



Expanding Public Participation in Science Practices Beyond Data Collection

RESEARCH PAPER

LEIGHANNA HINOJOSA

ROBBIN RIEDY

JOSEPH POLMAN

REBECCA SWANSON

TIFFANY NUESSELE

NICOLE GARNEAU

**Author affiliations can be found in the back matter of this article*

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ABSTRACT

This study was conducted in a museum-based lab setting where scientists research the genetics of taste. Unlike academic labs with graduate students, the museum lab model trains volunteers (community scientists) who are (in true citizen science fashion) primarily responsible for enrolling museum guests into clinical studies; thus, they collect the bulk of the data for the research. Like most public participation in science research, the non-professional contributions have historically been largely limited to data collection; however, this study shows the power of invitations and structured opportunities for expanded participation among citizen scientists in a wider range of science practices. Through interpretive case study research, we examine how community scientists exercise agency and respond to opportunities for expanded participation in scientific practices including study design, data analysis, and dissemination of scientific findings through work on scientific articles. The case study research findings show that providing opportunities for involvement is only part of what accounts for community scientists' expanded participation. Dialogic negotiation of participation is also necessary, through bids and responses to bids, and through proffered guidance and scaffolding. Committed involvement thus entails deep cultivation and nurturing by both the museum staff, and at times, other more knowledgeable volunteers. Expanded participation is also bolstered by one's capacity, motives for, and satisfactions from pursuing those opportunities that align with past, present, or future interests and identifications. Such interests and identifications contribute to community scientists' willingness to overcome barriers and time constraints when they arise.

CORRESPONDING AUTHOR:

Leighanna Hinojosa

University of Colorado Boulder,
US

lehi6796@colorado.edu

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INTRODUCTION

The citizen science movement frequently calls for increasing the participation of nonprofessionals in scientific practices beyond data collection. This expanded participation may take different forms (Bonney 2009; Shirk et al. 2012) and have potential benefits that increase science literacy among nonprofessionals, improve the relevance of the science to a more diverse public, and provide experiences that may enable participants to move toward careers in science (NASEM 2018). However, it is also necessary to capture how a citizen scientist (or community scientist) moves beyond the role of data collector to include expanded forms of participation. It is important to describe potential trajectories for increased participation, and to denote how pivotal transition points occur over time. Based on case study research, this paper traces the ways community scientists increased their participation in a wider range of scientific practices in a genetics research lab at a nature and science museum, paying particular attention to the actions and reactions of both the professionals leading the program and volunteer community scientists.

Our main research question was, “How are opportunities for expanded participation in the scientific process offered, and then accepted or rejected in this community science program?” Other questions we asked were, “What might expanded participation look like?” and “What influences expanded participation?”

Results from this study may inform other citizen science initiatives on how to design and enact research opportunities in which participants build off prior knowledge and skills, create new knowledge, and use practice-based expertise to contribute to science.

THEORETICAL AND CONCEPTUAL FRAMEWORK

Community and citizen science initiatives can be well understood as apprenticeships (e.g., Lave and Wenger 1991; NASEM 2018; Rogoff 2008). This framing stresses how experts—in this case, professional scientists—guide the learning of novices—in this situation, community scientists.¹ In the lab where this study was conducted, all community scientists undergo training in proper laboratory practices, ethics training for working with human subjects, and enrollment techniques necessary for human subject studies. New community scientists are apprenticed into the laboratory by staff and more experienced community scientists, with informal mentoring and guiding occurring organically.

However, most apprenticeship learning models do not explain how novices exercise their will, or agency, to bring about change in community practices. Agency refers to capacity to act independently and make decisions. One theoretical framing that overcomes this limitation is a sociocultural approach incorporating a strong sense of dialogue (Wertsch 1991, 1998). In this view, community members interact and collaborate with one another using cultural tools, such as knowledge of genetics or statistics, to exercise agency and create action that neither the experts nor the novices would have alone. This can be seen in how community scientists and staff interact and participate in lab tasks together in ways that move beyond apprenticing during established procedures and into more expansive or new practices. In this paper, we draw on notions of dialogue to examine how the agency and action of community scientists are welcomed, or not, in scientific practices beyond data collection.

