DESIGNING CITIZEN SCIENCE
FOR ENVIRONMENTAL HEALTH JUSTICE

by

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As members of the Master's Committee, we certify that we have read the thesis prepared by **Leona F. Davis**, titled **Participatory Citizen Science for Environmental Health Justice** and recommend that it be accepted as fulfilling the thesis requirement for the Master's Degree.

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Final approval and acceptance of this thesis is contingent upon the candidate's submission of the final copies of the thesis to the Graduate College.

I hereby certify that I have read this thesis prepared under my direction and recommend that it be accepted as fulfilling the Master's requirement.

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ABSTRACT

Citizen science (CS) has become increasingly popular as a method of collecting data, and participants in CS projects have been shown to gain knowledge and self-efficacy to effectively address community issues through participation. However, a participation gap exists as volunteers in CS projects are overwhelmingly college educated, affluent, and white. Acknowledging the potential benefits of CS participation to understand and address environmental health risk, how can researchers design projects to invite and engage diverse participants? A mixed methods approach is used here to analyze 1) Environmental health literacy in participants of participatory environmental health trainings, and 2) Motivation, support, and barriers to participation in an environmental health CS project. This research involves 53 training participants, 127 CS project participants, and 7 *promotoras* in five Arizona communities with documented environmental contamination, who participated in the co-created CS program Project Harvest. Over half of these participants are "low-income" or below, over half are people of color (predominantly Latino/Hispanic), and over half do not have a college degree. Findings suggest the following as effective criteria for promoting participation and learning of diverse citizen scientists: 1) Relevant research questions, 2) Appropriate communication methods, 3) Adaptive and contextual project design, and 4) Balancing flexibility and relationship-building at all levels of the project. Finally, the concept of designing participatory CS for participants to function as a community of practice is discussed as a novel conception of building a supportive culture for learning and action within an environmental health justice context.

INTRODUCTION

"I find brown spots on my car and wish I could call someone because I know it's from the mine. I had 2 epileptic children, epilepsy is very common around here, so is kidney disease and lupus. I would contribute this to contaminants in the mine. My husband is retired from 46 years [at the mine], and he has Myasthenia gravis and failing kidneys, these are common around here, but people don't talk about it. … [The mine] is our employment here- it's the only thing keeping our school going. People, even my husband, don't like if you say anything bad about it. My husband says when I complain about the pollution or threaten to call the EPA, he says, 'Don't complain, they'll shut it down.' I really don't think they will shut it down though, and there is a nice way to bring up issues that are hurting people."

- Project Harvest participant in Hayden/Winkelman, AZ, Aug 2018

Background

For the past two years, I have had the privilege of working closely with researchers, *promotoras*, and participants of Project Harvest around the shared goal of gathering and interpreting environmental monitoring data in communities with known sources of contamination. Prior to working with the Project Harvest team, I was unfamiliar with terms like "co-created citizen science" and "participatory research," however I soon discovered many parallels to my prior experiences in community development and community organizing.

If I could respond now to the participant quoted above, after conducting the research presented in the following pages, I would offer that participatory citizen science (CS) may be the "nice way," but more importantly a highly effective way, to address local environmental health issues and prompt responsive action. Community members have intrinsic motivation to participate in participatory environmental health research relevant to their own lives (Carrera, Brown, Brody, & Morello-Frosch, 2018; S. A. Sandhaus, 2017). However, numerous limitations on time and resources, as well as lack of positive exposure to science, may mean those most affected by environmental contamination are the least likely to participate in research aimed at addressing it (Pandya, 2012). Participants in

Project Harvest are economically and racially diverse, with over half self-identifying as low-income or below based on HUD guidelines and over half self-identifying as a non-white race/ethnicity. The research described in the following pages was initially provoked by my curiosity in what specific research design elements enabled or deterred CS participation and learning for different demographic groups, and how the participatory research *process* can best leverage institutional power for meaningful outcomes for participants.

Study Rationale

"Citizen scientists are the new community activists," a recent Washington Post article proclaimed (Milloy, 2018). As participants in CS projects are shown to gain scientific knowledge and self-efficacy to address local problems (Bonney et al., 2009; Dickinson et al., 2012), participatory CS offers a powerful advocacy tool for disenfranchised communities facing environmental health risks (Averett, 2017). With appropriate research design, participatory CS can 1) Produce rigorous data that is commonly understood and valued by residents and decision-makers (Balazs & Morello-Frosch, 2013), 2) Redistribute power to oppressed residents (Dhillon, 2017; Ottinger, 2010), and 3) Inform equitable and effective health policy (Den Broeder, Devilee, Van Oers, Schuit, & Wagemakers, 2018). However, CS projects generally have overwhelmingly attracted volunteers that are educated, affluent, and white (Evans et al., 2005; Pandya, 2012; Soleri, Long, Ramirez-Andreotta, Eitemiller, & Pandya, 2016). Potential economic, cultural, and racial barriers to relationship building between professional researchers and historically disenfranchised community members poses the threat of unsuccessful research, or even exacerbating harms to community members. Recognizing the important differences in the target participant population, CS projects for environmental health justice must be uniquely designed for 1) Disenfranchised community members affected by potential risks to engage, and 2) Research processes to shift power balances and prompt responsive action.

Although scholars have recently called attention to participatory citizen science as a strategy for environmental health research (Averett, 2017; English, Richardson, & Garzón-Galvis, 2018), as well as provided guidance for environmental health researchers on specific participatory strategies (Barzyk, Huang, Williams, Kaufman, & Essoka, 2018; Dunagan et al., 2013), there remains a lack of comprehensive study design framework for practitioners in designing effective participatory CS projects with environmental justice (EJ) communities for environmental health. Although substantial literature has discussed principles, methods, and evaluation framework for community-based participatory research for health (Israel, Eng, Schulz, & Parker, 2012; Minkler & Wallerstein, 2011; Wallerstein, Duran, Oetzel, & Minkler, 2017), this literature may remain under the radar for researchers within the CS field.

Acknowledging the interconnectedness of place, local ecology and environment, local history, environmental health, and socioeconomic and political structures; this project aims to cross-pollinate methodological concepts from learning theory and participatory research for environmental health. In the following paper set, I aim to address the research question, "What specific participatory CS study design elements effectively engage EJ community member participants around environmental health, and promote learning?" To answer this question, I examine two unique sets of data. In Chapter 2, I describe and analyze a series of hands-on environmental health trainings conducted with Arizona community members, with focus on environmental health literacy and contextual learning. In Chapter 3, I analyze direct feedback from participants and *promotoras* in one participatory environmental health CS project, Project Harvest, with focus on motivation, support, and barriers for participation in CS for community members living near sources of pollution. In Chapter 4, I synthesize conclusions from these complementary analyses and provide my own reflection on the role of participatory research to address environmental health injustice.

Theoretical Frameworks

1. Participatory research

Community-based participatory research (CBPR) is an approach defined by a working partnership between academics and community members with the shared goal of elevating community knowledges towards more comprehensive understanding of local issues. The National Institute of Environmental Health Sciences (NIEHS) promotes the following six principles of CBPR: 1) defining community as a unit of identity, 2) ensuring projects are community-driven, 3) promoting active collaboration and participation at every stage of research, 4) fostering co-learning, 5) disseminating results in useful terms, and 6) ensuring research and intervention strategies are culturally appropriate (O'Fallon & Dearry, 2002).

Acknowledging the mutual benefits to both participants and researchers, CBPR and other participatory methods are increasingly utilized in environmental health studies (O'Fallon & Dearry, 2002). Similar methodologies include community-engaged research, participatory action research (PAR), youth participatory action research (YPAR), and others, all of which I refer to generally as "participatory research." As participatory research engages community members throughout the research process, from designing the research question and collecting data to analyzing data and drawing conclusions, study findings are more likely to reflect lived experiences of community members and convey complex understanding of the issue. For example, data produced through participatory methods have largely shaped the understanding within public health that multiple stressors and risk pathways, including psychological stress, have compounding health effects for many disadvantaged community members (Finn & Collman, 2016; Morello-Frosch, Zuk, Jerrett, Shamasunder, & Kyle, 2011; Sexton, 2012). This perspective questions the common method for assessing environmental health risk, based on the concentration of each contaminant through a specific exposure pathway. As demonstrated in this example, participatory research, through valuing multiple perspectives on a problem, is often able to produce more multi-faceted understanding, as well as guide researchers to further relevant research questions.

2. Citizen science

Although citizen science (CS) has traditionally been used to crowd-source large quantities of scientific data from public volunteers (Hudson et al., 2017, e.g.), scholars have increasingly acknowledged the many benefits to CS participants, such as increased scientific knowledge and self-efficacy (Bonney et al., 2009; Evans et al., 2005), and proposed CS not just as a strategy for data collection, but also for community education, empowerment, and resilience (Bonney, Phillips, Ballard, & Enck, 2016; Dickinson et al., 2012; Jordan, Ballard, & Phillips, 2012). Furthermore, public health scholars have argued that participant-driven creation of health knowledge and health policy through CS methodology may produce better data and improved health outcomes than traditional top-down health policy making approaches (Den Broeder et al., 2018).

In the past decade, there has been an exponential rise in the use of CS within ecological and environmental sciences (Pocock, Tweddle, Savage, Robinson, & Roy, 2017), and a similar rise in the use of CS and other participatory research methods within an environmental health context (see Chapter 2). Researchers using CS to address environmental health risks often draw heavily from participatory research methods such as PAR or CBPR (Corburn & Gottlieb, 2005). Scholars have recently aimed to define and promote the participant-led citizen science approach, using terms such as “collaborative” or “co-created” citizen science (Shirk et al., 2012), “extreme citizen science” (English et al., 2018), and “strongly participatory research” (Allen, 2018). Despite differences in terms, these approaches share a foundation of using the research process to advance understanding of local priorities, directed by local people and local knowledge.

Although a nuanced understanding of stakeholder relationships and power dynamics in the research process is core tenet of CBPR and other forms of participatory research, it has not traditionally been central to CS methodology. In an environmental health justice context, CS researchers must incorporate principles from other participatory research approaches, environmental justice, and knowledge justice, to work effectively with disenfranchised community members.

3. Environmental justice

Environmental justice (EJ) recognizes the cumulative environmental burdens that disproportionately oppress people of color and people living in poverty. These cumulative burdens are the product of political, economic, and cultural values which co-locate devalued land uses, such as toxic dumps and power plants, with residents who lack economic and political power. Communities which suffer from environmental injustice, referred to as EJ communities, may be urban or rural communities where environmental stressors are compounded by lack of protection from government and non-governmental regulatory agencies. Additional stressors related to poverty and discrimination, such as underfunded area schools, lack of access to health care, and discriminatory bank lending, may compound stress experienced by EJ community members.

In 2017, nearly 80,000 facilities in the US reported releasing toxic chemicals that threaten human health (US EPA, 2017). Despite the concept of environmental justice reaching mainstream American audiences in the 1990s (Bullard, 2008; Cole & Foster, 2000; Shrader-Frechette, 2002), and the 1994 Executive Order which mandated that federal agencies strive to achieve EJ as part of their mission (Clinton, 1994), public commitment has yet to bring about effective, enforceable policies that prevent systematic harm to EJ communities (Checker, 2016). In fact, some recent federal policy, such as exemption of hydraulic fracturing activities from federal pollution control standards (Tiemann & Vann, 2015), have made it more difficult for EJ communities to protect themselves through legal means.

Robert Kuehn (Kuehn, 2004) breaks down the process of EJ into its core components; 1) Distributive justice- determining where burdens are located and who is affected by them, 2) Procedural justice- determining how are decisions made and whose knowledge is considered in decision making, and 3) Corrective justice- translating community knowledges into responsive actions that redistribute power and reverse harms. (Corburn, 2017) describes anti-reductionist, anti-determinist, and anti-positivist theory within the EJ framework as guiding authentic research processes as well as outcomes. Anti-reductionism and anti-determinism mandate that researchers acknowledge the host of environmental health stressors that community members face in the research question and design. This marks a philosophical difference to western scientific method, which aims to understand the whole by studying individual pieces. For research with EJ communities, framing the problem too narrowly may result in data that misrepresents a more comprehensive reality, potentially producing invalid data that could exacerbate existing harms. Embracing anti-positivism means the acknowledgement of the intersecting histories, present realities, and possible futures of EJ community members, as well as the role professional science has played, and continues to play, in delegitimizing community knowledges and experiences (Allen, 1998; Finn, Herne, & Castille, 2017). As a core principle of EJ, affected community members have the, “right to participate as equal partners at every level of decision-making, including needs assessment, planning, implementation, enforcement and evaluation," (People of Color Environmental Justice Summit, 1991). This principle suggests participatory methods as the most appropriate type of research with EJ communities. Moreover, some scholars assert that co-production of scientific knowledge with historically disempowered communities is necessary for achieving EJ (B. R. Cohen & Ottinger, 2011).

4. Knowledge Justice

Underlying the principles of EJ, and especially pertinent to professional researchers, is the acknowledgment that only limited forms of knowledge have informed the majority of decisions made by people in power that affect people's lives. This hegemonic knowledge prioritizes cost efficiency, professional credentials of data sources, and political/economic power (R. Lave, 2012; Visvanathan, 2005). Notably absent from public decision-making spaces is indigenous knowledge and traditional ecological knowledge (de Sousa Santos, 2008), despite the depth of understanding they provide for environmental health issues (Finn et al., 2017). Also absent are the lived experiences of residents, which creates hermeneutic injustice within EJ communities (Abma et al., 2017; Allen, 2018; Jalbert, 2016; Scott, 2016). Additionally, neglect of low-income communities by environmental regulatory agencies may produce "knowledge gaps" or "produced ignorance" of environmental risk in certain areas (Frickel et al., 2010; Kinchy, Parks, & Jalbert, 2016). Applying a knowledge justice lens aids in understanding how a full year was able to pass between when residents began tasting, smelling, and seeing contamination in the tap water in Flint, MI, and when decision-makers first acknowledged the urgent public health risk (Krings, Kornberg, & Lane, 2018).

A significant challenge for participatory researchers is to create a platform where community knowledges are valued and promoted, acknowledging the present structures, including academia and potentially the researcher's own presence, that suppresses them.

One strategy for honoring local knowledge is for local community members to serve as knowledge mediators in a project. The *promotora*, or community health worker, model of health promotion, as one example typically used in Latina communities, trains local women in certain evidence-based health practices, who then teach and discuss these practices with their community members in culturally appropriate settings (Deitrick et al., 2010; Ingram, Sabo, Rothers, Wennerstrom, & de Zapien, 2008).

A further challenge to enacting knowledge justice is the multiplicity of lived realities that may exist in a community- rarely will all community members share personal experiences, opinions and beliefs about a local environmental health issue (Clapp et al., 2016). Participatory research and citizen science, as well as qualitative methods such as personal interview, allow researchers to source data from diverse community knowledges to build a comprehensive perspective.

Article

Increasing Environmental Health Literacy through Contextual Learning in Communities at Risk

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1. Introduction

Communities that are disadvantaged by dominant social, economic, and political systems also often suffer disproportionately from environmental health risk (Bullard, 2008; Gee & Payne-Sturges, 2004; National Environmental Justice Advisory Council (NEJAC), 2004). Additionally, the increase of extreme and unpredictable weather events due to climate change is further widening this environmental health risk disparity (Frumkin, Hess, Luber, Malilay, & McGeehin, 2008; Oleson et al., 2015; Wilson, Richard, Joseph, & Williams, 2010). Environmental justice (EJ) integrates the many potential layers of subjugation these communities face; for example, residents may suffer from discriminatory land use planning, limited access to health care, limited employment opportunities, and substandard sanitation infrastructure (Bullard, 2008, 2015). Though we acknowledge the four partnering communities in this study are EJ communities (Table 1), we use the term "environmental health risk communities" here to locate the specific study emphasis on environmental health, and to highlight environmental health risk as the focus of our partnership with these communities.

The natural interdependence of science literacy, health literacy, and environmental literacy have led to the evolution of current environmental health literacy (EHL) frameworks (Finn & O'Fallon, 2017; Gray, 2018; A. Hoover, n.d.; A. G. Hoover, 2019; MD Ramirez-Andreotta et al., 2016; Zarcadoolas, Timm, & Bibeault, 2001). The Society for Public Health Education states that EHL "integrates concepts from both environmental literacy and health literacy to develop the wide range of skills and competencies that people need in order to seek out, comprehend, evaluate, and use environmental health information to make informed choices, reduce health risks, improve quality of life and protect the environment" (Society for Public Health Education, n.d.). As the mitigation or prevention of community-level environmental health risk often requires coordinated action, scholars have identified the need for EHL to not only include knowledge and efficacy for personal environmental health actions, but also for community level action (Gray, 2018; White, Hall, & Johnson, 2014; Zarcadoolas et al., 2001). Case studies have demonstrated increasing EHL as an effective strategy to equip environmental health risk community members to develop and implement their own contextually appropriate strategies for addressing environmental health risk (Corburn, 2007; A. Hoover, n.d.; S Madrigal et al., 2016; Stokes, Hood, Zokovitch, & Close, 2010; Zarcadoolas et al., 2001). Thus, increasing EHL in environmental health risk communities is a strategy for realizing environmental justice.

Aligning with Gray's (2018) proposed refinement to the definition of EHL (Gray, 2018), illustrated in Figure 1, we define EHL here as: (1) environmental science knowledge and awareness related to the community's specific environmental risks; (2) skills and self-efficacy for learning science, doing science, and environmental action; and, (3) community action for systemic change.

