of the data entry sessions offered weekly on Wednesday afternoons in a building in the community near one of the canyons.

8. How was the presence of a scientist associated with returning visits?

✜ The chance to interact with a scientist on the first visit was not associated with increased rates of participation in future sessions.

As shown in Figure 15 on the following page, of those individuals who were repeat participants in the initiative, 27% (9 of 33) had the opportunity to interact with a scientist on their first visit and 73% (24 of 33) did not. These percentages are comparable to those for individuals who attended only one session, for whom 29% (34 of 116) had the opportunity to interact with a scientist on their first visit and 71% (82 of 116) did not. Individuals who came with their classes at school (none of whom returned for a second visit) are excluded from these data.

[12] Because participants could give more than one answer, numbers do not sum to 100%.

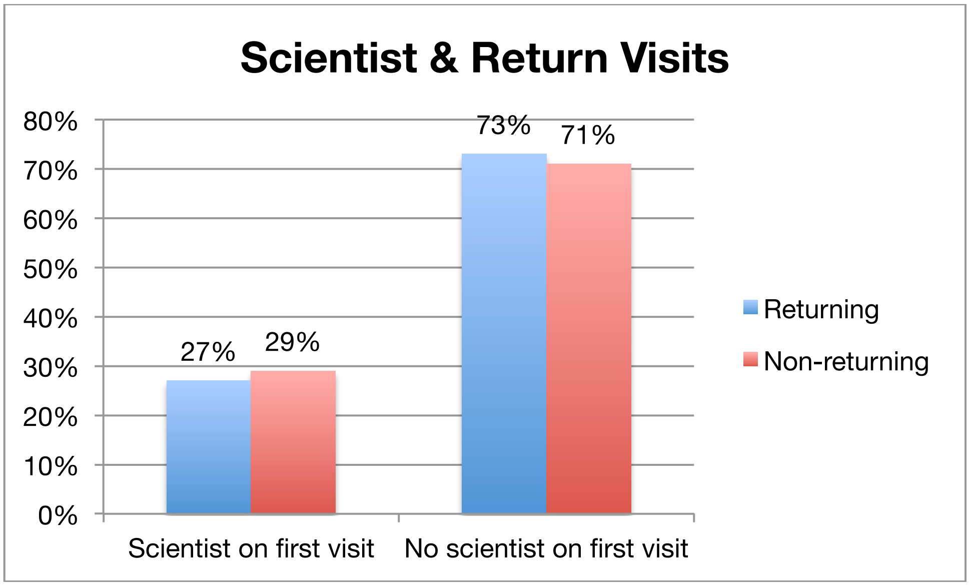

Figure 15. Scientist and return visits, all exploratory study participants (n=143).

9. Did participants increase their understanding of STEM principles?

✜ On average, participants did not demonstrate increased understanding that water flows to the mouth of a watershed after participating in the citizen science initiative. Roughly half (53%) of participants were able to correctly identify at least one aspect of the purpose of the citizen science study after participating.

We had both pre and post assessment data on participants' understanding of how water flows through a watershed for 125 of the 198 participants in the exploratory study (63%). As shown in Table 1, below, there were no statistically significant differences in performance on the science question before and after participation in the initiative for any age group or for the group as a whole. Approximately three quarters of individuals answered the question correctly both before and after participating in the initiative.

Table 1. Performance on science assessment, all participants with pre-and post- data (n=125).

	Child (8-12) (n=67)		**Youth (13-17)** (n=28)		**Adult (18+)** (n=30)		**Total** (n=125)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Number (%) correct	48 (72%)	47 (70%)	23 (82%)	20 (71%)	25 (83%)	28 (93%)	96 (77%)	95 (76%)
Statistically significant?[13]	No		No		No		No	

We had data on individuals' understanding of the reasons for the citizen science study for 30 of 32 individuals (94%) who were interviewed after participating. Sixteen (53%) were able to correctly identify at least one aspect of the purpose of the study, which was to investigate the sources, pathways, and types of plastic in the local portion of the

[13] Paired t-test, $p \leq .05$

watershed. As shown in Figure 16 on the following page, eight (27%) thought the purpose of the study was to identify types of trash in the canyon, seven (23%) how much trash was in the canyon, four (13%) if or how trash moves in or through the canyon, two (7%) where trash is or accumulates in the canyon, and one (3%) what trash appears most in the canyon. The other fourteen individuals were not able to correctly state a purpose for the study.