Furthermore, through dialogue, participants connect their past, present, and future selves as they participate in social activities and scientific practices to work toward communal goals. In this way, participants make sense of who they are in this research community, which further influences how they interact with and subsequently experience environments. Another factor that impacts interaction and participation in communities is the positioning of the people involved. Positioning or identification occurs in moment-to-moment interactions and actions of participants with other community members, when individuals signal the kinds of person they see themselves or others to be—i.e., what identities are ascribed to them (Wortham 2006). How individuals position themselves and are positioned by others are both important. Individuals can either accept or resist forms of external positioning, which can be seen in the manner they relate to identifications as evidenced by their social interactions and actions (Polman 2010; Polman and Miller 2010).

Acceptance typically includes telling stories of oneself aligned with external, outside positionings and identifications attached to them. Resistance can come in many forms; of interest here is saving face. Goffman (1967) wrote that preservation of face maintains comfortable social interactions and individual confidence. Erickson et al. (2008) underscored the ways face threat can hinder risk-taking in learning environments. When learners fear mockery or criticism, they are less likely to try new things in front of others. We draw on this scholarship to interpret community scientists' experiences of wanting to maintain appearances of competence and knowledgeability in the lab. Saving face can be seen in how opportunities for expanded participation are negotiated during interactions

among volunteers and professional scientists. This is discussed in depth in one case study below.

Thus in our conceptualization, identity is dialogically negotiated, and the enactment of envisioned identities—both by self and by others—shapes how individuals participate within community over time, creating a “trajectory of identification” (Polman and Miller 2010). Furthermore, “coordination of past, present, and future-oriented actions and identities sets the conditions for new forms of agency central to realizing possible futures” (Gutiérrez and Jurow 2016, p.3). In exerting independence (and competence) in community tasks, community members position themselves as agents. To understand how individual agency emerges over time, we specifically look at whether bids for expanded participation are accepted or not in dialogue and in interactions between professional scientists and community scientists, as well as how those bids are accepted or not. We use the term bidding to describe a bounded communicative event in which community scientists or lab staff used spoken words or written texts to discuss possible expanded participation. We analyzed these communicative patterns with reference to message form and content, as well as action sequences following the speech event, as suggested by Saville-Troike (2008). Lastly, we connect how people are positioned with their career and life trajectories. According to life course theory, trajectories are framed as “sequences of roles and experiences” that are marked by changes or transitions in one’s life (Elder, Johnson, and Crosnoe 2003, p. 8). Career and life stages involve transitions in education and professional pathways. Although these categories are not all encompassing of identity, we sought patterns and similarities across career and life stages related to volunteering as community scientists, and to agency within the volunteer program environment and participants’ social worlds.

RESEARCH CONTEXT AND METHODS

ORGANIZATION OF THE LAB

This study was conducted in a museum-based genetics lab that invites museum guests to participate in double-blind genetics studies about taste (Nuessle, McNamara,

and Garneau 2020). From 2009 to 2019, the museum ran six scientific studies. Our research on community scientists’ experience is focused on the last three scientific studies, “Science of Sour” (2016–17), “Savory and Sour” (2017–18), and “Genes and Grains” (2018–19). Museum volunteers at least 16 years of age had the option to choose to be placed in the lab after going through an interview process conducted by museum volunteers and staff. Volunteer citizen scientists in the lab are known as community scientists, wear white lab coats, and participate in study tasks and support tasks for an adjoining health exhibit. All active community scientists from 2016 through 2019 were invited to participate in this study, resulting in 59 total study participants across life and career stages, with a higher proportion in their late career volunteering long term (see [Table 1](#) for life and career stage demographics). All 59 participants consented to participate in the learning science research study approved by the researchers’ Institutional Review Board. Pseudonyms are used in this paper for all participants; researchers also changed or masked some details about individuals to maintain confidentiality.