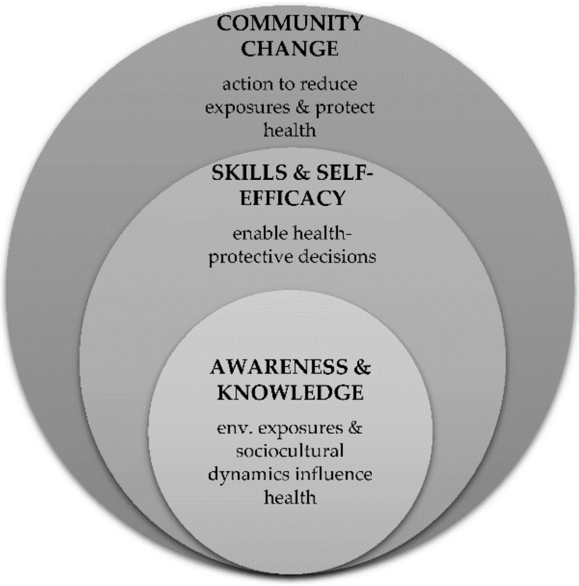

Figure 1. Three dimensions of environmental health literacy (EHL), as proposed by Gray (Gray, 2018)

Gray further suggests EHL as a "continuum" of learning that is often "tied to active engagement of participants throughout the research process, especially in communities directly impacted by environmental contamination" (p. 466). The contextual EHL trainings described and evaluated here represented both an educational event on their own, and a starting point for participants to continue learning alongside researchers through a citizen scientist program, if they chose to do so.

In a previous study, 74% of survey respondents reported that they get "some or a lot" of their science- and technology-related learning from "life experiences" (J. Falk, 2002). The Contextual Model of Learning, as proposed by Falk and Dierking (J. H. Falk & Dierking, 2000), asserts that, "learning can be conceptualized as a contextually driven effort to make meaning in order to survive and prosper within the world; an effort that is best viewed as a continuous, never-ending dialogue between the individual and his or her physical and sociocultural environment" (J. Falk & Storksdieck, 2007). Research has shown people learn more when content is grounded in local culture and context (Laura Colucci-Gray, Perazzone, Dodman, & Camino, 2013; E. B. Johnson, 2002;

Lee, Lemyre, Mercier, Bouchard, & Krewski, 2005), and when participants' knowledge, beliefs, and experiences are shared and honored in a participatory learning experience (S Madrigal et al., 2016; Stokes et al., 2010; Zemits, Maypilama, Wild, Mitchell, & Rumbold, 2015). Previous EHL research has emphasized the contextual nature of defining and evaluating EHL, and the importance of matching learning content to specific local environmental health risk factors (Adams et al., 2011; Ratnapradipa, Middleton, Wodika, Brown, & Preihs, 2015; S Madrigal et al., 2016).

2. Materials and Methods

2.1. Contextual Training Design

The contextual EHL trainings discussed here were designed and promoted to residents of the four partnering communities as "Step 1" of participation in an environmental citizen science project titled Project Harvest. Project Harvest is a co-created citizen science project (Shirk et al., 2012) aimed at assessing environmental contamination in harvested rainwater with environmental health risk communities, presently ongoing. The trainings discussed here served multiple purposes: (1) engage and educate environmental health risk community members around environmental health issues, and increase EHL in these communities, (2) provide an easy entry point for community members to volunteer as citizen scientists in Project Harvest, continuing to learn and contribute to research through local environmental monitoring, and (3) pilot the sampling methods, instructional materials, and survey methods, as formative evaluation for future Project Harvest participant materials.

In the initial project design phase of Project Harvest, principal investigators drafted the content for public community trainings to include climate change, energy conservation, air and water quality, microbiology of food and water, basic inorganic and organic chemistry, practical household actions for environmental health and environmental sustainability, and hands-on experiences that are related to collecting soil, water, and plant samples for environmental monitoring. These topics were chosen based on specific contamination issues in the partner communities, expressed concerns from community members through prior partnerships, and their importance to comprehension of relevant environmental health information.

2.2. Partner Community Selection

Four communities, located in Arizona, USA, were selected to host these trainings based on their proximity to a federal Superfund site and other toxic release site(s), expressed interest from community members or local organizations, and previously built relationships between researchers and community members. The term "community" is used here to define a group with shared local source(s) of environmental health risk, though each defined community varies in size and municipal designation. For two of these communities, Hayden/Winkelman and Globe/Miami, two adjacent municipalities were considered as one community as they share common sources of environmental health risk and associated environmental health concerns, as well as similar demographics. Although the Superfund site located in Tucson, which is a significantly larger city, poses greater health risk to residents in closer proximity, the Tucson training was not restricted from any local residents for ethical reasons, and thus the City of Tucson is defined as a community here. Table 1 describes these four communities and rationale for their partnership for this study, and Figure 2 shows geographic locations.

Table 1. Partnering Communities Demographics, Environmental Health Risk, and Partnerships

City/town, County	Population [1]	Median Household Income [2]	Predominant Races/Ethnicities Represented [1]	% Spanish-speaking households [2]	Sources of Environmental Health Risk Recognized by Community [5]	Prior/Current Partnerships
Tucson, Pima	520,116	$37,973	White, not Hispanic/Latino: 47.2% Hispanic/Latino: 41.6	28.8	Tucson International Airport Area Superfund Site (US Environmental Protection Agency, n.d.-d), where aircraft and electronics manufacturing, fire drill training, and an unlined landfill have contributed trichloroethylene (TCE) and other contaminants observed in soil, groundwater, and municipal water (Conforma Tech, Inc., 2014; Rodenbeck Sven E. & Maslia Morris L., 1998)	Prior collaboration with non-profit organization Sonoran Environmental Research Institute (SERI), a community participatory research institute with extensive experience working with low-income Tucsonans around environmental health issues
Hayden [3], Gila	662	$36,094	Hispanic/Latino (of any race): 84.4%	61.8	ASARCO Hayden Plant Alternative Superfund Site, which includes the ASARCO smelter, concentrator, former Kennecott smelter and all associated tailings facilities. (US Environmental Protection Agency, n.d.-a) In 2016, ASARCO was involved in a $150 million settlement with the US Department of Justice and US Environmental Protection Agency for violations of the Clean Air Act. (Clean Air Act, 1970)	National Institute of Environmental Health Sciences Superfund Research Program partnership School superintendent enthusiastic about gardening and rainwater harvesting served as local "champion" (Gallagher, 2009) to involve teachers and students in environmental health learning
Winkelman [3], Gila	353	$45,000	Hispanic/Latino (of any race): 84.2%	55.6		
Globe [4], Gila	7,532	$42,557	White, not Hispanic/Latino: 55.3% Hispanic/Latino (of any race): 36.8%	14.9	Active copper smelter, rod mill, and open pit mine in Miami (Freeport McMoRan, n.d.) The Mountain View Mobile Home Estates in Globe, AZ, sits on the site of a former chrysotile asbestos mill. This site was on the Superfund Program's National Priorities List (NPL) due to asbestos contamination of soil and groundwater until clean-up activities were completed in 1988. (US Environmental Protection Agency, n.d.-c)	Gila County Cooperative Extension agent became a local "champion" for environmental health learning (Gallagher, 2009), and successfully spread the enthusiasm to the Globe-Miami community
Miami [4], Gila	1,837	$36,298	Hispanic/Latino (of any race): 56% White, not Hispanic/Latino: 40.6%	23.6		
Dewey-Humboldt, Yavapai	3,894	$50,173	White, not Hispanic/Latino: 85.5%	5.2	Iron King Mine - Humboldt Smelter Superfund Site, which includes approximately four million cubic meters of mine tailings from legacy mine and smelter (US Environmental Protection Agency, n.d.-b)	Community members participated in past UA research projects: 1. Citizen science project Gardenroots related to soil contamination and backyard food gardens (M. D. Ramirez-Andreotta, Brusseau, Beamer, &

	2012–2013 analyses of drinking water in local homes demonstrated arsenic above the US EPA drinking water standard (10µg/L) (Loh et al., 2016)	Maier, 2013; M. D. Ramirez-Andreotta, Lothrop, et al., 2016; MD Ramirez-Andreotta et al., 2016; S. A. Sandhaus, 2017) 2. Biomonitoring project related to metal exposure in homes (M. D. Ramirez-Andreotta, Brody, et al., 2016)

[1] 2010 US Census; [2] 2012–2016 American Community Survey (ACS) 5 year estimate; [3] Although these neighboring municipalities joined as one community for this study, they are separated in Census data collection (Town of Hayden and Town of Winkelman); [4] Although these neighboring municipalities joined as one community for this study, they are separated in Census data collection (City of Globe and Town of Miami). [5] More information about sources of environmental health risk in these communities is available from the US EPA EJSCREEN tool, www.ejscreen.epa.gov/mapper/, and from the US EPA Toxic Release Inventory (TRI) Program database, https://www.epa.gov/toxics-release-inventory-tri-program.

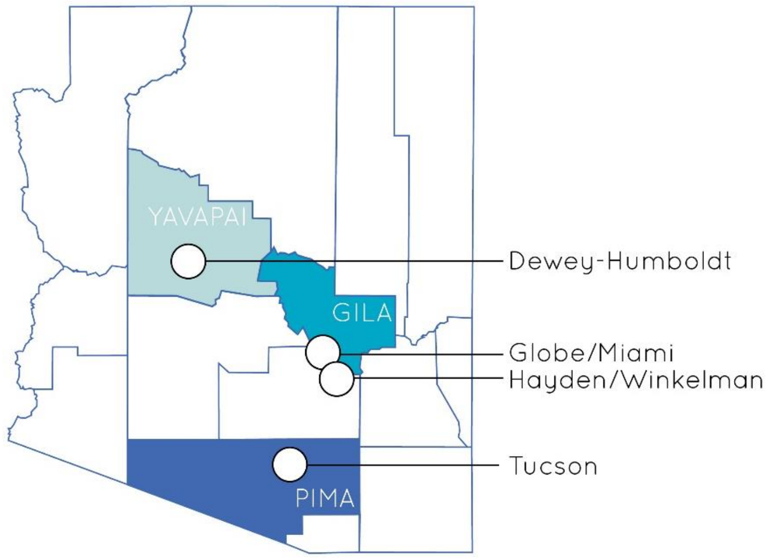

Figure 2. Partnering community locations in Arizona, USA.

2.3. Participant Recruitment

Recruitment for training participants was conducted primarily via: (1) information tables at community festivals, community group meetings, and/or town Council meetings; (2) follow-up mailings, telephone calls and emails to community members and local organizations; (3) press releases for local media outlets; (4) announcements in newsletters; and (5) the Project Harvest website. In every community, principal investigators participated in multiple events involving in-person engagement with community members. All promotional materials were produced in Spanish and English, to welcome and encourage Spanish-only speakers in addition to English speakers. See Supplemental Materials for examples of promotional flyers distributed. Table 2 details specific engagement methods that were conducted in each community.

Table 2. Training Participant Engagement Methods by Community.

Engagement Activity	Tucson	Hayden/ Winkelman	Globe/ Miami	Dewey-Humboldt
Press Releases		X	X	X
Local Newspaper		X	X	X
Town Newsletter				X
Cooperative Extension		X	X	X
Master Gardeners	X	X	X	X
Federal Superfund Site Meetings	X	X		X
Community Advisory Boards	X	X		X
School Superintendent & Teachers	X	X		X
SERI participants	X			
City of Tucson Water program participants	X			

2.4. Training Facilitation

Principal investigators of Project Harvest, representing research fields of Soil and Water Science, Microbiology, Organic Chemistry, Inorganic Chemistry, and Public Health, served as training facilitators, along with other specialists on climate change and rainwater harvesting. The term "facilitator-scientist" is used henceforth to refer to individuals in this role.

Community trainings were hosted in locally familiar public sites and scheduled either over 1–2 consecutive full days or over 3–5 consecutive mornings. See Supplemental Materials for the full agenda of each training. Tucson and Globe/Miami trainings were facilitated bilingually in English and Spanish, to accommodate Spanish-only speakers present. All of the participants in Dewey-Humboldt and Hayden/Winkelman trainings were English speakers. Four of the facilitator-scientists are Spanish-English bilingual and conducted their presentations and discussions in two languages. All other content was provided bilingually through:

1. Simultaneous translation during the lectures, with bilingual facilitator-scientists acting as translators.
2. Dual projection of slide presentations in English and Spanish (all slides were identical in content and presented and projected in English and Spanish).
3. Spanish language kit and manual during sampling hands-on education, and bilingual educators on site to provide one-on-one assistance.
4. English and Spanish take-away copies of all slides and supplemental education materials provided in a binder (S. Sandhaus, Ramírez-Andreotta, et al., 2018, sec. Supplemental Materials) (Supplemental Materials).

2.5. Research Methods

A 17-item survey consisting of multiple-choice and short answer questions and a 33-item Likert scale survey (see Supplemental Materials) were administered to all willing participants at the beginning and end of the training, to assess changes in participant EHL. Additionally, a pre-training survey to collect demographic information, and post-training survey to gain feedback on participants' experience of the training, suggestions for future trainings, and current rainwater harvesting practice, were also administered. Participant feedback (both via survey and verbal) informed adjustments in training design and facilitation as the series of trainings progressed.

Of 67 total participants in the four trainings, 53 participants attended the entire training, completed both pre- and post-surveys, and consented under the University of Arizona IRB rule as an approved project. Of these, 14 participants were in Tucson, 15 were in Hayden/Winkelman, 14 were in Globe/Miami, and 10 were in Dewey-Humboldt. De-identified survey data included closed-ended question (Likert scale and multiple choice) responses that were recorded and analyzed quantitatively by one researcher and research assistant. Open-ended responses were reviewed and analyzed using validated qualitative methods by two research assistants and a supervising researcher. A coding scheme was created for each question that captured main concepts reflected in participant responses. The group met periodically throughout the coding process to revisit codebooks, sometimes choosing to create or merge categories based on emerging themes in the data. All survey data was organized in Microsoft Excel, and statistical analyses were performed while using Microsoft Excel and Statistical Package for Social Sciences (SPSS) software (*IBM SPSS Statistics for Windows 25*, 2017).

Table 3 outlines the specific data collected as it relates to each research question identified. The numerated list following Table 3 details specific analysis methods for each category of assessment.

Table 3. Research goals and associated data analysis methods.

Assessment Category	Data	Survey Responses Coded for:
Research goal: Gain understanding about training participants' (1) initial motivation to learn about environmental health, and (2) attitude towards the environment.		
Assessment Category	Data	Survey Responses Coded for:
1. Motivation to learn	Four short-answer questions (pre-survey only)	Themes (qualitative)
2. Attitude towards the environment	Two multiple choice questions (pre- and post-survey)	Level of pro-environmental attitude (quantitative)
Research goal: Measure change in training participant EHL, as comprised of (3) environmental science knowledge, (4) skills and (5) motivation for environmental health action, (6) self-efficacy, and (7) community action for systemic change.		
Assessment Category	Data	Survey Responses Coded for:
3. Environmental science knowledge	Four multiple choice questions, one matching question, one rank order question, seven short answer questions (pre- and post-survey)	Level of understanding (quantitative), and for themes in specific knowledge concepts (qualitative)
4. Skills for environmental health	One multiple choice question, three short answer questions (pre- and post-survey)	Level of knowledge (quantitative), and for themes in specific knowledge concepts (qualitative)
5. Motivation for environmental action	Eleven Likert-scale items (pre- and post-survey)	Level of motivation (quantitative)
6. Self-efficacy (SE)	Six Likert-scale items measure SE for learning science, four items measure SE for doing science, twelve items measure SE for environmental action (pre- and post-survey)	Level of self-efficacy (quantitative)
7. Community change	Two short answer questions (pre- and post-survey), one short answer question (post-survey only), facilitator-scientist survey responses	Themes of political advocacy, teaching others, meeting/talking/networking with others, or other collective strategies.[1]
Research goal: Gain understanding of (8) training participants' experiences in the training, and (9) facilitator-scientists' experiences in the training.		
Assessment Category	Data	Survey Responses Coded for:
8. Participant experience	Three short answer questions (post-survey only)	Themes (qualitative)
9. Facilitator-scientist experience	Open-ended survey conducted via email with a subset of the facilitator-scientists	Themes (qualitative)

[1] Volunteering as a citizen scientist for Project Harvest post-training considered as a collective strategy.

2.6. Data Analysis Methods

1. Motivation to learn was measured through four questions on the pre-program participant survey asking participants why they chose to attend, what they hoped to gain from the program, about their current rainwater harvesting practices, and what prior training on similar topics they may have received. Participant responses were coded for common themes, and occurrence of themes were aggregated to understand common motivations for choosing to attend the training.

2. Attitude towards the environment was measured by two closed-ended survey questions about preference towards environmental protection and environmental investment. Participant responses were aggregated and evaluated as a group, and pre-post change was evaluated per participant.
3. Environmental science knowledge was measured through seven open-ended and six closed-ended survey questions. Responses to four multiple choice questions were scored for level of knowledge. Responses to seven short answer questions were analyzed for both specific knowledge concepts, using qualitative coding for themes; and, for level of knowledge, by assigning a 0 (no knowledge), 1 (partial knowledge), 2 (baseline knowledge), or 3 (advanced knowledge) to each response. Coding rules for level of knowledge were specific to the question being analyzed. Table 4 describes the coding rules and example responses to one open-ended survey question.

Table 4. Level of knowledge coding rule and example responses to open-ended survey question.

Code	0—No Knowledge	1—Partial Knowledge	2—Baseline Knowledge	3—Advanced Knowledge
Coding Rule	Response is blank or reflects no knowledge of key concepts.	Response suggests some correct knowledge of topic but does not identify key concept.	Response describes key concept and is otherwise correct.	Response describes key concept with higher complexity or details.
Example question: How is the use of energy derived from coal (electricity) and climate change related?				
Example Response	*"Climate Change is the Glaciers melting, Didn't understand!"*	*"Dirty air and chemicals from burning coal"*	*"Increase in CO_2 green house gases"*	*"Burning of fossil fuels is the main contributor of rapidly increasing atmospheric CO_2"*

A dependent samples t-test was performed per question to assess significant change in participants' mean level of environmental science knowledge for each topic area. Because participants who scored below baseline knowledge pre-training had more opportunity for learning gains, an additional dependent samples t-test was performed to look at knowledge change in those participants only. For this test, questions that could only be scored right or wrong were omitted.