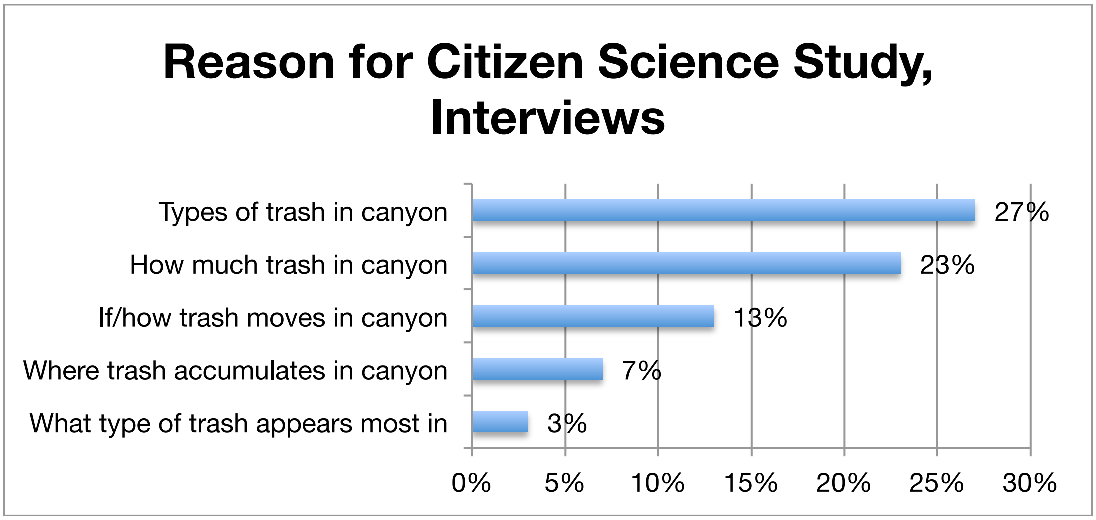

Figure 16: Reason for citizen science study, interview participants (n=30).[14] Note that 46% of participants could not identify a purpose for the study.

10. What did participants report learning from the initiative?

✜ The majority of those interviewed reported learning about trash in the canyon and/or human impacts on animals or the environment by participating in the citizen science initiative. No individual reported learning about scientific processes or methods.

We had data on what individuals reported learning after participating in the initiative for 28 of 32 individuals (88%) who were interviewed. As shown in Figure 17 on the following page, eight (29%) individuals reported learning how trash gets into the canyon. Eight (29%) reported learning about the impacts he or she personally or humans generally have on the environment, with seven (25%) learning the impacts human trash has on animals, the canyon, and/or the ocean and two (7%) learning how his or her personal actions have an impact on the environment or animals (one individual reported learning about both general and personal impacts on the environment). Seven individuals (25%) talked about learning specific actions – such as not littering – that a person can take to prevent trash from flowing into the canyon or the ocean and subsequently hurting the environment and/or animals. Three individuals (11%) reported learning about how water moves in or through the canyon, and three (11%) about how much trash flows into or was in the canyon. Five individuals (17%) explicitly stated that they did not learn anything through the experience.

[14] Because participants could give more than one answer, numbers do not sum to 100%.