We categorized 27% of participants as pre-professionals, 47% as in early-to-middle phase of life and career, and 27% as in late career. We defined three meaningful stages in these participants’ life courses (Elder et al. 2003): pre-professionals had not yet started their formal career (e.g., participants in high school or college); those in early-to-middle career had moved beyond an undergraduate degree but were not yet retired (these participants were actively working or not currently working, or were in graduate or professional school); and those categorized as late career were retired or semi-retired from their profession. Three times as many female community scientists were observed than males. This population was also largely white, and many—especially those in the late-career stage—held advanced degrees. All participants had an interest in science in general and/or in a career in a science field. Our case studies reflect this population. During lab volunteer shifts, community scientists tended to be white and older, with more senior citizens volunteering than teens and young adults over longer time periods. Pre-professionals tended to volunteer on weekends and over summers, then exit the lab for school transitions. Volunteers in their pre-

CAREER/LIFE STAGE	NO. OF PARTICIPANTS (%)	PSEUDONYMS OF CASES
Pre-professional	16 (27%)	N/A
Early-middle career	27 (47%)	Summer, Breana, Avery, Jaclyn
Late career	16 (27%)	Samuel, Maya, Patricia

Table 1 Career and life stages of 59 case study community scientists.

professional and early-career stages, in general, tended to leave the lab in pursuit of life goals and during major life transitions. Many early-to-middle career and life stage community scientists took pauses from volunteering and returned when their schedules allowed.

DATA COLLECTED

The first four authors (Hinojosa, Riedy, Polman, and Swanson) collected data for this study. We conducted participant observations and observations during a variety of program activities from July 2016 through August 2019, yielding fieldnotes from 103 volunteer shifts or related events (e.g., symposia, outreach, and appreciation dinners). In year two through three, observations deliberately targeted expanded forms of scientific participation by community scientists in the lab. Guest, staff, and peer interactions were also recorded with permission and transcribed for inclusion in fieldnotes. We invited a sample of community scientists stratified across career and life stages to participate in semi-structured interviews about related past experiences and interests, motivations for participating in the lab, experiences in the lab, and perspectives on lab activities, during each of the three scientific studies from this period. During the second and third years, some interviewees were deliberately selected for follow up interviews, some interviewees were new community scientists, and some were exit interviews. All 64 interviews were audio recorded and transcribed. (Please see Supplemental File 1: Appendix for all interview protocols.) To provide additional context, we also refer herein to a survey of all active community scientists conducted in 2017, which received 31 responses.

DATA ANALYSIS AND REPORTING

Our data analysis followed an interpretive case study approach (Erickson 1985; Polman 2000) in which the broadest level of case was the program's scientific studies, and within the program, we constructed cases of individuals and groups. Codes for analysis were deductive based on the theoretical and conceptual frameworks described above and supplemented by emergent themes in the data related to those themes (i.e., supplemented by techniques based on grounded theory; Glaser and Strauss 1967). We describe the particular codes bounding this interpretive case study of expanded participation below. We coded data and compared coding analysis concurrent with data collection (Coffey and Atkinson 1996). We discussed coding analysis, and refined inductive code definitions after each coding round based on disagreements or elements requiring increased clarity. Inductive codes not used in subsequent coding rounds were marked obsolete and removed from the code book. We periodically shared analysis and findings

with lab members and study participants for the purposes of general feedback and member checking.

We coded fieldnotes and interviews for lab and scientific interaction moments. A moment is defined as an occurrence or a reference to a past or future anticipated occurrence. Moments were coded in the following dynamic ways. Staff-peer teaching moments refer to lab staff showing volunteers procedures. Practicing moments refer to volunteers doing lab tasks while being monitored by another volunteer or staff member. Peer-to-peer teaching moments refer to a lab volunteer teaching another volunteer or staff member how to complete a procedure. Independent moments are when lab volunteers complete tasks they have demonstrated competence in and know how to do. Agency moments are when a lab volunteer affects the way a procedure or lab task is done, or when a volunteer is asked for their expertise and advice. Those who participated in practices in more scientifically agentic ways tended to be those in their later career phases. Of the 59 participants, 45 were observed and/or interviewed, and 16 were observed participating in expanded lab practices in years two and three of the study (i.e., participating in more scientifically agentic ways).

We subcoded forms of expanded practices under a "lab & scientific practices" parent code. Scientific practices carried out in the lab are shown in [Table 2](#).

To understand how opportunities for expanded participation were accepted or not in the lab among the 16 participants observed, we used a bidding code broken into offered, accepted, rejected, and ambivalent. These indicated whether the bid for expanded participation in scientific practices were clearly offered, accepted, or rejected; ambivalent bids were when opportunities for expanded participation were not rejected, but also not taken up. We also used codes for constraints and boundaries to continued and expanded participation. These included temporal barriers (e.g., meetings outside of shift hours), managerial barriers (e.g., lab staff not present due to scheduling), financial barriers (e.g., having a job that takes precedence over volunteering), psychological/emotional barriers (e.g., fear of failure or looking unknowledgeable), informational barriers (e.g., exposure to information) and knowledge barriers (e.g., people present not knowing how to do a task).