4. Skills for environmental health comprised a significant portion of training content. Three survey questions asked participants about specific actions they could take to 1) "curb the effects of climate change", 2) "make a positive impact on water reliability in the future", and 3) "protect the environment, conserve water, conserve energy, and protect the health of your family and neighbors". Responses to these questions were coded for categories of environmental health action. The number of participants describing each skill category was compared pre- and post-training. Additionally, specific strategies described per participant pre- and post-training were averaged per participant and compared using a dependent samples t-test.
5. Motivation for environmental action was assessed by eleven Likert scale items. These items were modified from literature provided by the Cornell Lab of Ornithology (Phillips et al., 2014), who use a similar measurement tool with their citizen science program participants. Five items were designed to measure external motivation for environmental action, and six items were designed to measure internal motivation. Following the recommended analysis methodology from Cornell, the sum of external motivation scores were subtracted from the sum of internal motivation item scores, to calculate an overall motivation score per participant. Positive scores indicate predominantly internal motivations, while negative scores indicate predominantly external motivations. A dependent samples t-test was used to analyze pre-post change in motivation for environmental action overall. A Wilcoxon Signed-Rank test was used to test for significance between the mean pre- and mean post-survey scores by community.

6. Self-efficacy (SE) is defined as a person's belief in their own capabilities (Bandura, 1982). SE was measured using a Likert scale in the categories of "SE for learning science" (six items), "SE for doing science" (four items), and "SE for environmental action" (12 items). These items were modified from the literature provided by Cornell Lab of Ornithology (Phillips et al., 2014), and analyzed using their suggested methodology. Four items on the survey were worded in reverse (statements reflected lack of SE), were therefore scored in reverse. From a total dataset of 41 paired surveys, 12 "high self-efficacy" participants were removed who met the criteria of having 15 or more responses of a 4 or 5 on the 1-5 Likert scale, to isolate the participants with an opportunity for change. Using this "low pre SE" dataset (n = 29), the mean SE for each SE category was calculated pre- and post-training for each participant, and were analyzed using the Wilcoxon Signed Rank test to assess differences between communities.
7. Community change is defined broadly here to include relationship building, network building, collaboration, educational advocacy, and political advocacy. Participant responses to three survey questions and reflections from facilitator-scientists were analyzed for community action themes. Additionally, the individual decision by a participant to further invest their time and effort as an environmental citizen scientist post-training was considered to be a community-level action, as participation in co-created citizen science involves translating results into responsive action as part of the study design (Shirk et al., 2012).
8. Participant experience was assessed through qualitative coding for themes in responses to four open-ended survey questions related to participant perception of benefits of the training, their intentions to harvest rainwater, and suggestions for training improvements and future trainings.
9. Facilitator-scientist experience was assessed through an open-ended survey via email with four of the facilitator-scientists, all who were involved in the design and agenda planning for the trainings. Survey questions asked for general reflections, specific surprises or challenges in the trainings, and for specific anecdotes of participants connecting content to local knowledge or life experiences.

3. Results

Summary: The majority of training participants came to the training with intrinsic motivation to learn, high internal motivation for environmental action, and pro-environmental attitudes. Before and after the training, the majority of participants demonstrated baseline knowledge or above in the topics of greenhouse gases, climate change, scientific method, soil and water contamination, and contaminant transport. Participants who demonstrated below-baseline knowledge pre-training in the topics of climate change impacts, fossil fuel impacts, soil and water contamination, and chemical concentrations demonstrated significant knowledge gains post-training. Participants who demonstrated low self-efficacy (SE) pre-training demonstrated significant increase in all SE categories post-training. Survey responses reflecting community-level action for environmental health were present but not frequent. Participants' reflections on the training experience emphasized gaining knowledge, strategies for environmental health, and greater appreciation for the environment and science. Facilitator-scientists reflected on the benefits of gaining first-hand contextual knowledge of an area from community members, building trust relationships with community members, and gaining a deeper sense of meaning in their work through learning directly with members of environmental health risk communities. The following subsections provide further detail.

3.1. Participant Demographics

Overall, training participants (n = 53) were 64% female, 36% male. 62% identified as White/Caucasian, 36% identified as Latino/Hispanic, with other ethnicities being represented by 6% or less of the group. Three participants in Tucson and one in Globe/Miami were Spanish-dominant speakers, the rest were English-dominant speakers. All four Spanish-dominant speakers cited English as a secondary language, and 14 English-dominant speakers cited Spanish as a secondary language. 60% of participants reported having a college degree, though the level of education ranged to high school only (10%). Using 2015 HUD Income Guidelines, 28% of participants reported living in households designated as "Low Income" or below ($47,200 annual gross income or less for a family of four). 76% of participants were aged 45 years or older and 26% of the total group were 65 years or older.

3.2. Participant Motivation and Attitude

Overall, participants who volunteered to attend these trainings showed a high level of motivation to learn, high internal motivation for environmental action, and pro-environmental attitudes before and after the training. In Hayden/Winkelman, 19 out of 22 participants were teachers at the local school and were attending as part of their professional role with endorsement from the school superintendent. In Tucson, four of participants are employed as *promotoras* (community health workers) with SERI, participating as part of their paid employment, as required training for their upcoming role in Project Harvest. Otherwise, participants had elected to attend on their own time. 54% of responding participants reported attending previous workshops related to the environment, water, or energy. Participants' household rainwater harvesting or food gardening practices were often cited as reasons for wanting to better understand environmental health risks (48%). The desire to help the environment (34%), and to learn practical skills to improve environmental and personal health (22%) were also cited as reasons for attending. Some responses cited local knowledge or personal experience that motivated their interest in environmental health. As one Globe-Miami participant stated:

"We dug a cistern and have harvested rainwater for 30 years. We live in the canyon where Dioxin / Agent Orange was sprayed in the Pinal [Mountain]s 1965–1969. Many problems associated with that. Interested in present contamination, also because we grow our own vegetables".

Participants indicated their motivation for environmental action via eleven Likert scale statements on a 1-5 scale. Pre-training, the mean internal motivation was 4.4, and mean external motivation was 3.1. Post-training, the mean internal motivation score did not change, and mean external motivation was 3.0. A dependent t-test using the mean internal-external motivation scores resulted in no significant difference pre-post ($p > 0.05$). Wilcoxon Signed-Rank test results demonstrated no significant pre-post change in motivation by community ($p > 0.05$).

Additionally, two survey questions asked for participants' preference of environmental protection and environmentally sustainable investment. 84% of responses ($n = 38$) favored all environmental proposals in both the pre- and post-surveys. Only one participant had pre- and post-responses for both questions that consistently reflected negative attitudes towards environmental protection.

3.3. Environmental Science Knowledge

As outlined in Table 5 below, participants generally came to the training with at least baseline knowledge of greenhouse gases, climate change, scientific method, soil and water contamination, and contaminant transport. Significant knowledge gains were demonstrated in the topics areas of climate change, including increased specific concepts cited related to climate change causes and impacts (see Figure 3); and, in understanding chemical concentration nomenclature, which is critical to understanding environmental contamination information.

Table 5. Level of environmental science knowledge pre- and post-training, all participants.

Survey Question # and Content	Mean Pre-Training Score [1]	Mean Post-Training Score [1]
1. Greenhouse gases	1.37	1.45
2–4. Impacts of climate change	1.79	2.42 *
6. Fossil fuel use impacts	1.00	1.74 *
8. Scientific method [2]	0.84	0.87
9. Contaminant transport [2]	0.92	0.97
10. Soil composition [2]	0.95	0.97
14–16. Soil/water contamination	1.87	2.23
17a. Chemical concentrations	1.45	2.32 *
17b. Chemical concentrations	0.92	2.05 *

* Significant change pre-post ($p < 0.01$); [1] Responses were assigned one of the following: 0 = No Knowledge, 1 = Partial Knowledge, 2 = Baseline Knowledge, and 3 = Advanced Knowledge. [2] This was a right/wrong question, which could only be scored as 0 = Incorrect, 1 = Correct.

Isolating only participants who scored below the baseline level of knowledge on specific questions, significant knowledge increase was observed post-training related to impacts of climate change and fossil fuels, soil and water contamination, and chemical concentrations, as shown in Table 6.

Table 6. Level of environmental science knowledge in "below-baseline pre" participants only.

Survey Question # and Content	Below-Baseline Participant *n*	Mean Pre-Training Score [1]	Mean Post-Training Score [1]
1. Greenhouse gases	20	0.80	1.10
2–4. Impacts of climate change	13	0.77	1.92*
6. Fossil fuel use impacts	27	0.37	1.44*
14–16. Soil/water contamination	13	0.31	1.85*
17a. Chemical concentrations	21	0.24	2.10*
17b. Chemical concentrations	32	0.22	1.88*

* Significant change pre-post ($p < 0.01$); [1] Responses were assigned one of the following: 0 = No Knowledge, 1 = Partial Knowledge, 2 = Baseline Knowledge, and 3 = Advanced Knowledge.

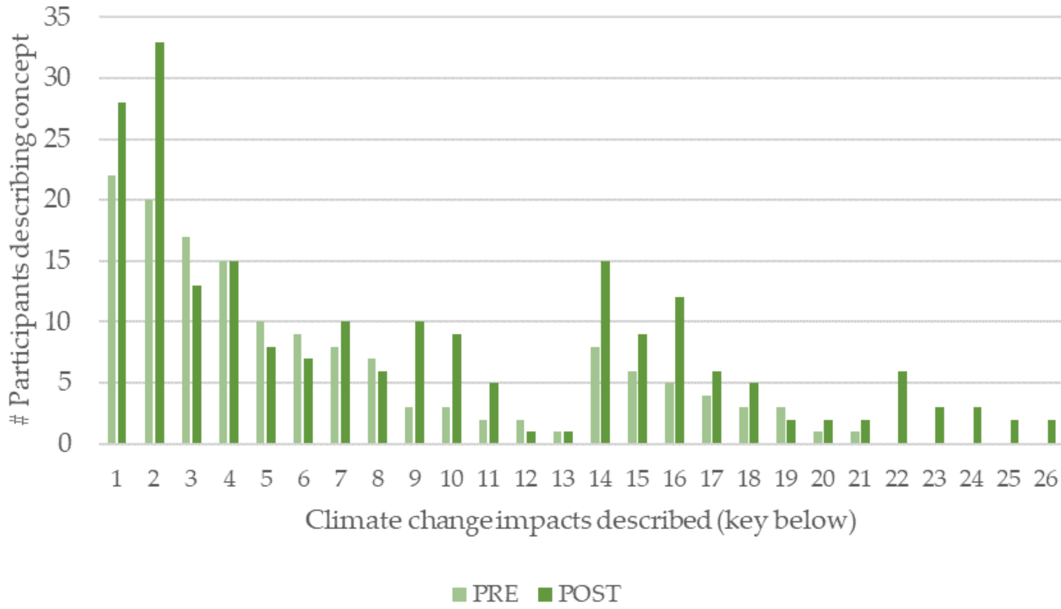

Figure 3. Described knowledge concepts of climate change impacts.

Baseline Knowledge Concepts:

1. Earth temperature increasing
2. Melting glaciers/ sea level rise
3. Extreme weather events
4. Droughts
5. Warmer summers
6. Floods
7. Loss of plant/ animal species
8. Decrease cold days/ cold temps
9. Land loss due to sea level rise
10. Atmospheric CO_2 increasing
11. Air quality decrease
12. Negative effects on human health
13. Decreased ozone layer

Advanced Knowledge Concepts:

14. Negative effects on agriculture
15. Human/animal migrations
16. Warming oceans, loss of coral
17. Increased regional water stress
18. Changes in precipitation patterns
19. Social instability
20. Coastal floods, higher tides
21. Increase fire events
22. Changes in global wind patterns
23. Plant zones changing
24. Changes in polar and ocean currents
25. Increased energy use
26. Keeling's Curve shows CO_2 increasing

Although the level of knowledge related to soil and water contamination did not change significantly, the following environmental contamination concepts were described more frequently post-training, as illustrated in Figure 4: historic land uses as a contamination source, wind transport of contaminants, herbicides or pesticides as contaminants, microorganisms as contaminants, correctly naming organic (carbon-based) and inorganic (salts and metals) contaminants, and auto emissions as contaminants.

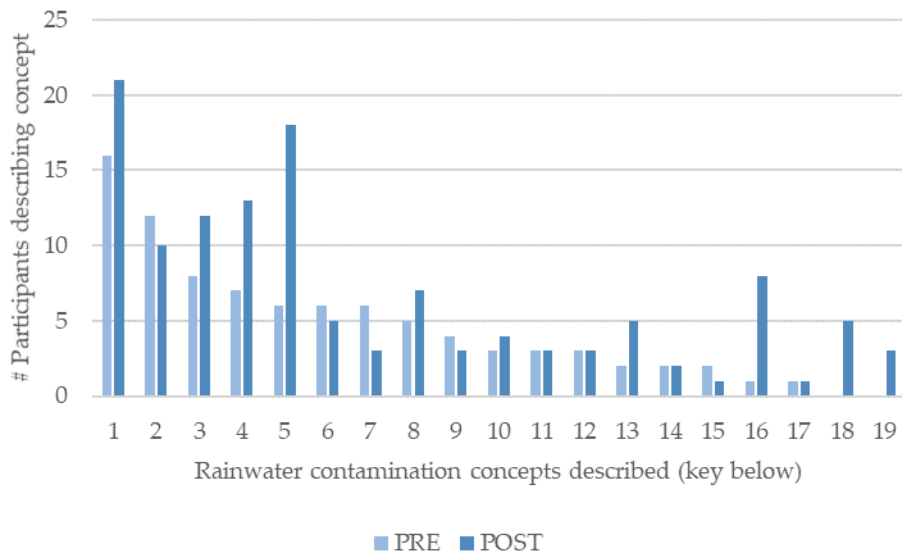

Figure 4. Described knowledge concepts related to rainwater contamination.

1. Source: Roof/Home Materials
2. Source: Agriculture/Livestock
3. Source: Air pollution
4. Source: Historic land uses
5. Contaminant transport by wind
6. Source: Industry
7. UV-breakdown releases contaminants
8. Contaminant transport to food
9. Source: Naturally occurring contaminants
10. Environmental policy affects local contamination
11. Source: Sewage
12. Source: Dust
13. Source: Herbicides/pesticides
14. Contaminant transport through precipitation/sheet flow
15. Source: Improper material disposal
16. Source: Microorganisms
17. Source: Animals/insects
18. Organic vs inorganic contaminants
19. Source: Auto emissions

3.4. Self-Efficacy

Significant self-efficacy (SE) gains post-training were observed in all SE categories for participants who did not demonstrate high self-efficacy pre-training, with the largest gain in SE for doing science. This may be due to the hands-on portions of the training, where participants practiced sampling and analysis of water for contaminants, using laboratory equipment and following methods developed by professionals. Table 7 illustrates results of a Wilcoxon Signed-Rank test to assess pre-post change in SE by category.

Table 7. Wilcoxon Signed-Rank Test Results for Participants' Pre-Post Self-Efficacy (SE) Change.

Self-Efficacy (SE) Type	Mean Pre	Mean Post
SE for learning science	2.70	3.76*
SE for doing science	2.63	3.47*
SE for environmental action	3.53	4.00*

* Significant change pre-post ($p < 0.01$)

3.5. Skills for Environmental Health Action

Analyzing paired surveys ($n = 36$), the mean number of specific skills mentioned per participant pre-training was 9.6, the mean skills mentioned per participant post-training was 13.2. A dependent samples t-test produced a significant ($p < 0.01$) increase post-training.

General strategies, such as “conserve water” or “save energy”, were not counted as a “skill” towards the total skills cited per participant described above, though these general statements were summed under the category “General”. More participants described skills that were emphasized in training content in post-training responses, including rainwater harvesting, planting native plants and trees for shade, and home energy conservation practices. Figure 5 illustrates the most frequently described skills for environmental action pre- and post-training.