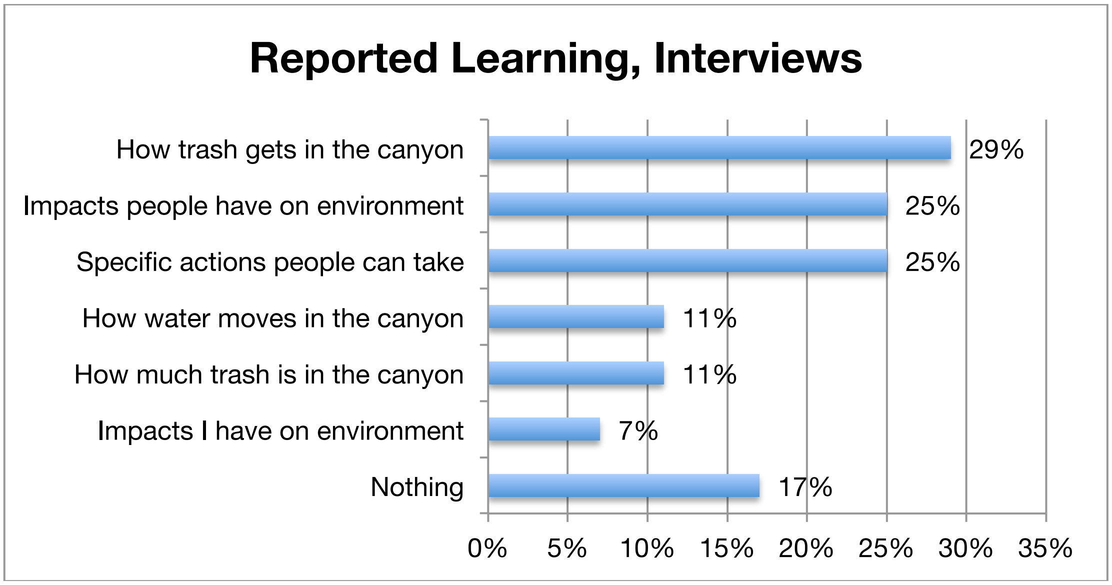

Figure 17. Reported learning, interview participants (n=28).[15]

During the course of the full interviews, six individuals (21%) stated or described how water and/or wind moves trash into the canyons or ocean (one of the explicit focuses of the citizen science study), while five (19%) stated that trash gets into the canyons because individuals throw their trash on the ground in the canyon. The other seventeen individuals (61%) did not comment on the reasons trash occurs in the canyon.

11. Did participants increase their interest in STEM topics and activities?

✜ The topics for which there were the largest increases in reported interest after participation in the initiative related to the focus of the citizen science experience, but through a personal or community-based conservation or stewardship lens rather than a science lens.

We had both pre and post survey data on interest in particular topics for 84 of the 198 participants in the exploratory study (42%).[16] As shown in Table 2, below, the items for which there were statistically significant differences in interest before and after participation in the initiative were topics related to the focus of the citizen science project: 'How the local watershed affects my community', 'How my community affects the local canyons', and 'How I can help take care of our local canyons.'[17] All of these items focus on the individual and/or the local community, with a conservation/stewardship focus rather than a science focus. There was no statistically significant increase in interest, on average, for any of the other topics, including 'How I

[15] Because participants could give more than one answer, numbers do not sum to 100%.
[16] While this response rate is somewhat low, these 84 participants were similar to the participants in the research study overall in terms of zip code (67% from the local community, 33% from outside the local community); race/ethnicity (65% Hispanic/Latino, 11% White, 12% Asian, 10% African-American, 0% African, 2% Multi-race); gender (62% female, 38% male); and age (26% adult, 24% youth, 50% child).
[17] These changes in interest were reported by individuals across zip codes, race/ethnicities, genders, and ages.

can get involved in community science projects' after participation in the citizen science initiative.

Table 2. Interest in science and stewardship topics, all participants with pre- and post- survey data (n=84).

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

* $p \leq .05$

12. What might explain the findings about science?

✜ Analyses of interview and field data suggest at least two possible explanations for why participants did not, on average, demonstrate increased knowledge of or interest in STEM after participating in the citizen science initiative or mention being drawn to the initiative to engage in science, but did report increased interest in and new knowledge about watersheds, conservation/stewardship, and the effects of human activity on the local environment. These include participants' ideas about science and interactions during the fieldwork.

Ideas about science

Despite explicit and consistent marketing of the initiative as a community science opportunity, data from interviews suggest that the majority of participants did not connect the field activity to science as strongly as expected.

We explicitly asked participants whether they felt like they were doing science during the initiative in 19 of 32 interviews (59%). As depicted in Figure 18 on the following page, among these nineteen participants, fourteen (74%) said yes, two (11%) said maybe, and three (16%) said no.