We selected five focal cases of expanded participation to report in depth in this paper to demonstrate examples among participant types, and structured activities for guided collaboration and supported expert contribution. Two group cases and three individual cases were selected to reflect a range of participant types and to reflect forms of expanded participation in the lab. No pre-professional

ABBREVIATION	BROAD PRACTICE	DESCRIPTION
DEFIN	Study definition	Feasibility team, an expert-review-panel process for identifying and refining the next study's scope
METHD	Design methods	Design team and other data-collection protocol work
ANALY	Data analysis/interpretation	Using mathematical, statistical, or visual techniques to detect patterns, draw conclusions, etc.
BGRES	Background research	Review and synthesis of related information and research for papers, presentations, and projects
COMM-S	Communicate science to the scientific community	Contributing (as co-author) on scientific papers Presenting to scientists
COMM-P	Communicate science to the public	Explanations during enrollments Hosting or staffing outreach events Public presentations Contributions to materials for the public (videos, take-home packets, etc.)
DATAP	Process data	DNA extractions and routine data transformation processes
DATA C	Data collection	Doing study enrollments of museum visitors
MAINT	Lab/exhibit maintenance	Use of lab tools and manipulation of materials, following standards of practice (co-occurrence with other lab tasks)

Table 2 Community science lab practice codes and descriptions.

cases are included, because these participants did not expand participation beyond the lab's core practices of data collection, data processing, and lab maintenance. The perceived lack of involvement in expanded practices was in major part due to time constraints resulting from outside commitments (e.g., school) of pre-professionals. The case studies describe what expanded participation looks like and how bids for participation were received.

KEY FINDINGS

As noted, a key goal of the museum has been to expand and deepen the level of community scientists' participation in scientific practices beyond data collection. In interviews, many community scientists also expressed the desire to be given more agency and responsibility in the lab's scientific processes; this sentiment was expressed by early-to-middle-career and late-career, or retired, participants (but not by pre-professional participants) in 2016 through 2018. In the 2017 survey of a broad set of 31 community scientists, 30% of respondents said they would appreciate the opportunity for more in-depth involvement with the genetics studies. When opportunities were offered, we found community scientists took advantage of new opportunities to volunteer if certain criteria were present, such as persistent nurturing and encouragement by museum staff, their own prior or current interests, identifications, and/or experiences in science or related fields, and their schedules allowed

availability for involvement. Additionally, expansion drew on prior interests and experiences of the museum staff, which were used to guide volunteers and model authentic scientific practices that were collaborative and generative.

As in many other citizen science efforts (NASEM 2018; Shirk et al. 2012), the studies conducted in this museum-based lab in 2016–17 and 2017–18 included opportunities for volunteers to contribute to data collection such as enrolling museum guests in studies and collecting their DNA. During the “Science of Sour” (2016–17) and “Savory and Sour” (2017–18) studies, we observed some community scientists acting as not only what Shirk et al. (2012) characterized as contributors to data collection and data processing (e.g., DNA extraction), but also as collaborators with the staff scientists on data analysis and on public communication of lab findings. Expanded participation in even more scientific practices occurred in the “Genes and Grains” (2018–19) study. Community scientists had opportunities to engage in expanded practices toward the larger scientific goals of the laboratory, to the point where some began acting as co-creators (Shirk et al. 2012), contributing extensively to the formulation of the research questions, methods and procedures, and dissemination of research findings. As described below, we observed several community scientists take significant advantage of opportunities to expand their levels of participation.

In 2017 and 2018, invitations to collaborate were emailed from the museum to all community scientists, and were spread by word of mouth from the lab manager and

assistant lab manager. These invitations asked community scientists about interest in increasing lab participation. Lab staff next sent out invitations to a specific project, both electronically and verbally, to volunteers. Invitations were then rejected, ignored, or accepted. Approval for collaboration was needed from the principal investigator (PI; the fifth author), who heard ideas from the lab manager (the fourth author), who worked day-to-day with the community scientists. The PI and lab manager discussed how best to accommodate the needs of community scientists and the capabilities of lab manager and staff. The five cases below show how volunteers took on more responsibility to pursue the types of practices beyond data collection described in [Table 1](#).