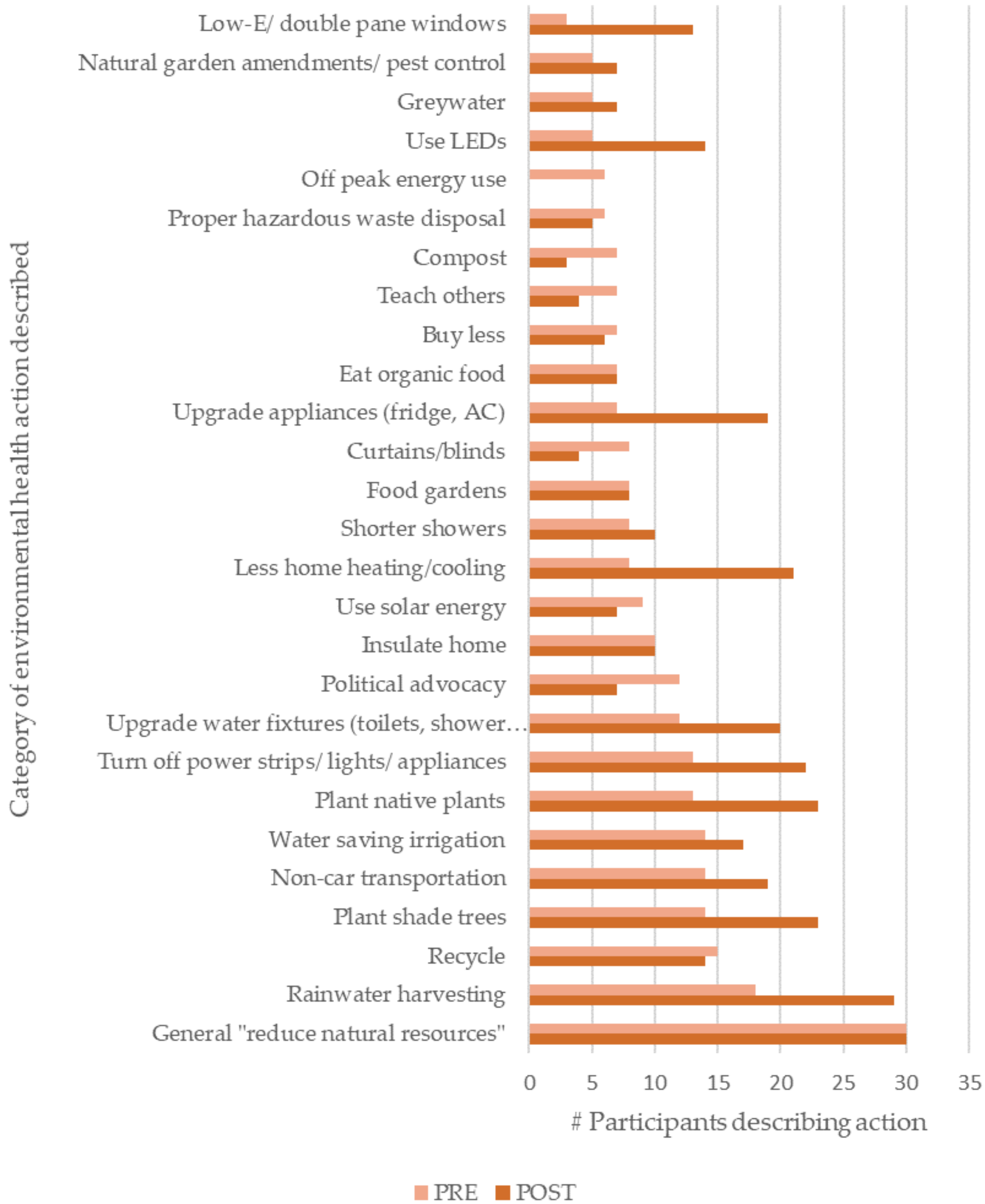

Figure 5. Most frequently described skills for environmental action.

3.6. Community Change

The act of bringing interested people together around learning from each other is, at its core, a community action. The hands-on portions of the training allowed participants to build relationships and shared skills, and discussion portions allowed for participants to share personal and family experiences related to environmental health. One facilitator-scientist observed participants most often responding with stories or questions from personal experience following presentation content about specific contaminants of concern for the area.

As one facilitator-scientist reflected, *"During [the Globe/Miami] training, we would talk about the potential for heavy metal contamination of water—and the community members, who had lived under these huge smokestacks their whole lives, would tell stories of living and working in an environment where the mines were providing a living but were also potentially spewing toxins—which could get onto the roofs and wash into the rain barrels".*

Another facilitator-scientist reflected, *"[In the Hayden/Winkelman training] we spent 20–30 minutes talking about their experiences as a child growing up in the area, swimming in the river with what they suspected to be tailings and waste water from the mine, their child's lead biomonitoring data, and air quality".*

The skills for environmental health that were described in Section 3.5 included two skills categories that emerged related to community action: social/political advocacy around environmental health issues, and teaching others about environmental health, as detailed in Table 8. Comments related to community action were mentioned by less than 5% of participants, though they were also not emphasized in training content nor being directly solicited by survey questions. However, this may also reflect a conceptualization of environmental health action limited to the individual or family scale for the majority of participants.

Table 8. Participant survey responses related to community action.

Type of Community Action	Examples
Political/ Social Advocacy	*"Learn, listen, and organize with people & neighborhood"* —Tucson participant *"If possible share emails to be able to get in touch with others"* —Tucson participant *"Call political representatives to let them know we need to keep the EPA intact"* —Globe/Miami participant
Teach Others	*"Networking, collaboration and information to help educate others in our community including in our school garden program"* —Dewey-Humboldt participant *"So much info! Shared with grandparents who already harvest water"* —Hayden/Winkelman participant

Six of the training participants had been already been hired as *promotoras*, or community health workers with citizen scientists in Project Harvest prior to the EHL training. One especially enthusiastic participant in Dewey-Humboldt was later hired as an additional community health worker for her community after the training. Nine other participants from the EHL trainings volunteered after the training for the three-year commitment of serving as a citizen scientist in Project Harvest, continuing to monitor local environmental contamination alongside other community members and university researchers.

3.7. Reflections from Participants

When asked, "What did you gain this week?" participants most often cited gaining scientific or environmental knowledge (69%), practical environmental health strategies or skills (44%), or greater awareness or appreciation for the environment and/or environmental science (40%). Examples included:

"*An appreciation of how things are connected. How these connections can be identified & monitored for protecting our public health*".—Globe/Miami participant

"*Calentamiento global, el peligro de algunos microorganismos. Importancia de conservar*". (Global warming, the risk of some microoganisms. Importance of conservation.)—Tucson participant

"*Deeper understanding of how and why CC [climate change] is occurring, stronger appreciation for the efforts of the scientific community, understanding and appreciation for the idea of "democratized science"*. —Hayden/Winkelman participant

3.8. Reflections from Facilitator-Scientists

Reflections from a subset of facilitator-scientists (n = 4) largely reflected benefits that were gained from conducting in-person training with community members, categorized below.

3.8.1. Formative Evaluation of Materials

Instructional booklets and sampling kits used in the trainings were piloted in part for their intended use with citizen scientists in Project Harvest the following year. Verbal and survey feedback from participants provided formative evaluation of these materials, and many suggestions were incorporated in material revisions or prompted the creation of new materials, such as video tutorials on sampling methodology.

3.8.2. Gaining Local Knowledge to Inform Research

Spending time with community members in person allowed for scientists to gain understanding about community culture, beliefs, concerns, events, and history that informed the design of future research with these communities.

One facilitator-scientist described learning local contaminant history that researchers were not previously aware of: "*A husband and wife [in Globe/Miami] told us about how they suspected Agent Orange was sprayed in their neighborhood; we actually looked into this and confirmed indeed they had sprayed Agent Orange-there are a number of documents about it available.* (Shoecraft, 1971; U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, 1998) *So we added it to our contaminant list for analysis. There is a legacy of spraying by the federal government on Forest Service land southwest of Globe and on the nearby Apache Reservation east of town*".

Another facilitator-scientist described learning of a concern community members had about local contamination study: "*A participant at one of the trainings shared a story where they had recruited a few fire fighters to join and do the training. They were excited and planned on attending, but were talked out of it by a firefighter's wife. The wife stated that if the study observed any pollutants/elevated concentrations it would affect their ability to sell their home. The participant expressed frustration about their community and stated '…so when she said that I said, so your home value and selling your home is more important than your children's health?'*" This anecdote highlights specific fears and social pressures present within the community.

3.8.3. Building Relationship and Co-Creating Hope with Community Members

Relationships are built face-to-face, through dialogue and personal sharing. In rural areas especially, community members may feel distrustful of the motives and interests of research institutions. One facilitator-scientist reported some participants expressing skepticism about research motives being expressed in the trainings. However, in a face-to-face setting, she could explain her personal motivation for studying environmental health, and gain trust of community members. These personal relationships are immensely important for continued research in these communities with high environmental risk. Facilitator-scientists also expressed gaining a deeper sense of meaning in their work from the training experience. One stated, *"I derived a sense of hope by witnessing the participants engaged in learning our presentation topics".* Another shared, *"To be perfectly honest, I approached this project as a scientist—in the beginning, I was much more interested in the water quality results, and the trainings/teaching was kind of secondary. But halfway through the first training I found myself really enjoying it—and ended up looking forward to the following trainings very much*".

4. Discussion

4.1. Study and Survey Design

The mixed methods evaluation approach of using both closed-ended and open-ended survey questions, in addition to soliciting open-ended reflections from participants and facilitator-scientists, provided a comprehensive understanding of the training experience and outcomes from multiple perspectives. Additionally, facilitating trainings sequentially in four different communities provided valuable process feedback that allowed for continuous improvements.

Post-training surveys were administered immediately following the training experience, which limits our understanding of how the training might have contributed to participant knowledge, skills, and actions on a longer term. Additionally, all data was self-reported, which introduces the possibility for participant bias (Tourangeau & Yan, 2007). For example, participants may have felt social pressure to align with pro-environmental norms present in the training content.

Results reveal some limitations with the survey instruments used and inform recommendations for future survey design. The thirteen survey questions testing environmental science knowledge were specifically designed to vary in style and difficulty. However, closed-ended questions 9 and 10 (see Supplemental Materials) provided little value as almost all participants answered correctly both pre- and post-training, suggesting that the results might be due to "easy" question design rather than participant knowledge. Open-ended questions allowed for greater insight into participants' thinking, though were more difficult to assign a quantitative level of knowledge to. For future assessments of environmental health knowledge, experience from this study informs the recommendation that survey design 1) Be as specific as possible to the local environmental health risks and contaminants in the community, and 2) Use matched open-ended and closed-ended questions that assess the same topic for the effective analysis of both level of knowledge and specific knowledge concepts and misconceptions.

Adhering to Bandura's statement that there is "no all-purpose measure of perceived self-efficacy" (Urdan & Pajares, 2006) (p. 307), it proved successful to tailor previously tested Likert scales for SE (Phillips et al., 2014) to the specific types of SE relevant to the training (learning science, doing science, and environmental action; all related to soil and water quality). The survey also included modified Likert scale statements for motivation for environmental action from the literature (Phillips et al., 2014). Grounded in self-determination theory (Deci & Ryan, 2008), these motivation statements include separate items for internal and external motivations. We followed suggested analysis methodology from the authors of the original scale by subtracting external from internal motivation to achieve a "true" motivation score (Cornell Lab of Ornithology Evaluation Research, 2017; Phillips et al., 2014). However, averaging all motivation items (internal and external) per participant produced similar pre-post change results. Acknowledging the sociocultural emphasis in contextual learning, and the value of peer-to-peer negotiation of knowledge observed in these trainings, we inquire whether external motivation might have real value in its influence on environmental action. This inquiry draws from recent research in science education, which places greater emphasis on discourse, social identity, and sociocultural context as primary, rather than background, elements of learning (Bingle & Gaskell, 1994; B. A. Brown, Reveles, & Kelly, 2005; Sadler, 2009). Furthermore, when community action may be necessary to address the specific environmental health risk posed, social motivation might play a valuable role in collective action, especially in rural areas (Bramston, Pretty, & Zammit, 2011). Thus, measuring motivation for environmental health action may necessitate weighting external and internal motivations equally.

Questions assessing participants' motivation to learn were open-ended and not designed for discriminating between internal and external motivation in responses. However, general motivation to learn and a pro-environmental attitude was observed in nearly all training participants pre- and post-training, suggesting that these qualities may be prerequisites for any volunteer-based EHL program.

4.2. Contextual Learning and Collaborative Relationships

In the recruitment, planning, facilitation, and evaluation of these community-based EHL trainings, the importance of contextual learning and teaching stands out. In each of these four communities, the unique history and culture dictated the appropriate manner of communicating environmental health information. In Globe/Miami, for example, the copper mine is both the main source of environmental health risk and the largest local employer. If a facilitator did not present environmental health risk information with knowledge and sensitivity to residents' loyalty to the mine, then they would risk participants rejecting the information completely, and create barriers to future collaboration. However, by honoring local values and beliefs in the presentation of information, participants remain open to learning, even when information may challenge their perceptions. As most of the facilitator-scientists had limited prior experience with the partnering community, introducing a topic with guided open-ended questions ("How could your rainwater be contaminated?") allowed for participants to provide culturally-appropriate content, often in the form of personal stories, that informed understanding of cultural context and allowed for connecting training content to participant experience and perceptions. At the conclusion of some training sections, the facilitator-scientist would pose the questions, "What else should we be measuring for? Is there anything else we need to know?" which allowed for participants to fill in gaps of the formal presentation with local knowledge. The critical role of local context in EHL education aligns with complementary research in the fields of health communication, environmental communication, and science education (Adams et al., 2011; L. Colucci-Gray, 2014; Lee et al., 2005; Neuhauser, 2017; Pezzullo & Cox, 2017; S Madrigal et al., 2016; Zemits et al., 2015).

Environmental health risk communities might approach university researchers with distrust, as we experienced in this study. In all four communities, prior relationship and collaboration with reputable local organizations paved the way for further trust building with community members. In two communities, specific local individuals that were enthusiastic about the training program served as local "champions" (Gallagher, 2009) to motivate others. Additionally, a supportive learning environment, as observed in these trainings and prior research (Carlone et al., 2015), is a critical element in a learner's willingness to explore and accept new ideas and experiences. The importance of details in curating this kind of environment, from a familiar setting to supportive micro-interactions between community members and "experts", cannot be understated.

4.3. Environmental Health Literacy and Community Action

Evaluating these trainings using the three dimensions of EHL, as proposed by Gray (Gray, 2018), described in the Introduction and outlined below, was instrumental in defining participant "learning" in the context of an environmental health risk community, as well as identifying opportunities and challenges in future EHL research.

4.3.1. Knowledge and Awareness

As other scholars have discussed, EHL is highly contextual and it thus presents challenges for creating generalizable education or evaluation materials (Adams et al., 2011; Ratnapradipa et al., 2015; S Madrigal et al., 2016). Relevant knowledge and awareness for EHL is specific to the community, the environmental health risks present, and the broader ecological, economic, and political dynamics of these risks. Although this reality poses challenges for defining and evaluating knowledge, it also forces us to critically examine what constitutes "relevant knowledge" for a given environmental health risk community. Whose knowledge? For whose benefit? In some cases, academic environmental health knowledge has been positioned in conflict with local knowledge, albeit unintentionally (Allen, 2004). The face-to-face interactions between participants and facilitator-scientists in these EHL trainings were critical in facilitating the exchange of formal and informal knowledge as equal contributions to the construction of group knowledge.

To further honor the concept of knowledge as it is relevant to the community context, future survey evaluation of knowledge for EHL might benefit from moving away from formal science questions, towards more open-ended inquiry that allows for the community member to determine what knowledge is valuable. If a follow-up study with participants of these trainings was conducted, a question like, "What thoughts, ideas, or questions have you had since the training related to your health and environment?" may provide the most pertinent data.

Many previous environmental health interventions have disseminated health information from an authority (via brochures, website, etc) as the primary strategy (Fitzpatrick-Lewis, Yost, Ciliska, & Krishnaratne, 2010; Harvey & Fleming, 2003). It is critically important that EHL education not approach community members as blank slates. Rather, new knowledge is mediated by prior beliefs and experiences (J. Falk, 2002; J. Falk & Storksdieck, 2007), as well as through interaction within a social group (González-Howard & McNeill, 2016; Olitsky, 2007; Wenger, 2011). Finn and O'Fallon describe EHL as "a process that individuals and communities embrace as a means of critical reflection within their local socioeconomic context rather than as a type of health literacy that incorporates specialized knowledge of environmental factors (Finn & O'Fallon, 2017)". Thus, what defines knowledge for EHL in an environmental health risk community should ultimately prioritize community concerns over academic biases, as has been skillfully demonstrated in some prior community-based environmental health research (Allen, 1998; deLemos et al., 2007; Stokes et al., 2010; Zemits et al., 2015).

4.3.2. Skills and Self-Efficacy (SE)

As learning leads to curiosity and further conversation, we saw EHL knowledge leading directly to the development of skills and SE for environmental health in training participants. Like knowledge, relevant skills and SE are specific to the community context and local risks, and they should be defined and evaluated accordingly. There may be several specific types of SE to measure for a single environmental health risk community. For example, a study may want to know participants' SE for sampling water and SE for talking to others about water quality results, to fully understand community members' capability to address an environmental health risk.

Just as Cornell Lab of Ornithology has developed modifiable Likert scales for any specific SE type (Phillips et al., 2014), which were used effectively in this study, generalizable evaluation tools for the knowledge-to-skills continuum of EHL should be further developed and tested. Finn and O'Fallon suggest a model that is based on Bloom's taxonomy to assess literacy development for specific environmental health issues (Finn & O'Fallon, 2017), which is already being applied in the field (S Madrigal et al., 2016). Their model suggests that actions taken at various levels of EHL could be an important indicator of EHL development.

4.3.3. Community Change

If a project to increase EHL in an environmental health risk community does not ultimately aim to reduce harmful exposures, it is difficult to identify how the project might benefit the community. Although many EHL programs, including this one, have focused on individual- and household-level actions to reduce environmental exposures, reducing environmental health risks at their primary sources (industry, mining, city or state land use decisions, eg) require larger coordinated efforts. Some environmental health researchers have used community-based approaches not only as a purposeful tool for research, but also for community-level action (Ablah, Brown, Carroll, & Bronleewe, 2016; Ali, Olden, & Xu, 2008; Commodore, Wilson, Muhammad, Svendsen, & Pearce, 2017; Gonzalez et al., 2011; Ponder-Brookins et al., 2014), and academics are well positioned to support environmental health risk communities in making systemic change. Explicitly defining community change as the highest level of EHL mandates that EHL interventions measure their success at least partially on whether positive community change transpires. This may mark a significant shift in programs to increase EHL moving forward, towards closer alignment with approaches such as community-based participatory research (CBPR), which state community action grounded in research findings as an explicit goal (M. D. Ramirez-Andreotta, Brusseau, Artiola, Maier, & Gandolfi, 2014). Although many studies have successfully used qualitative and community-based research methods to elucidate the more complex and dynamic factors influencing environmental health, including social factors, these methods remain underrepresented in the environmental health field (Baron et al., 2009; Scammell, 2010).