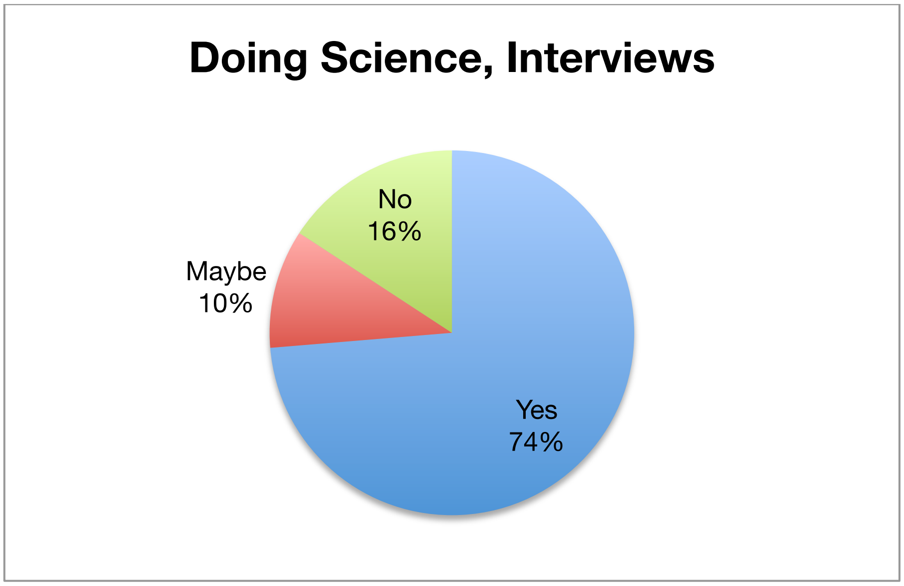

Figure 18. Doing science, interview participants (n=19).

Of the twelve who said they felt like they were or might be doing science and who gave a reason, see Figure 19 below, five (42%) said they were or might be doing science because they were collecting data, while four (33%) said they were doing science because they learned, heard, or were told facts or information.

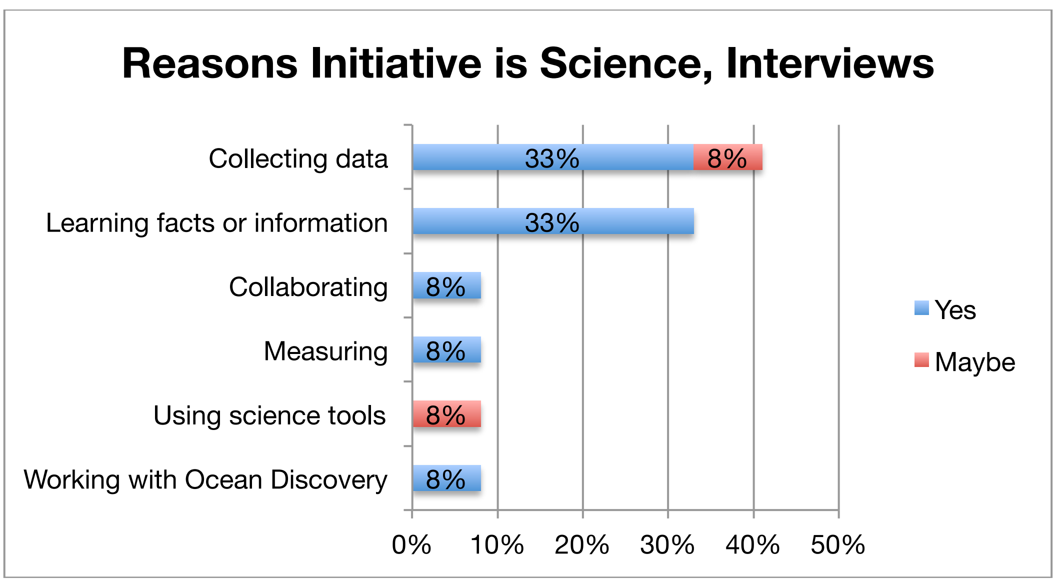

Figure 19. Doing science, interview participants who said yes or maybe (n=12).[18]

Three additional participants said they were or might be doing science because they were collaborating, measuring, or using science tools.

[18] Because participants could give more than one answer, numbers do not sum to 100%.

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/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 they were not doing what happens in science in school, as shown in the interview excerpt below:

Interviewer: Do you feel like you were doing science today?
Participant: No.
Interviewer: Why not?
Participant: Because it's different than science. Usually in science I learn different things, like I usually do physical science like with chemicals.

Altogether, only 5 of 19 participants (26%) interviewed about whether they were doing science referred to an aspect of the hands-on, authentic citizen science activity (measuring, collecting data, and/or collaborating with others) and defined it as science.

That 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 the community may partially explain why some participants did not conceive of the field activity as participation in a scientific study, why no participant mentioned science as a reason for attending, why no individual reported learning about scientific processes or methods, and why the largest increases in reported interest after participation related to the focus of the citizen science experience but through a conservation or stewardship lens rather than a science lens.

Interactions during the fieldwork

A related potential explanation for these findings about science knowledge and interest includes the patterns of interaction during the citizen science fieldwork. Based on the analysis of twenty-two hours of audio recordings from three purposely selected field sessions, participants had widely different experiences with science content even in the same groups.

While the scientist consistently engaged with others nearby, the high school aged project leaders tended to work more silently and focus on the project task of collecting and sorting trash, meaning only small numbers of participants had consistent access to science mentoring during any one session. In addition, participants tended to stay in the groups with which they came. Because of these dynamics, participants sometimes engaged in no science talk, sometimes engaged in short amounts of science talk, and sometimes had frequent and rich science-related conversations.