Our analysis of the entire corpus of observations and interviews, using the conceptual codes described in the theoretical and conceptual framework section, yielded several key patterns. [Table 2](#) and [Figure 1](#) show the types of participations among the 45 participants with observational and/or interview data. The foundational and most common practices were lab maintenance (100% of participants), communicating science to the public (96%), data collection (60% of participants), and data processing (60% of participants). Far less common were practices related to preparing scientific papers: contributing to the study design (31%), conducting background research (13%), communicating science to the scientific community (9%), and data analysis (7%). Although 22% of observed community scientists (N = 10) were invited to participate in

manuscript drafting, only 9% (N = 4) were observed in the long-term process of writing and submitting to journals. Finally, a select few community scientists also participated in defining the study (9%, N = 4).

With regard to agency, we found: (1) the invitations for expanded participation were instrumental, (2) those opportunities were negotiated, (3) expanded participation relies on cultivation and nurturing by both professional staff and other volunteers, and (4) in contrast to pre-professional participants, those in early-to-mid-career and in late-career stages exercised more scientific agency in utilizing existing expertise or seeking to build expertise. Those who participated in expanded practices in more agentic ways tended to be those in later career phases. Of the 45 study participants, 38 were observed and the remainder interviewed. Of those 38 observed participants, 21 community scientists were observed in invited bids to broaden participation, and 16 were observed in and/or interviewed about expanded participation activities; 7 of those participants were volunteers in the late-career stage; 8 were volunteers in the early-to-mid-career stage; and 1 was a volunteer in the pre-professional stage of her career (she declined). Important to note however, invited bids to participate in expanded participation, as we have defined it (i.e., participating in scientific practices as a collaborator), were not always accepted, nor did participants necessarily follow through. In the following cases, we describe the dynamics of how community scientists responded to opportunities for expanded participation.

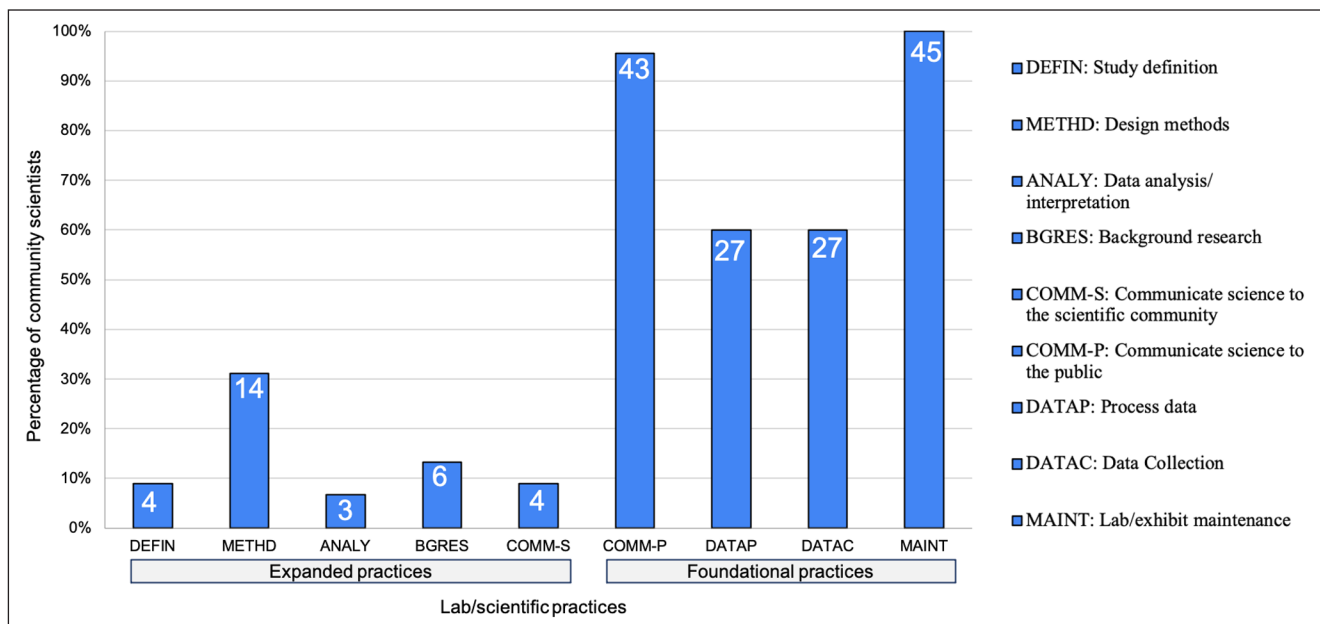


Figure 1 Prevalence of scientific practices among 45 participants. The figure depicts the percent and number of participants who participated in each scientific practice (definitions also in [Table 2](#)).