Community action was not a focus of the trainings discussed here, as facilitator-scientists understood the sensitive nature of their role as outsiders and wanted to position themselves as supporters rather than instigators. However, these trainings were designed in part to recruit volunteers for an environmental health citizen science project, which was envisioned as the community action that training participants would be excited to pursue. Although hands-on practice with sampling methods was included in the training, and a significant increase in SE for doing science was observed post-training, it was surprising that only nine training participants signed up as citizen scientists. However, harvesting rainwater at home was a requirement to sign up as a citizen scientist, as the project involves monitoring harvested rainwater, and only twenty training participants indicated that they were currently harvesting rainwater at home. Thus, just under half of eligible participants (9 out of 20) did continue with the "action" part of the project. Over 160 residents of these four communities did ultimately volunteer and are currently acting as citizen scientists, however their recruitment to the project largely came through one of the designated project promotoras or other local leaders, rather than through attending a training. Acknowledging the barriers to citizen science participation that persist especially for diverse community members (Pandya, 2012), successful recruitment of diverse participants for Project Harvest suggests the promotora model as a recommended method (Monica Ramirez-Andreotta, 2019; S. Sandhaus, Ramírez-Andreotta, et al., 2018), which should be applied and studied further.

The hesitation expressed by a few training participants to learn about pollution on their property indicates a potential barrier to community-level environmental health action. Their concerns were primarily the potential decreased property values or legal responsibilities if unsafe contaminant levels were found. Additionally, especially in active mining communities, environmental monitoring can be perceived as a direct challenge to the status quo, potentially threatening jobs and economic viability in the area. Particularly in small communities, social pressure might inhibit a community members' intrinsic motivation to act despite their concerns about health risk.

By creating a supportive environment for shared learning and relationship building, these trainings allowed community members and university researchers to gain understanding and trust, which sets the stage for further collaboration. Academics engaging directly with members of environmental risk communities in shared learning is in itself a community action, which allows alliances to be built and knowledge to be shared across cultural divides. We hope this study will motivate other environmental health researchers to invest in contextual learning with members of the communities who could most benefit from, and best inform, their research.

5. Conclusions

This study reveals a unique approach to both increasing EHL in environmental health risk communities and opening the door for community-academic partnerships for environmental health research and action. Although this in-person approach requires a considerable time commitment from both university researchers and community members, both parties benefit from the investment. Community members increase EHL specific to local risks, network with others interested in environmental health learning and action, build relationships with university researchers, and inform the direction of future research. University researchers share their professional knowledge directly with those for whom it is most personally relevant, build relationships with potential future research collaborators, and learn local knowledge and context to inform future study. In this study, awareness of cultural context (setting, language, cultural beliefs) was the most critical aspect of a successful training program to increase EHL. By meeting members of environmental health risk communities "where they're at", quite literally, academics position themselves to work alongside the public for greater impact of their research.

Supplementary Materials: More information about Project Harvest can be found at projectharvest.arizona.edu. Instructional videos on water, soil, and plant sampling methods taught for home environmental contamination analysis can be found at https://projectharvest.arizona.edu/get-started#videos. The following are available online at www.mdpi.com/xxx/s1, S1: Recruitment flyers in English and Spanish, S2: Agendas from community trainings, S3: Pre-program survey, English version, S4: Content Survey, English version, S5: Post-program survey, English version.

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Engaging Citizen Scientists for Environmental Health: Recommendations from Participants and *Promotoras* in Project Harvest

1. Background

1.1 Research context

Citizen science (CS) has been gaining rapid popularity over the past several decades (Pocock et al., 2017) as employing volunteer data collectors can dramatically increase both scale of a research project and attention to local detail in the data. Recently, researchers have demonstrated mutual benefits for CS volunteer participants, who may gain a better understanding of science, increased awareness of their surroundings, and increased confidence to participate in scientific activities, because of their CS participation experience (Bonney et al., 2009; Dickinson et al., 2012; Evans et al., 2005; Jordan et al., 2012; National Academies of Sciences, 2018; Trumbull, Bonney, Bascom, & Cabral, 2000).

As CS participants have also been demonstrated to increase knowledge and self-efficacy to address local problems, participatory CS may also offer a powerful advocacy tool for disenfranchised communities burdened by environmental health risks (Allen, 2018; Averett, 2017; Bonney et al., 2016; P. Brown, 1997; Ottinger, 2010; S. Sandhaus, Kaufmann, & Ramirez-Andreotta, 2018). In limited cases, communities have self-organized to collect data and take action against environmental health risks without the backing of a research institution (Dhillon, 2017; E. Hoover, 2016; Scott, 2016). However, for university-funded CS projects, volunteer participants are overwhelmingly educated, affluent, and white (Evans et al., 2005; Pandya, 2012; Soleri et al., 2016).

As dominant political and economic structures systematically co-locate people in poverty with environmental contamination and create disproportionate burdens on their time and resources (Bullard, 2008; Cole & Foster, 2000; Morello-Frosch et al., 2011), those most likely to be affected by environmental health stressors may be the least likely to participate in research aimed at addressing it. Additionally, potential economic, cultural, and racial barriers to relationship building between professional researchers and historically disenfranchised community members increase the possibility of unsuccessful community engagement, or even exacerbating harms to community members (Allen, 1998; Foster & Dunham, 2015; Saxton et al., 2015). Recognizing the important differences of a CS participant population in an environmental health context, where community members are more likely to be affected by historic and present forms of oppression, CS for environmental health must be uniquely designed to motivate community members affected by potential risks and facilitate accessible engagement.

Researchers have provided recommendations for conducting environmental health CS projects (Barzyk et al., 2018; Den Broeder et al., 2018; English et al., 2018). Defined best practices emphasize incorporating elements of community-based participatory research (Balazs & Morello-Frosch, 2013; P. Brown, 2013; Israel et al., 2012; O'Fallon & Dearry, 2002) and participatory action research (Baum, MacDougall, & Smith, 2006; Freire & Ramos, 2014) into standard CS methods. However, prior literature on best practices have lacked direct input from participants to inform recommendations. In this study, 127 participants and 7 *promotoras* in Project Harvest, an ongoing co-created CS project, contribute their perspectives toward the creation of a "deliberate design" (Shirk et al., 2012) for evidence-based participatory environmental health CS research methods, with the goal of advancing more effective research projects and more equitable outcomes for communities facing environmental health stressors. As the larger body of CS practitioners also moves towards the goal of greater inclusion and equity at all levels, this study also aims to produce findings generalizable to inclusive CS project design.

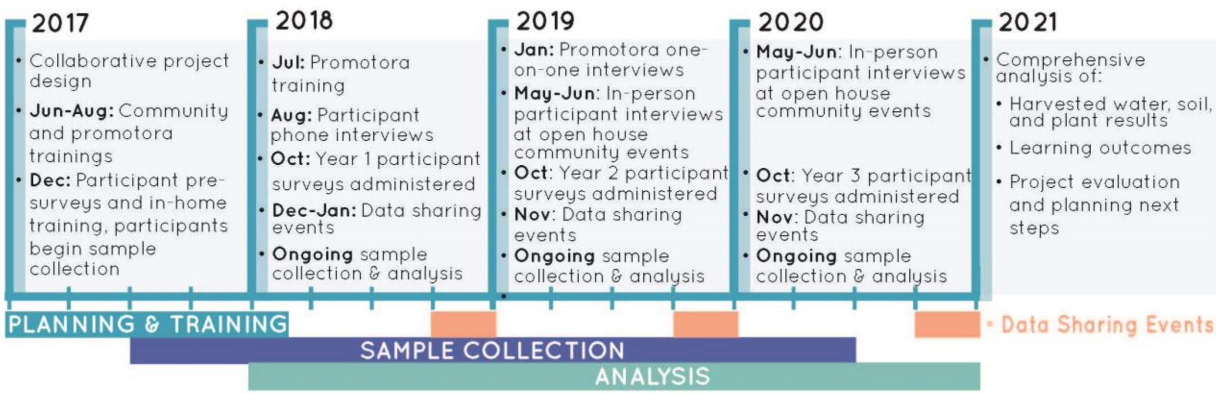
1.2. About Project Harvest

Project Harvest (www.projectharvest.arizona.edu) was launched in 2017 as a collaborative effort by researchers at the University of Arizona (UA) and the community-based organization Sonora Environmental Research Institute, Inc. (SERI), to facilitate community-led environmental monitoring in four geographic areas of Arizona, USA, with known sources of environmental contamination. Primary project goals are to produce local data on contaminants present in harvested rainwater, as well as rainwater-irrigated soil and food plants; increase community involvement in environmental decision-making; and increase environmental health literacy in underserved rural and urban communities.

Project Harvest is a co-created CS project (Shirk et al., 2012), for the following reasons: 1) The central research question, to determine the degree of health risk or safety in harvested rainwater, and rainwater-irrigated soil and food plants, originated from the voiced concerns of community members in Dewey-Humboldt, AZ, during participation in a previous CS project (M. D. Ramirez-Andreotta, Brusseau, Artiola, Maier, Gandolfi, et al., 2014), 2) Research design and project proposal was collaboratively crafted by UA researchers and SERI, 3) Throughout the project, feedback from SERI staff, *promotoras*, and participants continues to provide formative evaluation and inform responsive modifications in project methods.

Project Harvest is in its 2nd year of participatory data collection at the time of this writing, as shown in the project timeline (Figure 1) below. The data and findings presented herein serve both as formative evaluation for the project, and to share lessons learned at this point with the broader community of CS practitioners. Although much of the participant research in Project Harvest is focused on measuring environmental health literacy, here we focus on what has motivated and facilitated *participation*, especially for underrepresented CS participants.

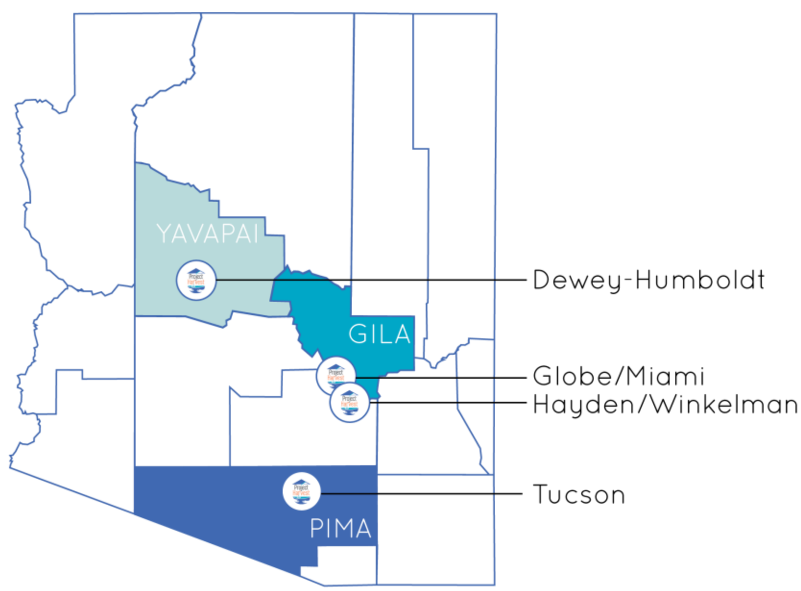
Figure 1. Project Harvest timeline



1.3. Project Harvest Communities and Participants

Figure 2 illustrates geographic locations, and Table 1 describes each defined community and its project participants. Three locations- Dewey-Humboldt, Globe/Miami, and Hayden/Winkelman- are considered rural, while Tucson is considered urban. Following established recommendations for community-based participatory research (CBPR) (Israel et al., 2012), communities were defined as a unit of identity, rather than by municipal boundaries. For this reason, in two of the rural geographic areas, neighboring municipalities which share histories, sources of environmental health risk, and cultural attributes were defined as one identity. In the urban area of Tucson, two distinct communities were defined by how they were recruited to the project. As SERI's organizational focus is low-income households, participants recruited directly by SERI are predominantly low-income and Spanish speaking. Other Tucson participants who had previously received a rebate for a home rainwater harvesting system were recruited through the water utility (Tucson Water). Though these participants were also partnered with a SERI staff *promotora* for the duration of the project, participants recruited through Tucson Water are defined as a separate community as they are predominantly non-low-income, college educated, and English speaking.

Figure 2. Geographic locations of Project Harvest participants



Initial community outreach and participant recruitment took place through public trainings facilitated by project staff in the four selected areas, which focused on rainwater harvesting and water contamination while incorporating participants' prior environmental health risk knowledge and lived experiences to co-create training content (Davis et al., 2018). Due to the requirement that participants live in specific geographic areas and harvest rainwater at home, some interested workshop participants were ineligible to participate in Project Harvest. The majority of the Project Harvest participants were recruited through their *promotora* or another community organization, some who had prior relationships. As illustrated in Table 1, participants in Project Harvest are economically and racially diverse, with just over 50% 1) self-identifying as low-income or below based on HUD guidelines, 2) self-identifying as a non-white race/ethnicity (predominatly Latino/Hispanic), and 3) not having a college degree. Additionally, 25% of participants speak Spanish as their primary language.

Table 1. Project Harvest Communities and Participants

Comm-unity; # Active Participants	City/Town, County, Population[1]	Participant Recruitment Methods	Participant Race/Ethnicity; Language[4]	Participant Low-Income (LI) Status[4]	Participant Education Level Range and Median[4]	Local Environmental Health Risk Sources
Tucson SERI (TS) N=55	Tucson, Pima, 520,116	Recruited through community-based partner organization SERI, who works with low-income Tucsonans on environmental health issues.	80% Latino/Hispanic 7% White 4% Multiple Races 78% Spanish 16% English	73% LI 9% Non-LI	Range: Elementary to bachelor's degree Median: High school	Multiple Toxic Release Inventory (TRI) sites including Tucson International Airport Area Superfund Site and an unlined landfill. Aircraft and electronics manufacturing have largely contributed to trichloroethylene (TCE) and other contaminants observed in soil, groundwater, and municipal water (Conforma Tech, Inc., 2014; Rodenbeck Sven E. & Maslia Morris L., 1998)
Tucson Water (TW) N=38		Email sent by water utility Tucson Water to past recipients of a rainwater harvesting system rebate. Interested respondents were screened via phone by SERI staff.	69% White 8% Latino/Hispanic 5% Asian 5% Multiple Races 84% English 3% Spanish	16% LI 68% Non-LI	Range: High school to graduate degree Median: Graduate degree	
Dewey-Humboldt (DH) N=12	Dewey-Humboldt, Yavapai, 3,894	5 participants recruited through community training, others through outreach by *promotora*. UA researchers had prior community relationships through other local participatory research projects (Ramirez-Andreotta et al., 2016; Ramirez-Andreotta, Brusseau, Artiola, Maier, & Gandolfi, 2015).	58% White 8% Multiple Races 8% Other 83% English	33% LI 33% Non-LI	Range: Some college, degree not completed, to bachelor's degree Median: Trade or technical school	Iron King Mine - Humboldt Smelter Superfund Site includes approximately four million cubic meters of mine tailings from legacy mine and smelter. Documented dioxin spraying in Pinal Mountains in the 1960s (U.S. DHS, 1998) Home drinking water demonstrated arsenic above the US EPA drinking water standard in 2013 (Ramirez-Andreotta, Brusseau, Beamer, & Maier, 2013)

Globe/ Miami (GM) N=25	Globe and Miami[2], Gila 9,369	6 participants recruited through community training, others through outreach by *promotora* and Gila County Cooperative Extension.	72% White 16% Latino/Hispanic 8% Asian 96% English	44% LI 36% Non-LI	Range: High school to bachelor's degree Median: Trade or technical school	Two active open pit mines, active smelter and rod mill, and legacy mine in Miami. Additional active open pit mine 15 mi outside of study area in Superior, AZ. Mountain View Mobile Home Estates site in Globe was on the Superfund Program's National Priorities List (NPL) for asbestos contamination of soil and groundwater until clean-up activities completed in 1988.
Hayden/ Winkelman (HW) N=21	Hayden and Winkelman[3], Gila, 1,015	Prior relationship between community and university formed through National Institute of Environmental Health Sciences Superfund Research Program partnership. School superintendent enthusiastic about the project promoted teacher involvement. Most participants recruited directly through *promotora*.	76% Latino/Hispanic 10% White 86% English	33% LI 48% Non-LI	Range: Middle school to bachelor's degree Median: Some college, degree not completed	ASARCO Hayden Plant Alternative Superfund Site, includes the ASARCO smelter, concentrator, former Kennecott smelter and all associated tailings facilities. In 2016, ASARCO was involved in a $150 million settlement with the US Department of Justice and US Environmental Protection Agency for violations of the Clean Air Act. (Clean Air Act, 1970)

[1] Data obtained from 2010 US Census.

[2] These neighboring municipalities are considered as one community in this study, though they are separate municipalities (City of Globe and Town of Miami).

[3] These neighboring municipalities are considered as one community in this study, though they are separate municipalities (Town of Hayden and Town of Winkelman).

[4] Participant data may be missing (percentages do not sum to 100%) due to participants choosing not to answer a survey question or choosing not to consent for human research.

1.4 Project Harvest *Promotoras*

A significant challenge for participatory researchers is to value and promote community knowledges while acknowledging present structures, including academia and potentially the researcher's own presence, that suppress them. The *promotora* model of health promotion is a strategy that has been successfully employed in disempowered communities to increase community-level knowledge of health issues and health behavior (Deitrick et al., 2010; Hunter et al., 2004; Ingram et al., 2008). *Promotoras*, or community health workers, are members of the community who teach and discuss project content with their peer community members in culturally appropriate methods and settings.

Applying this model and experience from prior applications of this model in environmental health contexts (May et al., 2003; Ramírez et al., 2015), Project Harvest employs *promotoras* as the designated educators and support persons for participants. As SERI staff *promotoras* have in-depth experience with Tucson residents, four SERI *promotoras* were designated to support all Tucson area participants through an inter-organization agreement. In the three rural communities, *promotoras* were recruited through public community training events, described further below, and local organizational partners and champions. Rural *promotora* positions are university staff positions that were advertised through the UA jobs website. Applicants who met the criteria of living in the community and speaking the dominant language were interviewed by the project director and staff. Applicants who best expressed a nuanced understanding of working with and educating community members in an informal home setting were hired as staff.