Scientist

Based on data from the field audio, the scientist engaged with others consistently throughout each one-to-two-hour session. The scientist's comments focused on managing the logistics of the scientific activity, sharing context-related scientific facts and concepts in response to others' experiences or questions, and modeling comfort with the natural environment, as can be seen in the excerpts below. In these interactions – all taken from a single, three-minute-long interchange – the scientist asks multiple questions and covers four separate topics (how trash gets in the canyon, how to stop trash from getting in the canyon, what type of trash is in the canyon, and the paleontological history of the canyon) while engaging closely with the individuals nearby:

Scientist: This area was clean a few months ago.
Child1: Whoa.
Scientist: Where do you think all this is coming from?
Child2: The ketchup factory!
Scientist: The ketchup factory? Yeah. How did it get from the ketchup factory out to here? What do you think—
Child2: Because people use it and they just throw it on the ground. And they don't throw it in the trash.

Child1: This is a lot of work.
Scientist: People have to do this, come out and do a lot of work every couple months to keep this canyon clean. Do you have a better solution?
Child2: Hmm.
Scientist: How do we keep the canyon clean without having to…What are some of the things we need to do to stop all this trash from coming in the canyon?

Scientist: What do you see, in the canyon here? What kind of trash are you seeing?
Child1: I see a cup!
Scientist: A cup? Yeah. And we saw ketchup packets.
Child2: I see like a little smushed ice cream thing.
Scientist: Yeah, more food packaging.
Child2: There's so many trash.
Scientist: So if it's a lot of food, right — it's coming from restaurants, that's part of it…What do you see most of? Plastic, right?

Child2: I found a seashell!! Look! I found a seashell.
Scientist: Oh that's funny. May I see it? Oh my gosh. So this used to be ocean, millions and millions of years ago. This area of San Diego in the canyons, they found the highest density of marine mammal fossils — so seals, dolphins — than anywhere else. So this was all underwater at some point. May I hold onto this?
Child2: Yes!
Scientist: I need to put it somewhere safe.
Child2: I must be lucky to find it.
Scientist: You were very lucky to find it…It's a bent nosed clam.
Child2: It's a clam?
Scientist: It's the top of a clam.
Child2: It's the top of a clam [says another child's first name].
Scientist: It could be a bird flew up and dropped it, so that's the other option, but it could be a fossil.

While the scientist engaged with the participants as an equal in the task of collecting trash – as one participant characterized it, "We didn't have to all do it by ourselves because she helped us pick it up too," – even when engaging with adults, the sharing of knowledge typically ran in a single direction from scientist to participant, rather than between the two.

Project leaders

Based on data from the three case studies, the high school aged project leaders tended to engage similarly whether or not there was a scientist present in their group. They followed directions from the scientist or ISE educator, helped with and engaged participants in logistics, and collected and sorted trash as part of the citizen science initiative.

At the beginning and the end of each session, the project leaders typically spent a few minutes engaging participants in logistical tasks related to the citizen science initiative. When they did so, they tended to be very clear in their instructions for the specific task, but did not tend to put the specific task in the context of the study or science more generally, as in the example below:

Project leader: Would someone like to help me take the picture? [long pause] Come on over here. [long pause] I forgot the date. Six twenty. 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.

In addition, on a few occasions, a project leader shared a piece of science knowledge with those nearby, as in the example below:

Project leader: Have you seen these guys around San Diego, or California?
Participant: These?
Project leader: No, these ones, these ones right here. The ones that look like bamboos. These are actually Arundo donax. It's not bamboo, it's like an invasive species from I think, Asia, I believe, or I don't quite remember.
Participant: So you're saying that they were planted here?
Project leader: Yeah, they were planted here, they're not from this area. And what they do is just overgrow all the native plants, they grow really tall really quickly, I think they grow up to like six inches in a day, and in the dry seasons they dry up and they look kind of like dry cornfields…
Participant: Yeah, they do. That's what I was looking at.
Project leader: …and that's not good because if a spark falls in here it all just burns up. They've been trying to remove Arundo from the canyons for like five years now, and it still looks kind of the same.

Except for a limited number of interactions along the lines of the two examples above, the project leaders spent most of their time working silently. When they did engage in conversations with others, these conversations were not typically focused on science-related topics. For example, during one field session, one of the project leaders worked silently and had almost no interaction with other participants except for a single animated conversation about video games with a younger participant that stopped the work and lasted for more than eleven minutes.