EXPLORING PRIOR INTERESTS AS A LAUNCHPAD TO FUTURE EXPERTISE

Current early-career community scientists with little to no background in science, including Breana, were guided in new forms of participation. Breana began volunteering in the museum lab in July 2017. She started her undergraduate career with an interest in biology; however, she finished with a degree in marketing while maintaining interest in science. In September 2018, she was preparing to become a nurse by taking required courses, volunteering with a physical therapist, working as a chemistry and biology stockroom technician at a local college, and volunteering at the museum. Breana had been volunteering in the museum for a little more than a year when she was invited to collaborate on a manuscript about sour taste with the study's PI. This was not the first time Breana was invited into opportunities for expanded participation; she had been previously invited to become a member of the study's design team—discussed in more detail below—but was unable to join because of scheduling conflicts. The PI noted in her email that working on the manuscript “would be great” for Breana. As a volunteer community scientist, Breana was free to either take up or reject this bid. She accepted this opportunity.

The PI left extensive feedback on a draft that Breana started, but Breana needed help interpreting the feedback. They met in person to discuss it, and the PI said she would follow up with additional resources. For the next several weeks, the PI encouraged Breana to action. She emailed Breana with specific writing goals, and she shared resources that modeled how to write a research article's introduction. The PI made efforts to apprentice Breana in the genre of academic writing, uncovering hidden aspects of the work, sometimes explaining, “It's not really clear, but this is how scientists think” (observation, September 19, 2018). Breana also met with the lab manager for manuscript writing support.

Toward the end of 2018, the PI took a step back, inviting an outside scientist to help draft the paper, and it was during this step back that Breana initiated active bids for more agency. Eventually, Breana worked with the outside scientist to suggest new research questions to the PI. Breana wrote, “We came to the conclusion that there may be more interesting questions to answer regarding our data versus just comparing the behavior of acids to each other” (Email, November 2018). This bid was acknowledged with the PI's response: “Thanks everyone, I'll think this over, it seems like a great idea at the outset” (Email, November 2018). This was a pivotal agentic moment, when Breana moved from a helper on the paper to an initiator directing it. Although the PI did not respond with an outright acceptance of Breana's idea, she acknowledged it and said she would

consider it, rather than stifling it or deeming it out of place for a community scientist. In a later communication, the PI referred to the team as “sour folks” (after the topic of the paper), positioning Breana as a specialist within the lab. Breana's bid to change the direction of the paper was taken up.

One reason Breana may have decided to participate in the manuscript writing was because she had prior interest. When discussing the potential to be published in a research journal she stated,

That's like some bottled dream when I first started undergrad in 2007. Like, “Oh, if you're in science and you're doing these labs, this is what you end up doing in research.” So it was like a little background goal (interview, September 14, 2018).

Ten years prior to joining the lab, Breana was interested in scientific publication.

Breana's work on the manuscript also created a bridge to potential future practices, such as working with statistics in pursuit of her nursing degree. The manuscript project required her to review several research papers and discuss statistics with the PI and an outside scientist. When the project first began, she mentioned she felt she was getting a head start on statistics courses that would be a part of her future nursing program. A few months into writing the paper, she was suggesting different types of analyses to run and suggesting graphic displays to convey their paper's findings, indicating confidence and agency.

AN EXPERT BIDDING FOR RECOGNITION AND UTILIZATION OF EXPERTISE

In addition to being invited to participate in deeper forms of scientific practices, volunteers were observed using their background knowledge and prior practice-based expertise to contribute to scientific research without being formally invited. For instance, Summer demonstrated agency in the lab when approaching data and research relating to her field of expertise, human genetics. In the first year of our study, Summer had expressed feeling underutilized for her genetics expertise and her prior experience managing a science lab. Her genetics expertise felt at times lost on shifts where more knowledgeable peers were not present. Thus, her bids had been treated ambivalently, or altogether rejected. Summer described ways in which she felt her earlier bids were not accepted in the lab.