Two Project Harvest *promotoras* are predominantly Spanish-speaking, one is fluent in English and Spanish, and four are predominantly English-speaking. With the exception of one *promotora* who has only lived in her rural community for three years, *promotoras* have lived in their community for at least a decade, with one being a 4th generation resident. Professional backgrounds are diverse, including teaching, government program administration, and community organizing. Level of education in the group spans from high school diploma to graduate degrees. Each *promotora* supports 15-25 participant households throughout the three years of the project.

2. Methods

Data collected were grounded in the research questions: What are the motivations, support structures, and barriers to participate in an environmental health CS project? Are there demographic or community-specific differences in how CS participants feel motivated, supported, or frustrated? To address these questions, data was collected from 127 participants and seven *promotoras* in Project Harvest and analyzed using mixed methods. Participants and *promotoras* were consented under the University of Arizona IRB rule as an approved project.

Five data sources itemized below, with the exception of rank item scale survey items, were analyzed using established qualitative methods (Creswell & Poth, 2017; Scammell, 2010; Tracy, 2010). *Promotora* interviews and focus group discussions were recorded and professionally transcribed, and transcriptions were reviewed by the interviewer/facilitator and corrected for accuracy. Participant interviews were documented through interviewer notes, and other participant communication was either saved (email) or documented through staff notes (in-person or phone conversations). All data were reviewed and discussed collaboratively by a subgroup of the Project Harvest team dedicated to participant learning research (learning research team), which includes the project PI, the external project evaluator, the lab manager, and three student research assistants. Some deductive codes were created based on initial collaborative discussion and observations from team members. From emergent themes in the data, three research assistants created a codebook to capture main concepts and coded all data for themes using NVivo qualitative analysis software (QSR International Pty Ltd. Version 11, 2017). Early in the coding process the coding team compared individual coding on a subset of 25 responses to a survey question, and on two focus group transcripts, and observed 88% agreement, suggesting acceptable inter-rater reliability (Armstrong, Gosling, Weinman, & Marteau, 1997; Krippendorff, 2004). The team met throughout the coding process to revisit codebooks, sometimes choosing to create or merge code categories based on inductive themes in the data. The first author supervised coding activities for consistency and met regularly with the learning research team to discuss coding themes, trends, and examples, to collaboratively discuss results and interpret findings. Under each of the three parent codes, “Participant motivation to sign up/participate,” “Participant support in participating,” and “Participant barriers to participating,” a set of child codes was developed for each that reflected what was observed in the data. Quantity of participant communications, as well as non-emergence of new themes towards the end of the coding process, suggests data saturation to adequately address the research questions (Guest, Bunce, & Johnson, 2006; Mason, 2010; Saunders et al., 2018).

Following the coding process, all data was migrated into SPSS quantitative analysis software (*IBM SPSS Statistics for Windows 25*, 2017) so that codes by data source could be applied to specific participants. By performing analysis by participant, we could control for themes dominated by one or a few participants; for example- if one participant frustrated by an aspect of the study frequently discussed this frustration in multiple venues, this method would control for this theme being counted multiple times. From this, we were able to calculate frequencies of participants who expressed each theme, by data source and as a combined frequency over all five data types.

To understand if participants from different demographic or geographic groups may be motivated, supported, or discouraged differently in the project, Chi square tests were performed to assess correlation within participant groups expressing each child code theme to different demographic groups. For each child code category, we tested for correlation to participant groups by defined community (TS,TW, DH, GM, HW), self-identified race/ethnicity (White/Caucasian, Latino/Hispanic, Asian/Asian-American, Multiple, and Other were represented), income level ("low income" or "non low income" according to 2015 HUD guidelines), and education level (4-year college graduates or higher compared to non-college graduates). All demographic data was self-reported by participants and collected via survey administered by the promotora at the first home visit. For correlation in binary demographic categories (income and education level), Chi square tests were sufficient to produce a p value to indicate if one of the two demographic groups were either under- or overrepresented in the theme group beyond what would be expected by the null hypothesis. For demographic categories with more than two groups (community and race/ethnicity), if the Chi square test produced a statistically significant result, post hoc testing was performed to determine which demographic group(s) were either under- or overrepresented in the theme group beyond what would be expected by the null hypothesis using adjusted residuals to reduce the chance of Type 1 error (Beasley & Schumacker, 1995; García-Pérez & Núñez-Antón, 2003). In effort to not rely solely on statistical significance in making meaning of the data (Amrhein, Greenland, & McShane, 2019), Cramér's V was also calculated for every Chi square analysis to measure effect size (Kirk, 2007). Analysis for demographic correlation was also performed for the group of participants who had resigned from the project. All statistical analyses were performed using SPSS quantitative analysis software (*IBM SPSS Statistics for Windows 25*, 2017).

1. **Phone interviews with participants (N=73)**

Researchers attempted to contact all active participants (N=144) by phone in August 2018, after most participants had completed at least one sampling season and before data-sharing events were held. If participants were not reached on first attempt, a voice message was left with an introduction and callback number. After two call attempts within a three-week time period, researchers did not attempt to call again. Of the total, 73 participants (53 English-speaking participants, 20 Spanish-speaking) were reached and willing to participate in an interview. Interviews were conducted in the participant's dominant language.

Semi-structured interview questions were collaboratively designed by the learning research team to solicit participant feedback on project materials, sampling methods, data reporting methods, and overall experience. Phone interviews lasted between 8 and 45 minutes. Prior to the interview, participants were informed that participation was optional, their responses would be de-identified, and responses would not affect their role in the project.

To increase response rate and maintain an informal atmosphere, participant interviews were not recorded. Instead, the interviewer took detailed notes in an online spreadsheet shared with the learning research team. Upon completion of interviews, the learning research team met to review notes and share reflections from interview experiences.

2. **Participant surveys (N=73 paired surveys, N=87 Y1 surveys)**

Participants completed written surveys upon beginning participation in the project (Nov 2017-Jan 2018) and after approximately one year of conducting environmental monitoring (Oct 2018). These pre-participation (PRE) and Year 1 (Y1) surveys include open- and closed-ended questions designed to measure environmental science knowledge, environmental health skills, and self-efficacy (SE) for learning and doing science. Surveys are administered by *promotoras* as part of a home visit in the participant's dominant language.

For the purposes of these research questions, data from two survey sections were considered. First, an open-ended question included in the Y1 survey reads: "Since starting with Project Harvest, have you learned anything new? Please write any new ideas, observations or questions you have about…," followed by the headings 1) Rainwater Harvesting, 2) Rainwater Contamination, 3) Human Health and the Environment, 4) Doing Experiment or Taking Samples, and 5) Other. Written responses to this question were analyzed using qualitative methods as described above. Additionally, eight rank 1-5 scale items modified from literature developed by Cornell Lab of Ornithology (Phillips et al., 2014) to measure SE for learning science (four items) and SE for doing science (four items) were included in both PRE and Y1 surveys. This quantitative data allowed for assessment of baseline and mid-participation self-efficacy, as a related measure to participation and engagement. Paired samples t-test was used to examine change in self-efficacy over one year (N=73 paired surveys). Descriptive statistics and significance tests were used to examine any differences in baseline SE and SE change over one year by community, household income, language, and level of education.

3. **Data sharing focus groups (14 groups, total N=50)**

Following chemical analysis from the first season of rainwater samples, two data sharing events were conducted in each of the four geographic areas, as social events for participants to meet, see results from their own rainwater samples and the community, and discuss data with Project Harvest staff and each other. Following time to view the data and a presentation on data interpretation, participants met in focus groups of 2-5 with two staff member facilitators per group. Facilitators guided the group through understanding of the data and interpretation of rainwater risk or safety, as well as solicited participant feedback on their experience of receiving and interpreting their data, and what changes they plan to make after receiving this data, if any. As these focus groups were semi-structured, conversation also emerged related to general project methods and rationale, and participant experience in the project, including motivations, support, and challenges.

4. **Other participant communication (N=12)**

As challenges and unexpected project outcomes represent the greatest opportunity for learning, these were documented and considered as valuable data. Reasons cited by participants choosing to resign from the project (N=28), communicated directly by the participant or via their *promotora*, provided insight on what study design aspects may deter participation. Additionally, email, phone, and in-person conversations between participants and the Project Harvest staff were saved or documented, and reviewed and analyzed using methods described above.

5. **Individual interviews with *promotoras* (N=7)**

Researchers, research assistants, and *promotoras* had frequent collaborative meetings and phone calls over two years of working together in Project Harvest, which allowed for establishing rapport and trust. Because of this established relationship, research assistants were able to conduct one-on-one semi-structured interviews with *promotoras* with openness and honesty. Two research assistants developed six semi-structured interview questions based on established literature (Gall, Gall, & Borg, 2007; Turner, 2010) to solicit motivations, support, and barriers that the *promotora* experienced personally in their work, as well as what they perceived to be motivating, supportive, and frustrating to their participants. These interviews were conducted in January 2019 and lasted between 35 and 75 minutes. Prior to the interview, it was communicated that names would not be shared in publication and any critical feedback would not affect working relationship or job status. One research assistant, a native English speaker, conducted individual interviews in English over the phone with *promotoras* working with English-speaking participants (N=5). Another research assistant, a native Spanish speaker, conducted interviews in person in Spanish with *promotoras* working with Spanish-speaking participants (N=2).

3. Results

Figure 3 illustrates mean scores for self-efficacy (SE) for science for participants pre-participation (PRE) and after one year of participation (Y1), by demographic and geographic groups. There was no significant difference in pre-participation SE or change in SE after one year observed among the five defined communities, race/ethnicity groups, low income and non low income participants, or college graduates and non college graduates, respectively. Race/ethnicity groups with less than five participants (Asian N=3, Multiple N=2, Other N=1) were excluded from analysis due to insufficient sample size.

Tables 2-4 show frequency of themes observed in participant motivation and engagement, with noted significant differences in any demographic group (community, college degree, household income level, race/ethnicity) observed. Participants who did not report a certain demographic characteristic were removed from the data pool prior to demographic analyses. Of 127 total contributing participants, 19 did not report race/ethnicity, 21 did not report household income, and 41 did not report highest level of education achieved. Table 5 shows frequency of themes in participant motivation, support, and barriers observed and described by *promotoras*, and Table 6 shows frequency of themes in *promotoras'* motivation, support, and barriers to engaging participants.

To date, 23 participants have resigned from the project. There was no statistically significant correlation observed between resigning and community, level of education, household income, or race/ethnicity. Reasons cited for resigning are illustrated in Table 7.

Figure 3. Mean Participant Self-Efficacy for Science by Group

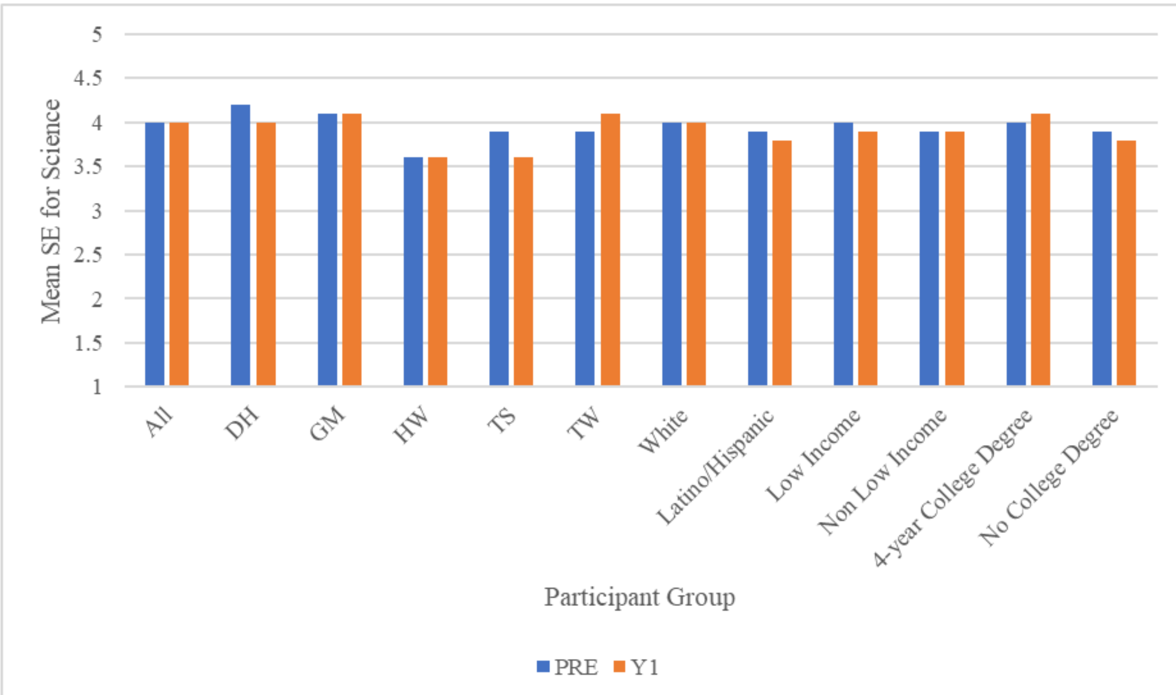


Table 2. Participant Motivation Theme Frequency and Difference by Group

Parent Code: Participant Motivation								
Child Code	Example of Child Code	Participant Phone Interviews (N=73)	Year 1 Survey (N=87)	Focus Groups (N=50)	Other Comm-unication (N=12)	Total Contributing Participants (N=120)	Significant Difference by Group[1]	Omnibus Significance and Effect Size[2]
Positive attitude about rainwater harvesting or gardening	"Rainwater is good for my plants, it has a lot of nutrients and it helps them grow more quickly." -T104, Y1S (Translated from Spanish)	26% (N=19)	23% (N=20)	18% (N=9)	0%	38% (N=46)	*TS (+) (50%)(N=23) *TW (+) (24%)(N=11)	*Community ϕ_c=.332
Desire to know contaminants in local environment	"Looking forward to results- I expect most contaminants will be onsite rather than environmental/airborne. I look forward to getting my hypotheses tested." -G413, Y1S	27% (N=20)	10% (N=9)	4% (N=2)	17% (N=2)	24% (N=29)	*Non-low-income (+) (59%)(N=17)	*Income level ϕ_c=.215
Project is interesting /want to learn	"Well, it's been very interesting for me and the program you present is what we're going to be seeing in the lab, too. It's something, well, we keep learning." -T161, Y1FG (Translated from Spanish)	25% (N=18)	46% (N=4)	12% (N=6)	0%	21% (N=25)	*College grads (+) (40%)(N=10)	*College grad ϕ_c=.240
Individual/family health risk concerns	"I live … below the Pinal Mountains, where it was sprayed with Agent Orange and lots of people here have cancer. I am curious and concerned about what might be in our soil." -G424, Y1PC	12% (N=9)	0%	22% (N=11)	0%	16% (N=19)	*GM (+) (42%)(N=8)	*Community ϕ_c=.363
Contribute to scientific research	"Collecting data for the UA and public to be informed about our environment is my main motivation." -G412, Y1PC	21% (N=15)	2% (N=2)	0%	0%	13% (N=17)	*Non-college grads (-) (6%)(N=1) *White (+) (82%)(N=14) *Latino (-) (12%)(N=2)	*College grad ϕ_c=.426 *Race/ethnicity ϕ_c=.350
Contribute to the environment	"It is important we better understand rainwater harvesting because we will be needing more of it when there is less water in the Colorado River" -T128, Y1S (Translated from Spanish)	12% (N=9)	7% (N=6)	0%	0%	12% (N=15)	None observed	-
Connection to project purpose	"What you're looking for in the water harvesting, it's important and I'm interested in it." -T171, Y1PC	16% (N=12)	0%	0%	0%	9% (N=12)	None observed	-

Table 2 (Participant Motivation themes) continued								
Contribute to the community	"Air and water quality impacts everyone in our community. These studies are very important." -H203, Y1S	10% (N=7)	2% (N=2)	4% (N=2)	0%	9% (N=11)	None observed	-

[1] Groups indicated are significantly different (p<0.05) in their representation in the theme compared to other group(s). Directionality of difference is represented by (+) for greater representation than expected by the null hypothesis or (-) lesser representation than expected by the null hypothesis.
[2] Effect size represented using Cramer's V (ϕ_c). Effect sizes included for significant results (p<0.05) indicated with *, and for non-significant medium or large (>0.3) effect sizes.