Participants

One reason that being exposed to a scientist may not have been predictive of whether participants returned for another session may be that participants in the "scientist groups" were not exposed to the scientist equally. Some individuals in the scientist groups had little exposure to the scientist, while others outside the science groups who attended on a day on which the scientist was present were exposed to the scientist's knowledge before the day began, during breaks, or while moving around the canyon.

In general, individuals had a tendency to stay with the groups with which they came, rather than integrating into one single "fieldwork" group, which may have limited both their exposure to the scientist and the opportunity to integrate and feel culturally like a part of a science team.

For example, one youth from the local community came to the event with a group affiliated with another organization. This individual spoke almost exclusively to members of that group throughout the day. When the scientist tried to engage members of the group, including the youth, some of the group engaged with the scientist, but this particular individual made single statements such as "I got a tiger as a pet" in response to questions or overheard conversations and did not engage further. This individual participated in no science talk during the event and had almost no interactions with adults, including the adults in the outside organization with which the individual was affiliated. Twenty minutes into the hour-plus long session, the individual stated that she was done and ready to take a break.

Likewise, on a different day, an adult came to the event with an individual of the opposite gender; they were placed together in a scientist group. The two stayed close together throughout the session, laughing, talking to each other, and sharing quiet jokes. This individual had a single three-line exchange about science with the scientist, but otherwise did not engage with the larger group or engage in any science talk during the session.

Interestingly, the individual from the three case studies who engaged in the most science talk – apart from the scientist – was from a non-scientist group. This individual, an adult, repeatedly approached the scientist, the ISE educator, and the project leader with questions about science and the study and engaged in the science-based conversations that resulted.

Summary and Discussion

Participation and retention

Based on data from the exploratory study, the citizen science model was successful at increasing participation in science by URMs from the targeted community. Approximately 70% of participants in the initiative were from the local community, and the races and ethnicities of participants across the initiative were similar to those in the local community as a whole. A slightly larger percentage of individuals who self-identified as Hispanic/Latino or white, non-Hispanic and fewer individuals who self-identified as Asian attended more than one session of the initiative as compared with participants overall, a difference that is aligned with the race/ethnicity of the individuals who led the citizen science initiative and interacted with participants in the field and is therefore consistent with the citizen science model.

The initiative was most successful at engaging females and young people. Two-thirds of participants in the exploratory study were female; nearly half were under the age of eighteen. An even larger percentage of those who attended more than one session of the initiative were female and/or under the age of eighteen, suggesting that young people and perhaps mothers with families may provide a worthwhile focus for future recruitment efforts.

More than half the individuals who attended more than one session reported first hearing about the initiative from a friend or family member, and those who first attended with their families or as individuals made up a larger percentage of repeat participants than those who first came to the event with their school or with another organized group. These findings suggest that working with formal or informal leaders in the local community who can share information about the initiative with potential participants may be a particularly effective method for recruiting individuals from diverse backgrounds to participate.

Interview data suggest that the majority of participants were drawn to the citizen science initiative in order to help or engage with the community or the environment or to have fun. No participant mentioned doing science as a reason for attending. These findings suggest that focusing on the most locally familiar aspects of science initiatives, such as the environmental and community-based aspects of this study, may provide a successful means for engaging new participants.

STEM learning and interest

On average, participants did not demonstrate increased understanding that water flows to the mouth of a watershed after participating in the citizen science initiative, and the majority of those interviewed reported learning about trash in the canyon and/or human impacts on animals or the environment but not scientific processes or methods. Similarly, the topics for which there were the largest increases in reported interest after participation in the initiative related to the focus of the citizen science experience, but through a personal or community-based conservation or stewardship lens rather than a science lens.

Analyses of interview and field data suggest at least two possible explanations for these findings: participants' ideas about science and interactions during the fieldwork.

In interviews, a number of participants defined science as learning, hearing, or being told facts or information, and only a quarter of those interviewed referred to an aspect of the hands-on, authentic citizen science activity and defined it as science. That 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 the community may partially explain why some participants did not conceive of the field activity as participation in a scientific study, why no participant mentioned science as a reason for attending, why no individual reported learning about scientific processes or methods, and why the largest increases in reported interest after participation related to the focus of the citizen science experience but through a conservation or stewardship lens rather than a science lens. These findings suggest that, for citizen science initiatives in communities without a rich history of science engagement, it may be most productive to focus on creating activities that clarify and broaden perceptions of science before focusing on improving scientific learning outcomes.