There feels like there's a lot of times when I'll make suggestions that—I don't know if it's because we don't have resources or because they don't really know what I'm talking about—but it never gets

followed through on ... (interview, November 11, 2016).

In year two of the study (2017–18), Summer saw an opportunity to examine data the lab was not otherwise going to use and made an off-hand comment to the lab manager. “There is no such thing as junk DNA,” she said (interview, August 08, 2019), and suggested the lab analyze that data. Summer’s proposal grew into a manuscript written by Summer and the PI. In this way, Summer became a collaborator within the larger science community. At one point during the project, Summer critiqued the statistical analysis of the PI. Outside collaborators agreed with her assessment, and the shape of the paper changed due to her comments. Later, the PI publicly thanked Summer at an appreciation dinner, saying, “This was data that we would not have used and she figured out where the story was and helped with the analysis and it’s amazing” (observation, volunteer dinner, June 13, 2018).

The work on the manuscript was not always easy. There were times when Summer exercised a great deal of agency in the project, and other times she simply wanted the PI to “tell [her] what to do.” Even though she was the one who reignited the project, she said during one interview (October 23, 2017) that she didn’t initially know what she was doing, but would “figure it out.” She had to navigate collaborating with several co-authors who worked varying shifts, while she was in the lab only part-time. The fact that they were using partially published data, and she was working with drafts that were missing data, contributed to the difficulty. It was a time-consuming task. The assistant lab manager, Crystal, mentioned Summer was at an advantage compared with other community scientists because she was at the museum several times a week (in different areas of the museum), whereas others typically volunteered once a week. Other writing projects (such as the one involving Samuel mentioned below) could take even longer.

Summer and the PI continued to work on the paper between February and August 2018, submitting it in the summer and receiving an invitation to revise and resubmit in September. The revision had complications. What began as a short paper evolved into a full-length manuscript that required a knowledge of statistics Summer felt was beyond her expertise. In a 2019 interview, she mentioned she was ready for the project to come to an end. Although she was happy to be involved, it had taken much more time than anticipated and at times she expressed doubt that she was really contributing, and was perhaps even slowing progress. However, she made it clear that though the project was at times difficult, she enjoyed the work and had no intention of quitting. Thus, Summer contributed her expertise in the lab, within her limits. Here we described Summer’s

involvement in data analysis and scientific article writing. The particularities of Breana’s and Summer’s contributions to scientific article writing were unique to them and relatively rare among the overall volunteer pool, but there were a few other community scientists who also worked on aspects of scientific paper writing during our study: Six contributed to background research, four to data analysis for a publication, and four to scientific writing. These highly engaged volunteers were also involved in various other types of collaborative work in the lab, such as in the design of the study, which is described in more detail in the next section.

TARGETED INVITATION FOR EXPANDED PARTICIPATION IN STUDY DEFINITION

In January 2018, after several rounds of emails between the lab manager, volunteers, and the principal investigator, four community scientists attended a meeting to discuss study proposals for the upcoming genetics lab study, which would run between November 2018 and August 2019. Prior to this taste study, the research topics were chosen by the PI with input from the lab manager. Two previous studies were developed as partnerships with external colleagues and built upon their work. Shortly before beginning data collection on each of those studies, lab staff involved community scientists in testing and refining the protocol (i.e., prototyping). For the study beginning in late 2018, the PI solicited proposals from the scientific community at large to collaborate with the lab, and the lab staff created an expert review panel they referred to as the “feasibility team,” comprising four community scientists. The formation of this team was informed by the results of the first year of research and evaluation (2016–17), which had revealed strong interest among community scientists to participate in study selection.

In the feasibility team, five community scientists and the lab manager discussed design and execution of two proposed studies. This meeting was intended to ascertain the feasibility of each study, which would be executed in the lab with museum guests, and to develop counter-proposals to share with external scientists. Volunteers participated in this panel during off-shift hours; one community scientist could not volunteer extra hours that week, and instead submitted her notes to the lab manager before the meeting. We observed, before and during the panel, how the lab manager positioned community scientists as having expertise:

So that’s why this is even so important...because you guys with the exception of Avery have done multiple studies and this is Avery’s first. You all have research [experience] and are really good at critical thinking to be like “okay, here’s what does work here but

this doesn't ..." because you guys know the space well and the requirements we have (lab manager, meeting observation, February 4, 2018).