Table 3. Participant Support Theme Frequency and Difference by Group

Parent Code: Participant support in participating								
Child Code	Example of Child Code	Participant Phone Interviews (N=73)	Year 1 Survey (N=87)	Focus Groups (N=50)	Other Comm-unication (N=12)	Total Contributing Participants (N=120)	Significant Difference by Group[1]	Omnibus Significance and Effect Size[2]
Direct communication with project staff to interpret data	PH staff: You spray the house with what? T158: With something for the bugs. PH staff: ...maybe you could also tell us the type of [pesticide] you use and in the lab we can check if that spray-- T158: If it's contaminating… I will send you a picture. – Y1FG	4% (N=3)	0%	86% (N=44)	33% (N=4)	41% (N=49)	None observed	-
Home visit training with promotora	"[Promotora] was very good at showing us what to do." -H218, Y1PC	66% (N=48)	0%	0%	0%	40% (N=48)	*Non-college grad (+) (56%) (N=27)	*College grad ϕ_c=.235
Promotora support	"Insecure while we're doing it…but I call my promotora and she helps me." -T169, Y1FG (Translated from Spanish)	38% (N=28)	5% (N=4)	4% (N=2)	0%	28% (N=33)	*GM (+) (36%)(N=12) *TW (-) (6%)(N=2)	*Community ϕ_c=.348
Direct communication with project staff to clarify methods	"Asked questions about when to upload results, whether to wash experimental vials, and if there is anything to get back to [her promotora]." -Staff notes on conversation with D308, Y1PC	11% (N=8)	0%	40% (N=20)	17% (N=2)	23% (N=27)	*DH (+) (26%)(N=7) *TS (-) (7%)(N=2)	*Community ϕ_c=.457

Table 3 (Participant Support themes) continued

Receiving/understanding results	"Every time I did a sample this year, I was so nervous that I wasn't doing it right… Having attended tonight's [data sharing event], and gotten the data, I realize that maybe I did okay. I think I have a lot more confidence to do it by myself next year." -T194, Y1FG	16% (N=12)	1% (N=1)	24% (N=12)	0%	19% (N=24)	None observed	-
Instructional booklet	"Instruction book is useful." -T137, Y1PC	18% (N=13)	2% (N=2)	8% (N=4)	0%	15% (N=19)	*TW (+) (58%)(N=11) *College grad (+) (42%)(N=8)	*Community ϕ_c=.316 *College grad ϕ_c=.238
Gain confidence with practice	"It reminds me of chemistry lab but I am getting the hang of it." -G415, Y1S	5% (N=4)	8% (N=7)	6% (N=3)	0%	9% (N=12)	None observed	-
Household members working together	"nice to have Dad help." -T004, Y1S	8% (N=6)	1% (N=1)	2% (N=1)	0%	6% (N=8)	None observed	-
Talks with other participants about project	"We just live two trailers down from each other... [the other participant lives] two trailers closer to the mine than I am... And I was remembering my [DIY experiment] results, and seeing her results, and then thinking, oh my goodness, there is a difference, even within the proximity there." -H212, Y1FG	7% (N=5)	0%	6% (N=3)	0%	6% (N=8)	None observed	-
Familiarity with past experiences	"I took [water] samples working for mines." -G425, Y1S "No problem- just like school!" -H214, Y1S	4% (N=3)	5% (N=4)	0%	0%	6% (N=7)	None observed	-
Talks with friends/family about project	"Yes, I do share. I – someone asked me for the phone number, and they wanted to know so they could come to the program… I gave them the paper so that [they] could call and register if they wanted to." -T169, Y1FG (Translated from Spanish)	3% (N=2)	0%	8% (N=4)	0%	5% (N=6)	None observed	-

[1] Groups indicated are significantly different ($p<0.05$) in their representation in the theme compared to other group(s). Directionality of difference is represented by (+) for greater representation than expected by the null hypothesis or (-) lesser representation than expected by the null hypothesis.
[2] Effect size represented using Cramer's V (ϕ_c). Effect sizes included for significant results ($p<0.05$) indicated with *, and for non-significant medium or large (>0.3) effect sizes.

Table 4. Participant Barriers Theme Frequency and Difference by Group

Parent Code: Participant barriers to participation								
Child Code	Example of Child Code	Participant Phone Interviews (N=73)	Year 1 Survey (N=87)	Focus Groups (N=50)	Other Comm-unication (N=12)	Total Contributing Participants **(**N=120)	Significant Difference by Group[1]	Omnibus Significance and Effect Size[2]
Tasks more time-consuming or complicated than expected	"The one problem I had was the arsenic test…Because we had this much liquid, this much space, and then a test strip that we couldn't get wet and had to agitate it for 45 seconds…I mean, this is a lot of failure built into this process, I thought." -D307, Y1FG	26% (N=19)	3% (N=3)	6% (N=3)	17% (N=2)	22% (N=26)	*Latino (-) (19%)(N=5)	*Race/ethnicity ϕ_c=.304
Not confident in sampling or doing experiments	"I had to constantly review steps of collection and testing as didn't trust my memory and didn't want to mess up results for that reason." -T122, Y1S	25% (N=18)	2% (N=2)	4% (N=2)	0%	18% (N=21)	None observed	-
No computer/ internet access	"Does not have internet access" – Staff notes on interview with T116, Y1PC	27% (N=20)	0%	2% (N=1)	0%	18% (N=21)	*TS (+) (52%)(N=11) *HW (+) (33%)(N=7) *TW (-) (5%)(N=1) *DH (-) (0%)(N=0) *Non college grad (+)(70%) (N=13) *Latino (+) (76%)(N=16) *White (-) (10%)(N=2)	*Community ϕ_c=.376 *College grad ϕ_c=.257 *Race/ethnicity ϕ_c=.417
Technical issues with rainwater harvesting	"Not going well because gutter system not collecting." -T133, Y1PC	15% (N=11)	3% (N=3)	2% (N=1)	8% (N=1)	13% (N=15)	None observed	-

Table 4 (Participant Barriers themes) continued								
Difficulty with instructions	"I'm pretty sure there's instructional booklet, but I'd rather just have her explain it to me." I'm doing an apprenticeship program [as part of employment at the mine] and have to do so much reading, it's hard for me to read stuff, I would rather just do it with someone." – H213, Y1PC	18% (N=13)	0%	0%	0%	11% (N=13)	None observed	-
Computer/tech use barriers	"Has a smart phone but does not know how to use internet on smart phone." -Staff notes on interview with T153, Y1PC	4% (N=3)	0%	2% (N=1)	0%	10% (N=12)	*College grad (+) (67%)(N=8)	*College grad ϕ_c=.365
Logistical barriers to sample drop-off	"Only thing difficult is the limited window and location for sample drop-off. Makes it difficult for working people." - T142, Y1PC	8% (N=6)	0%	2% (N=1)	25% (N=3)	8% (N=10)	None observed	-
Unexpected life events	"It's been a tough month with losses in the family so we've been away." -G425, Y1PC	12% (N=9)	0%	0%	8% (N=1)	8% (N=10)	*Non low income (+) (80%)(N=8)	*Income ϕ_c=.365
Unclear on how to submit samples or results	"Did both the winter and monsoon experiments for water, have the results and photos and pages of journal notes. Have been meaning to upload them, not sure if I remember how." -T122, Y1PC	10% (N=7)	0%	0%	17% (N=2)	8% (N=9)	None observed	-
Difficulty contacting promotora	"Again we are eager to participate but can't find the contact info for [promotora]." -H224, OTHER	5% (N=4)	0%	0%	8% (N=1)	4% (N=5)	*Latino (+) (60%)(N=3)	*Race/ethnicity ϕ_c=.312
Unclear on project goals	"I guess I wanted a better understanding of why we were doing [the experiments]." -D308, Y1FG	3% (N=2)	0%	6% (N=3)	0%	4% (N=5)	None observed	-

[1] Groups indicated are significantly different ($p<0.05$) in their representation in the theme compared to other group(s). Directionality of difference is represented by (+) for greater representation than expected by the null hypothesis or (-) lesser representation than expected by the null hypothesis.
[2] Effect size represented using Cramer's V (ϕ_c). Effect sizes included for significant results ($p<0.05$) indicated with *, and for non-significant medium or large (>0.3) effect sizes.

Table 5. Theme frequency in participant motivation, support, and barriers described by *promotoras*

Parent Code: Participant Motivation		
Child Code	**Example of Child Code**	# Promotoras Citing (N=7)
Connection to project purpose	"I think one of the most important things about citizen science projects is to make the participants feel like they're something- the need to feel like you're something, you're part of something bigger. You feel like you're contributing." - Promotora 4	4
Social connection	"[At the initial public community training] there were like minded people there that they could share with… so you had like minded people who came because they wanted to be there. …And then at the data-sharing dinner. I mean a couple at least one person said you know all my friends want to do this but I would think she'd really like this. ...You know so seeing the results plus I think the group camaraderie made it, you know, I felt really positive after that data-sharing event." – Promotora 7	3
Positive attitudes about rainwater harvesting or gardening	"People like the idea of saving water and they're very enthusiastic about participating." – Promotora 4	2
Contribute to scientific research	"[The participants] are motivated to be working with scientists and contributing to real research. Makes people feel like they're 'part of the team.'" – Promotora 3	1
Concerned about individual/family health risk	"And he is retired from the mines and he was having certain illness issues, health issues. They really saw this program will help him explain why he was sick." – Promotora 5	1
Contribute to the environment	"I'm going to tell you, [participant's name] joined because he truly cares about the environment." – Promotora 5	1
Parent Code: Participant support in participating		
Child Code	**Example of Child Code**	# Promotoras Citing (N=7)
Promotora support	"They trust that it is better that I can help them, but I cannot tell them you know that, 'I will not help you anymore. You have to do it, then I tell you you know that here is the …[instruction] book, here is the web page. You can look at it, you can do it.' I know that there are people who can do it and that they have the capacity to do it, but it is easier for me to do it." – Promotora 1 (Translated from Spanish)	4
Receiving/understanding results	"What motivated and excited them for example was the [data sharing event] they had there in the library when they looked at their results, because I have already returned to these houses after that meeting. Then they noticed and most of them told me the importance of them doing their samples well. Maybe [before the data sharing event] they did not think that this was serious." – Promotora 2 (Translated from Spanish)	4
Gain confidence with	"The beginning of the first year I would go to their homes. And usually when it would rain or whatever they would call	4

practice/experience	me and I would be going through the experiment you know and I was like wow are these people ever going to learn to just do it on their own? …But as I was doing the last sampling they were actually putting their gloves on and they were ready to do the whole thing themselves, collecting the dirt you know doing the experiment. They were motivated to do it themselves." – Promotora 7	
Gifts or rewards	"Then they were very excited too that we brought seeds to them... I see that when we give them something, they are encouraged. That is, they feel like I'm looking, they brought me seed! Something as simple as a seed that costs a dollar. But the fact that we gave them away and they felt good, right?" - Promotora 2 (Translated from Spanish)	3
Receiving recognition	"Then I was surprised when they gave us the certificates, even I, who was a promotora, said, "Wow, how cool I'm a scientist." That also motivates us, because to show off to your friends what they were doing." – Promotora 2 (Translated from Spanish)	2
Instructional booklet	"The booklet is really helpful for people." – Promotora 3	2
Online instructional videos	"A few families looked at the videos on YouTube and thought they were helpful." -Promotora 4	2
Parent Code: Participant barriers to participating		
Child Code	**Example of Child Code**	# Promotoras Citing (N=7)
Protocol more time-consuming or complicated than expected	"People not having a good understanding of the time commitment, Tuesday morning drop-off is discouraging. For DIY, some people were overwhelmed by the amount of time it would take- sometimes people had questions, but generally felt supported by booklet, was more unwilling to take the time." -Promotora 3	7
Not confident in sampling/doing experiments	"Because there are families that want to do it, but… like there is a lady and she says 'help me mijita if I want to do it but I need your help.'" – Promotora 2 (Translated from Spanish)	4
Difficulty understanding instructions	"They are trained to do it [by themselves]. They are supposed to learn it. But then they pull out everything they just might have been frustrated because they, [the instruction] wasn't that clear." - Promotora 5	3
Computer/tech use barriers	"But a lot of the people that are in my community are older people which do not like computers do not like to change their ways do not... And so that was like trying to go into a world where they didn't want that change. You know they didn't mind collecting the water. They didn't mind doing the experiment but they like- anything they had to do with the technology part, that was the hard part." - Promotora 7	3
Logistical barriers to sample drop-off	"I am collecting these samples because most of the participants do not drive, they cannot come to deliver them, it is difficult for them. But it does not matter I go pick it up." - Promotora 2 (Translated from Spanish)	2
No computer/internet access	"[A participant] doesn't have a smartphone or she doesn't have a computer." - Promotora 5	2

Local concerns about project	"I wasn't able to recruit people that speak Spanish in my area. ...but because of this perception you know that that we, the program was going to be done to find things that were damaging from the mine and then that will be the issue later. You know that, I think, had a lot to do with the not getting more people into the program." - Promotora 5	2
Difficulty contacting promotora	"Those who work and those who have had a little more difficulty in contacting us [during business hours] with their schedules and all that." – Promotora 1	1
Unclear on how to submit samples/results	"At least when I did Do It Yourself [participants], nobody sent any [results] to the lab other than what I told them. I spoke to them on the phone and asked them, 'How did your result come out? What is the line, white, orange? Do you understand me? The color.' Then I put there what they more or less told me." - Promotora 2 (Translated from Spanish)	1

Table 6. Theme frequency in *promotora* motivation, support, and barriers

Parent Code: Promotora motivation		
Child Code	**Example of Child Code**	# Promotoras Citing (N=7)
Connection to community	"The rewarding part is all the connections that I have got with my participants, the relationship. ...So all these connections with people in the community- I have been privileged to be let into their homes." - Promotora 5	5
Connection to project purpose	"Being able to come onsite to Tucson and see the lab and see the people and kind of like, how I think our data-sharing was good for the participants to see us and you know what happened, was good for me to see you know what happens once I give you stuff or who are people, you know, and names on the phone or faces, voices on the phone seeing names and people in person. Definitely make, I think, any project better. I liked the external board meeting, how that whole day went and again learning a lot about you know that here were people who felt our work was a value." - Promotora 6	4
Participant learning	"For me the best part that I like is actually making the- Going over you know and watching them perform the experiment. You know for them to do the experiment for them to put on the gloves and for them to actually look at the results you know when also because a lot of these people have lived in the community for a while. So for them to be interested in you know their environment and what's going on has been really motivating to me. For them to be more become more aware of their surroundings." - Promotora 7	3
Interest to learn about CS	"Interested in how you design something like this." - Promotora 3	3
Project is interesting/ want to learn	"It's interesting for me …because I am also learning much more than just the course we took at the beginning of the training we took." – Promotora 1 (Translated from Spanish)	2

Connection to university/science	“One of the great things of this program is that we are all in the same boat. I'm collaborating with university professors and university graduate students.” – Promotora 5	2
Contribute to scientific research	"And the fact that I know that I'm helping, in some way, to conduct this important science research. Because the way I see it, it’s the results in both research, the human part and the science, that they have a lot of great opportunities for, in the future, to be used as models in other places and benefit other communities." - Promotora 5	1
Desire to know contaminants in local environment	“And, and completely surprising because I was expecting to find worse results in the lab samples for the community. So that has been excellent for me! You know like… OK well I didn't do so bad a thing in this community raising my kids, health-wise.” – Promotora 5	1
Contribute to community	“It gives the participants a sense of that they are participating in doing something good for this world. Take care of this world. This will make them even learn new things. Do different things in a positive way. So I have appreciated that for me.” – Promotora 5	1
Parent Code: Promotora support		
Child Code	**Example of Child Code**	# Promotoras Citing (N=7)
Group membership, being "part of the team"	"I’ve wanted to stay involved because of your team- [Project Harvest staff] is amazing and everyone in your team is great." - Promotora 3 "Then I was surprised when they gave us the certificate, even I, who was a promotora, said, 'Wow, so cool I'm a scientist!' That also motivates us." - Promotora 2	4
Adequate training and preparation	"I mean... I never felt like I was doing something and didn't have the right tools. Because you gave them to us. Making sure we were very well trained and you know because I had participants that say, how come you [can] do [the experiments]? You know I said I well we had a lot of training and a lot of practice!" - Promotora 7	2
Engages "unlikely" partners in project	"We invited the board person of [the local community center] who used to work for the mine… And when he heard about the program initially he didn't like it, and when he was able to attend [the data sharing event] and see what the program was doing, he actually said, 'I don't know why we're not doing this here.' So now we have [the local community center] onboard." -Promotora 5	1
Regular communication (with project team and participants)	"So I think we would need to be more communicating more with them with the participants as well as the promotora." - Promotora 7	1
Parent Code: Promotora barriers		
Child Code	**Example of Child Code**	# Promotoras Citing (N=7)
Challenges	"I've put up flyers have gotten no response. Businesses- No	5

recruiting/engaging local community	response. One is the librarian because we hold our events there." - Promotora 6	
Computer use barrier	"And that's the frustrating part for me because … computers didn't come to [the community] til the maybe the last five years I want to say. We weren't accountable to be using the computer all the time. We had to have a hard copy of everything and so I'm still kind of like old school I guess… On The computer I can spend 20 - 30 minutes trying to figure out what I did wrong and never get to do what I wanted to do." - Promotora 7	3
Project feedback not considered	"I was there because when I attended the training in Tucson, in two different opportunities, we were invited to make comments. But those comments that we made didn't translate to the [participant instruction] books before they were printed. So it was… I think they were kind of behind in their deadlines. But that was, for me, was something frustrating." - Promotora 5	3
Project methods changed after training	"The instructions- to me it's not a problem- but maybe because of the, well that in the training it was all completely differently set up." - Promotora 6	3
Misconceptions about roles within project team	"But at the same time they stopped having one group meeting and they divided it. And so I am fine with the English speaking meetings which is nice. But I always wonder why ... If we would say we [are] all treated equally, the promotoras. So that is something that has been hard for me to deal with internally." - Promotora 5	2
Participant protocol more complicated than expected	"And I read the book I read all the protocols and I went to [the Project Harvest] half day training and I still...I know that you just fill the bottles but I still don't feel comfortable." - Promotora 4	2

Table 7. Participant Reasons for Resigning from Project

Reason Cited*	**# Participants**	**% Participants**
No reason given / Not able to contact	16	70%
Did not have enough time to participate	5	22%
Unexpected life event	5	22%
Technical challenges with rainwater harvesting	5	22%
Confused or frustrated with procedures	4	17%
Computer access challenges	1	4%
Moved	1	4%

*Participants may cite more than one reason.

4. Discussion

4.1. Study Limitations

As the research question relates to the personal experience of participants, the decision to solicit participant voice directly was a conscious one. However, the reliance on self-reported data introduces the possibility of bias. Multiple forms of participant data were used to be able to triangulate data and lend validity to findings.

Some types of participant responses were more solicited than others. For example, one of the participant phone interview questions was “Do you recall the home visit training with your promotora? How did it go?” In this case, all positive responses about the training were coded to indicate the training was helpful to participants, which likely increased the frequency of that theme in the phone interview dataset. Similarly, in focus groups, a primary goal of discussion facilitators was to guide participants’ interpretation of their data, so it is unsurprising that almost all participants who attended focus groups engaged in “direct communication with project staff to interpret data.”