In the fieldwork, while the scientist consistently engaged with others nearby, the high school aged project leaders tended to work more silently and focus on the task of collecting and sorting trash, meaning only small numbers of participants had consistent access to science mentoring during any one session of the initiative. While the scientist engaged with the participants as equals in the task of collecting trash, the sharing of knowledge typically ran from scientist to participant, rather than between the two. Individuals had a tendency to stay with the groups with which they came, rather than integrating into a single group, which may have limited both their exposure to the scientist and the opportunity to integrate and feel culturally like a part of a science team. These findings suggest that it may be beneficial to more explicitly establish a process for integrating all individuals into a single group that works closely with a scientist in activities that require the sharing of expertise among all participants in order to increase opportunities for interaction and the development of personal and community science identity and knowledge.

Limitations of the study and areas for future research

There are several limitations to this study. First, this was an initial exploratory pilot study. Its purpose was to identify potential early indicators of the effectiveness of the citizen science model and areas of interest for future research on engaging URMs in citizen science. Findings from this study do not, and are not intended to, demonstrate definitively whether the model proposed "works," or whether particular aspects of the model are associated with particular outcomes for participants. Second, while the rate of participation in the exploratory study was very high (95%), not all data were collected from all participants. Not all participants took both the pre and post versions of the survey, not all participants answered all questions on the survey, not all participants were selected for interviews, and not all interview questions were asked of all participants. While the data collected across instruments and individuals tell a coherent story, it is possible that experiences of individuals who were less engaged in the pilot activity or who were less comfortable speaking or writing in English or Spanish were underrepresented in the data and findings. Third, this study took place in a single community. While that 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 with large numbers of URMs in different regions of the United States or elsewhere in the world.

This exploratory study has resulted in the identification of a number of important areas for future research. These include the impacts of modifying the citizen science model to include a greater focus on identification of science, participant belongingness, and structured interactions between scientists and participants; a more in-depth study of the conception of science in communities with low levels of science exposure; a more in-depth exploration of the experiences of particular individuals from a range of cultural and ethnic backgrounds in locally-based citizen science in low SES communities; and the effects of implementation of community research initiatives based on the citizen science model in other regions and communities.

Works Cited

Ballard, H. L., & Belsky, J. M. (2010). Participatory action research and environmental learning: Implications for resilient forests and communities. *Environmental Education Research, 16*(5-6), 611-627.

Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education, 94*(6), 1008-1026. doi:10.1002/sce.20392

Bell, R. L., Blair, L. M., Crawford, B. A., & Lederman, N. G. (2003). Just do it? Impact of a science apprenticeship program on high school students' understandings of the nature of science and scientific inquiry. *Journal of Research in Science Teaching, 40*(5), 487-509.

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). *Public participation in scientific research: Defining the field and assessing its potential for informal science education. A CAISE Inquiry Group report.* Washington, DC: Center for Advancement of Informal Science Education (CAISE).

Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science, 25*(1), 2-16.

Boyle, O. (2012, August). *The Wisconsin Citizen-based Monitoring Network: Integrating social and ecological systems through the principles of ecosystem management.* Plenary session presentation at the Conference on Public Participation in Scientific Research, Portland, OR.

Brossard, D., Lewenstein, B., & Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education, 27*(9), 1099-1121.

Butler, D. M., & MacGregor, I. D. (2003). GLOBE: Science and education. *Journal of Geoscience Education, 51*(1), 9-20.

Cannon, A. R., Chamberlain, D. E., Toms, M. P., Hatchwell, B. J., & Gaston, K. J. (2005). Trends in the use of private gardens by wild birds in Great Britain 1995–2002. *Journal of Applied Ecology, 42*(4), 659-671.

Committee on Equal Opportunities in Science and Engineering. (2015). *2013-2014 Biennial report to Congress: Broadening participation in America's STEM workforce* (CEOSE 15-01). Arlington, VA: National Science Foundation.

Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: Issues and opportunities. *Environmental Monitoring and Assessment, 176*(1), 273-291.

Cooper, C. B., Dickinson, J., Phillips, T., & Bonney, R. (2007). Citizen science as a tool for conservation in residential ecosystems. *Ecology and Society, 12*(2). Retrieved from http://www.ecologyandsociety.org/vol12/iss2/art11/

Cooper, C. B., Hochachka, W., Butcher, G., & Dhondt, A. A. (2005). Seasonal and latitudinal trends in clutch size: Thermal constraints during laying and incubation. *Ecology, 86*(8), 2018-2031.