Although the study design differentiates between participant “motivation” to sign up for and participate in an environmental health CS project, and participant “support” to continue participating and staying engaged, some blurriness exists between these two categories. Depending on a participant’s experience and external influences, primary motivation may shift throughout participation in the project. For example, after receiving results from the first year of sampling, a participant may feel less motivated by the desire to know what contaminants exist in their local environment, however newly motivated by their confidence in collecting samples and performing experiments. Participant survey and interview data will continue to be collected over the next two years of Project Harvest to better understand this.

4.2. Motivation

Overall, Project Harvest participant motivations mirror typical motivations to participate in environmental citizen science (Phillips, 2018). The only motivation observed that is unique to this project is preexisting positive attitudes about rainwater harvesting and/or home gardening, which relates to the specific scope of this project.

Within some participant motivation theme groups, there were significant differences observed between communities. Participants motivated by their enthusiasm about rainwater harvesting or gardening predominantly included Tucson residents (50% from the TS community and 24% from the TW community). Rainwater harvesting is culturally popular in Tucson, which is home to internationally known rainwater harvesting experts and advocacy groups. Differences in perceptions of water quality between different racial groups in Tucson has been documented (Williams & Florez, 2002), and the perception that rainwater improves plant growth was expressed in many documented interactions with TS participants, but not heard in other communities. GM participants were more likely to cite health concerns as their motivation, which aligns with the history of environmental contamination (Table 1) and a recent cultural awareness of environmental health risk. Ironically, while some GM participants cited a perceived relationship between personal health issues and environmental contamination as motivation to participate, local rumors that the project aimed to prove harm caused by the local mining corporation, a major employer, was mentioned as a reason that some GM residents did not sign up for the project.

The desire to contribute to scientific research has been widely cited as a motivation for CS participants (Domroese & Johnson, 2017; Land-Zandstra, Devilee, Snik, Buurmeijer, & van den Broek, 2016; Raddick et al., 2013), although it has been noted that participants studied have not been demographically diverse (Hobbs & White, 2012). In this study, those motivated by contribution to science were predominantly White, while Latino/Hispanic participants and participants without a college degree were underrepresented in the group who expressed enthusiasm about scientific research as their motivation. These above findings are may relate to how scientific data has been used throughout modern history, in tandem with other economic, political, and legal structures, often to justify environmental contamination in communities in poverty and communities of color (Shrader-Frechette, 2002, 2017). Thus, people of color may be more likely to distrust scientific institutions (Scammell, Senier, Darrah-Okike, Brown, & Santos, 2009), while white and college educated people, who have historically benefitted from science, may feel more positive about being part of it. Additionally, those who were motivated by the opportunity for personal learning predominantly had college degrees, and non low income participants were overrepresented within the group motivated to find out about contaminants in the environment. These results may similarly suggest that the motivation to participate in citizen science for reasons of gaining knowledge may resonate more with higher socioeconomic status participants.

In Project Harvest, all TS participants are recipients of a low-cost rain barrel through the community organization SERI's low-income rainwater harvesting program. SERI *promotoras* expressed many of their participants may have signed up because of previous relationship with, and perceived sense of obligation to, the community-based organization, rather than motivation or understanding related to the project itself. This may have affected demographic distribution in motivation theme groups, as TS community members (majority Latino/Hispanic) predominantly cited motivations related to rainwater harvesting rather than the CS project.

Participants and *promotoras* alike described feeling motivated by the desire to contribute to their community and their local environment through their connection to the goals of the project. Recent research has suggested "research altruism" may be a significant motivator in participatory environmental health research (Carrera et al., 2018). Positive feedback from participants and promotoras on aspects of the study which connected participants to the study purpose and to the project team (community training events, participant newsletter, postcards, direct communication, data sharing events) reinforce the importance to participants of being connected to the project purpose and each other.

4.3. Support

Just as motivation differed by community, meaningful modes of support may also be community-specific. Within the group of participants who specifically cited promotora support as helpful to them, GM community members were represented more than the expected distribution and TW community members were represented less. The latter may relate to a local issue with one of the initial *promotoras* in the TW community, who faced challenges in early stages in the project and did not continue after the first round of home visits (another *promotora*, included in this study, was hired as her replacement). This personnel turnover in TW limited relationship building in the early stages of the project.

Project Harvest instruction booklets were written in both Spanish and English and went through several rounds of extensive revisions based on *promotora* feedback, in effort to make the information as clear and accessible as possible. However, college graduates and TW participants were overrepresented within participants who described the instruction booklet as helpful. This suggests that written materials may provide disproportionate support to educated and urban participants. Project Harvest staff also created short instructional videos as an alternate communication method, which some *promotoras* reported using during the home visit training. However, it was observed that the *promotora*'s own comfort level with technology, which is highly variable within the group, may play a large role in their participants' exposure to online project resources and tools. One of the rural *promotoras* discussed her inexperience and discomfort with using technology; subsequently very few participants in that community created an online participant account.

Participants in the DH community, as well as non low income participants, were more represented than the expected average in those who contacted project staff directly. As DH participants are predominantly White, English-speaking, and college educated, as well as many being transplants from more urban areas to the rural community, it is possible that their identities and past life experiences increase their comfort level in directly contacting professional scientists for support. Conversely, TS participants, who are predominantly Latino/Hispanic, Spanish speaking, and not college educated, were underrepresented in those who engaged directly with research staff. As one TS *promotora* said, "They waited for me to help …maybe because they were doing it themselves and they do not feel like chemists or biologists or doctors or whatever, they told me it was a bit difficult." This suggests sociocultural barriers exist for people of color who do not see themselves in dominant representations of "scientist," which could affect participation in CS similarly to how it affects participation in STEM generally (Hurtado, Newman, Tran, & Chang, 2010; National Center for Science and Engineering Statistics, 2019). In this case, it is interesting that demographic differences in direct communication were observed even when the director of Project Harvest herself is Latina and a native Spanish speaker.

In all communities, data sharing was cited as both a motivating way to connect more closely to the project and other participants, and a powerful incentive to follow procedures carefully and correctly. This aligns with ample research about the importance of data sharing in participatory environmental health research (Brody et al., 2014; MD Ramirez-Andreotta et al., 2016; Vousden, Sapru, & Johnson, 2014). Although Project Harvest was carefully designed to protect the privacy of participants, at many of the data sharing events participants were observed sharing openly about their community's history, household practices, and personal health issues. Participants had been previously given the option to decide whether to receive their personal results, however this form ended up causing additional confusion as some participants who had unintentionally not completed the form were then disheartened to not receive an individual results booklet at the event. This situation is echoed in (S. Johnson et al., 2016), who gave the option for home gardeners' lead measurements to remain anonymous, but no participants chose the anonymous option. The open sharing that emerged at the data sharing events suggests that designing for relationship building and social sharing of knowledge can deepen participants' sense of engagement and motivation to continue in the project.

4.4. Barriers

The most frequently cited barrier to participation, both by participants and *promotoras*, was that the participant protocols were too time-consuming or complicated. Interestingly, Latino/Hispanic participants were underrepresented in the group that reported this barrier, however this may be related to the previously discussed findings that Latino/Hispanic participants were less likely to directly contact project staff, and the perceived sense of obligation to the *promotora* organization among TS community members; both of which suggest these participants may have felt uncomfortable expressing negative feedback.

Among participant group without computer or internet access, Latino/Hispanic participants and non college graduates were statistically overrepresented, whereas White participants were statistically underrepresented. One participant cited “lack of computer access” as their reason for resigning from the project. Project Harvest participants were not required to have computer access, as *promotoras* were equipped and trained to upload participant results, and paper versions of surveys and results submission forms are available. However, the extra step of contacting the promotora to help complete the results submission process increased the burden of participation for some participants. College graduates were statistically overrepresented in the group that has computer access but some barriers to use, which is likely due only to the fact that non college graduates were overrepresented the group without any computer/internet access, and thus ineligible for the “computer/tech use barriers” category. Technology use barriers cited were varied: For example, the participant website requires a login ID which caused confusion for some participants. Another participant said, “I don't know why the upload step seems like a burden, it's just the part that's not as exciting and you want to put off for later.” As previously discussed, participants’ level of exposure and training with project-related online tools and resources was observed in some cases to be related to their *promotora*’s comfort level with these tools.

The technology-related challenges observed in Project Harvest were unanticipated, as the participant website does not require tech skills beyond those used on popular platforms like facebook, which many participants reported using. Challenges have been addressed to date by creating paper versions of all participant forms, including the results worksheet, and including self-addressed stamped envelopes in participant kits as an option to mail results. Still, these challenges provide important lessons for CS project design for accessibility. First, computer access and cultural relevance of technologies vary widely by community and within communities. Second, having access to computers/internet may not preclude other barriers to using project-related technology.

4.5. Next steps for inclusive citizen science

4.5.1. Equitable and accessible participant methods

Participant survey data measuring self-efficacy for science suggest no correlation between any demographic factors and self-efficacy (Figure 3). Additionally, there was no demographic trend in participants who chose to resign from the project. These results suggest that socioeconomic factors do not predict the level of engagement, self-efficacy, or learning of a citizen scientist. Consequently, the high proportion of White and educated participants in CS may be due in part to culturally biased project design. As Max Liboiron stated in the keynote address to the Citizen Science Association, "The inclusion model often is a model of equality, where it brings people into a space that's already not designed for them. It treats everyone the same, bringing them into contact with accredited science. We already know this doesn't work– you can bring many women and people of color into science and they still 'fall out of the STEM pipeline' because that pipeline is built for someone else" (Liboiron, 2019).

Although some general best practices have been established in environmental health CS, the study results here illustrate that what works well in one community may not work well in another. Specific project methods, materials, and communication style can facilitate *or* limit participation depending on how well they fit the context and culture of a community. Although all participant protocols in Project Harvest were field tested by *promotoras* and community members, several *promotoras* reflected two years later that having a longer pilot testing period with a subset of the participants, had it been possible within the funding timeline, may have been a more effective way to both make appropriate adjustments in the methods and better prepare *promotoras* to train their participants. The results herein advocate for highly contextual study design, tailored to the participant community, ideally through extensive in-person contact and relationship building between researchers and community members. In the experience of this study and others (Lichtveld et al., 2016), hiring on-the-ground project staff presents some working challenges (cultural/linguistics differences, remote communication) but are far outweighed by the benefits of the local knowledge and relationships. The *promotora* model of health promotion, modified for an environmental health CS research context, continues to be invaluable for Project Harvest as a way to better understand and meet the needs of participating community members, as well as to produce more meaningful scientific data.

Participants and promotoras most frequently cited the time and complication involved in participant protocols as a barrier for participating. When designing participant methodology, a project manager could ask questions like: How many steps is it? What could go wrong at each step? How can these possibilities be eliminated? Where can participants turn for support? Additionally, some CS researchers have designed for tiered levels of participation (Ablah et al., 2016), to simultaneously make participation accessible for those with limited time and resources, and provide those with more time the option to get more deeply involved. In Project Harvest, multiple iterative changes were made to the study design to increase flexibility and accessibility based on participant and *promotora* feedback, including: 1) *Promotoras* scheduling training visits with participants to fit their schedule, including breaking multiple activities into multiple visits, 2) Offering 3-5 sample drop off days per season for more flexibility, 3) Allowing participants to submit results forms online or via mail anytime, 4) Giving participants the choice of methodology (collect samples and drop off for lab testing, or complete their own contaminant testing experiments) in the third year of the project, after they have had the chance to practice each method for one year previously. Participants will also have the option to do both methods, if they are interested to compare their home experiment results to results from the university lab.

4.5.2. Citizen scientists as a community of practice

Woven throughout many interactions with participants and *promotoras*, it was evident that personal relationships are both the glue that hold Project Harvest together and the oil that allow it to run smoothly. In-person training events in each community were critical for recruiting participants and rural *promotoras*. The most widely cited motivation by *promotoras* was getting to know their community members and their mutual caring for their local environment and community. Almost 40% of participants interviewed expressed appreciation for their *promotora*, often using words more personal ("I just love her!") than professional. Participants described doing water sampling with their kids, parents, grandparents, school classrooms, and each other. Neighboring participants compared results to see if their contaminant levels are different. Participants at data sharing events were observed exchanging phone numbers. Although these social connections have remained difficult to measure, they may be immensely important to continued motivation and participation of a citizen scientist group, as well as offer other health-related participant benefits (S. Cohen, 2004).

Social participation learning theory (J. Lave & Wenger, 1991) asserts there is no separation between participating and learning, as the act of participation is embedded with cultural and contextual knowledge. In a community of practice (Wenger, 2011), a group of practitioners share an interest in something and continuously learn how to do it better as they practice, help each other, and share information. Through frequent participation, participants can move closer to the center of the community, where they fully assimilate to group culture, and teach others. Scholars have conceptualized online crowdsourcing-style citizen science groups as communities of practice (Mugar, Østerlund, Hassman, Crowston, & Jackson, 2014; Newman et al., 2012), but this model of learning and co-creation of culture is arguably more relevant and offers greater benefits to an in-person CS community. How can participatory CS projects create a community of practice among participants, which manifests a culture of co-learning and support for each other? In Project Harvest, multiple internal structures aim to create supportive cultural norms and regular, open communication, including 1) Weekly conference call check-in meetings with project staff and *promotoras*, 2) Annual *promotora* professional development events with project staff, 3) Regular opportunities for open, friendly engagement between project staff, *promotoras*, and participants; at community trainings, data sharing events, and informal "open house" events.

It may benefit CS project managers to deliberately design, and adequately allocate resources, for relationship building at every level of the project, ensuring that research staff, community-based staff, and participants are regularly acknowledged as "part of the team." *Promotoras* described the great value that small tokens of recognition - receiving a newsletter, postcard, or a certificate – had for many participants. However, as discussed above, both participants and *promotoras* also cited being overwhelmed by the time required to do project tasks as the biggest barrier to participation. Designing for relationship-building, which inherently requires participant time, while also honoring participant time constraints may be one of the most difficult challenges in participatory research. For example, less than one third of participants attended data sharing events, despite receiving postcard invitations and text message reminders, and events being held at familiar community locations with food provided. This is unfortunate as all participants who attended reported their experience as engaging and motivating. As the project staff and *promotoras* look forward to planning the coming year's data sharing events, we are challenged with how to increase social participation and co-learning, recognizing the many competing priorities that participants have on their time. Developing and sharing strategies to address this challenge of minimizing participant burdens while building authentic relationships should be a priority as the field of CS for environmental health continues to expand and evolve.

5. Conclusion

Environmental health CS offers an opportunity for historically disenfranchised community members to form research questions, collect and analyze data, and draw conclusions about contaminants in their local environments. CS studies can make participation more accessible and meaningful for underrepresented participants by understanding the partnering community's specific motivations to participate and designing study methods that align with local culture and context. Feedback from participants and *promotoras* in Project Harvest emphasize 1) Locally-specific motivation to participate in environmental health CS, 2) Personal relationships at multiple levels of the project as an important source of participant support, 3) Limited participant time as the largest barrier to participation. These findings serve to inform best practices in environmental health CS research design, as well as inclusive CS project design generally.

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CONCLUSION

Participatory CS is a valuable strategy for professional scientists and community members to use scientific tools to discover, understand, and communicate local environmental health risks, which can lead to informed, organized action at community-wide scales (Cole & Foster, 2000; Ottinger, 2010). However, for organized community action to be successful, community members must possess some degree of sociopolitical power. Personally, I am most inspired by participatory research processes in their potential to shift power balances. Scientific data, like community knowledge, is not inherently powerful- it can be discredited, doubted, or ignored by community members or policy makers. CS studies benefit by recognizing the importance that the *process* of building a diverse inclusive research team, collaborative planning and problem solving, and even working through conflict brings. It is through these sometimes messy and challenging activities that trust relationships are formed and strengthened, and where the greatest opportunity for meaningfully leveraging the power of research institutions and decision-makers with community members facing environmental health risks. If project stakeholders, including decision-makers previously unresponsive to the problem and disenfranchised community members who may feel distrustful of scientific research, share the experience of feeling respected, contributing ideas, and learning from each other, they are more likely to build trust in each other and the data produced.

Designing for meaningful process mandates significant investment in time; both the professional time of researchers and participants, and building flexibility into the timeline of the project to be responsive. Aligning with the recent call for "slow science" (Stengers, 2018), this may require environmental health CS to actively protest, or creatively work around, short-term project funding structures, which can undermine communities' long term goals (Mah, 2017). In addition to allocating adequate resources for communication and trust-building, CS researchers can model a culture within the project that is open, collaborative, trusting, and non-judgmental. I have been honored to be part of this type of culture building within Project Harvest, as well as witness to just how much time and energy it takes to maintain regular participant communication.

Many participatory environmental health research studies have cited benefits from employing members of the partnering community as staff (Evans-Agnew et al., 2018, p.; Lewis, Castleden, Francis, Strickland, & Denny, 2016; Lichtveld et al., 2016) or *promotoras*. Working with *promotoras* has benefitted Project Harvest researchers immensely in increasing understanding of community life, knowledges, and culture; while *promotoras* also cited benefits beyond the paid work, such as feeling more connected to their own community. As a vision for participatory CS moving forward, community members facing environmental health risks may move even closer to the center of project leadership. If a research institution aims to improve effectiveness in working with disempowered communities, as well as truly leverage their position of power for justice, residents of those communities should be prioritized in staff and faculty positions. When the individuals rooted in historically oppressed communities are the same individuals designing and implementing participatory research, efforts and reach will undoubtedly be more successful.

Participatory research for environmental health, if conducted with nuanced understanding and attention to relationships, power, and process, will result in better data understood and valued by a broader community of stakeholders, which more effectively redistributes power and can ultimately lead to health policies which meaningfully benefit more people (Den Broeder et al., 2018). From my personal experience and observations over the past two years as part of

Project Harvest, as well as the data presented in this thesis, I have confidence in the efficacy of participatory approaches in environmental health research, both to produce better data than non-participatory methods, and to advance the cause of environmental health justice.

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