Dee, T. S. (2004). Teachers, race, and student achievement in a randomized experiment. *Review of Economics and Statistics, 86*(1), 195-210.

Evans, C., Abrams, E., Reitsma, R., Roux, K., Salmonsen, L., & Marra, P. P. (2005). The Neighborhood Nestwatch program: Participant outcomes of a citizen-science ecological research project. *Conservation Biology, 19*(3), 589-594.

Evans, S. M., & Birchenough, A. C. (2001). Community-based management of the environment: Lessons from the past and options for the future. *Aquatic Conservation: Marine and Freshwater Ecosystems, 11(*2), 137-147.

Foster-Smith, J., & Evans, S. M. (2003). The value of marine ecological data collected by volunteers. *Biological Conservation, 113*(2), 199-213.

Graham, M. J., Frederick, J., Byars-Winston, A., Hunter, A. B., & Handelsman, J. (2013). Increasing persistence of college students in STEM. *Science, 341*(6153), 1455-1456.

Gregory, R. D., van Strien, A., Vorisek, P., Meyling, A. W. G., Noble, D. G., Foppen, R. P. B., & Gibbons, D. W. (2005). Developing indicators for European birds. *Philosophical Transactions of the Royal Society B: Biological Sciences, 360*(1454), 269-288.

Harrison, M., Dunbar, D., Ratmansky, L., Boyd, K., & Lopatto, D. (2011). Classroon-based science research at the introductory level: Changes in career choice and attitude. *CBE Life Science Education, 10*(3), 279-286.

Jordan, R. C., Gray, S. A., Howe, D. V., Brooks, W. R., & Ehrenfeld, J. G. (2011). Knowledge gain and behavioral change in citizen-science programs. *Conservation Biology, 25*(6), 1148-1154.

Lauver, S., Little, P. M., & Weiss, H. (2004). Moving beyond the barriers: Attracting and sustaining youth participation in out-of-school time programs*. Issues and Opportunities in Out-of-School Time Evaluation, 6.* 1-16. Retrieved from http://www.hfrp.org/publications-resources/browse-our-publications/moving-beyond-the-barriers-attracting-and-sustaining-youth-participation-in-out-of-school-time-programs

Miller-Rushing, A. (2013). Workshop 1: Conference on public participation in scientific research 2012: An international, interdisciplinary conference. *Bulletin of the Ecological Society of America, 94*(1), 112-117.

Miller-Rushing, A., Primack, R., & Bonney, R. (2012). The history of public participation in ecological research. *Frontiers in Ecology and the Environment, 10*(6), 285-290.

National Academy of Sciences, National Academy of Engineering, Institute of Medicine. (2010). *Rising Above the Gathering Storm, revisited: Rapidly approaching Category 5.* Washington, DC: National Academies Press.

National Center for Education Statistics. (2012). *The Nation's Report Card: Science 2011* (NCES 2012–465). Washington, DC: Institute of Education Sciences, U.S. Department of Education.

National Science Foundation. (2015). *Women, minorities, and persons with disabilities in science and engineering: 2015* (NSF 15-311). Retrieved from www.nsf.gov/statistics/wmpd

Pandya, R. E. (2012). A framework for engaging diverse communities in citizen science in the US. *Frontiers in Ecology and the Environment, 10*(6), 314-317.

Sadler, T. D., Burgin, S., McKinney, L., & Ponjuan, L. (2009). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching, 47*(3), 235-256.

Sauermann, H., & Franzoni, C. (2015). Crowd science user contribution patterns and their implications. *Proceedings of the National Academy of Sciences, 112*(3), 679-684.

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R.,… Bonney, R. (2012). Public participation in scientific research: A Framework for deliberate design. *Ecology and Society, 17*(2). http://dx.doi.org/10.5751/ES-04705-170229

Theobald, E. J., Ettinger, A. K., Burgess, H. K., DeBey, L. B., Schmidt, N. R., Froehlich, H. E.,…Parrish, J. K. (2015). Global change and local solutions: Tapping the unrealized potential of citizen science for biodiversity research. *Biological Conservation, 181*, 236-244. http://dx.doi.org/10.1016/ j.biocon.2014.10.021

Trumbull, D. J., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen‐science project. *Science Education, 84*(2), 265-275.

Wu, H. C. J., & Van Egeren, L. A. (2010). Voluntary participation and parents' reasons for enrollment in after-school programs: Contributions of race/ethnicity, program quality, and program policies. *Journal of Leisure Research, 42*(4), 591-620.