As the meeting progressed, the lab manager asked the four community scientists about each proposed study's pros and cons. This evolved into a discussion of each proposal's feasibility that included conceptual ideas behind the studies as well as the methods. The dialogue below is between community scientists and the lab manager, in which the community scientists shared their expertise on one particular DNA collection protocol in one of the proposed studies.

Avery: We didn't even talk about the DNA collection.

Lab manager: Yes. So the DNA collection [in the proposal] to me is a major con.

Maya: Actually I [initially] thought so too but really it's not a big deal.

Avery: There were a couple of things ... you can't have eaten for a half hour before you do it.

Summer: You can't eat and smoke or chew gum.

Maya: Oh, really?

Avery: You have to fill two milliliters [of the saliva sample] up --

Maya: That was done [in the past], that was easy.

Summer: Not for some people, not kids, yeah. You can't have it really including younger than 8 years for it (meeting observation, February 4, 2018).

Community scientists demonstrated a level of understanding of the current DNA collection techniques as well as the practice of collecting DNA from museum guests, and their expertise was voiced in dialogue with one another and the professional facilitating the meeting. Thus, the community scientists were agentic in this and other meetings of the feasibility team, which directly contributed to selection of what came to be known as the "Genes and Grains" study over the other proposal received. Through this process, the community scientists also contributed to protocol design (this discussion and subsequent meetings informed the counter-proposal sent to external researchers) and basic study definition. Furthermore, this was the first time in the history of this lab that community scientists participated in such practices.

TARGETED INVITATION FOR EXPANDED PARTICIPATION IN STUDY DESIGN

Community scientists were invited via email to participate in various lab activities in preparation for the "Genes and Grains" study. Fourteen community scientists chose the

option to join the design team, which would help design the study protocol and guest enrollment script, and included in-person meetings with the lab PI and lab manager, and commenting electronically on a draft of the script, which lab staff then finalized. Researchers observed three design team meetings. In the first (April 20, 2018), two community scientists, the lab manager, and a museum education staff member reviewed study logistics and learning goals for the public. This informed the draft enrollment script. The second meeting included community scientist Patricia, the PI, and a temporary lab staff member. The goal of this meeting, according to the PI, was "to go through the script and get Patricia's feedback, as a long-time, experienced community scientist, on the study script" (observation field notes, July 26, 2018). The script draft was shown to volunteers on shift, and 11 community scientists commented electronically. Comments were reviewed in the third in-person meeting in August, with Patricia, the PI, and two other lab staff. Two community scientists were unable to participate in design team meetings because of scheduling; some of these meetings did not take place during regular shifts. Lastly, prototyping of the script continued in the lab and involved community scientists on shift. Remaining issues voiced to the lab managers were discussed further with the PI.

Depending on the presence of community scientists and lab staff, we saw some differences in how bids were received and how the dialogic activity was structured among community scientists and lab staff. The chain of command dictated that the PI and education staff had the final word on all edits, and were thus positioned as the ultimate authority for study design and enrollment script. The lab manager and assistant lab manager acted as liaisons and buffers between the PI and community scientists. This was seen in the first meeting, where we observed many community scientists' bids initially accepted by the assistant lab manager ultimately rejected by the PI because of her constraints or those of the education staff. We observed much easy interaction between the assistant lab manager and community scientists, even when it was to discuss off-topic subjects such as background information on the genetics of wheat. This receptive dialogic style between community scientist and staff member continued with Patricia and the PI during the second meeting, when constraints were not yet laid out. The PI showed interest in Patricia's input by asking multiple times how community scientists would do things. Patricia suggested prototyping the script on shift with other community scientists, and the PI agreed.

The dialogic dynamic shifted from the second meeting to the third, in which proposed changes from the staff and comments from the community scientists on the enrollment script were reviewed. We noted community

scientist Patricia said little at this meeting compared with staff, and a suggestion she made was not initially accepted. After some persistence and re-wording, Patricia's suggestion was eventually received positively, after a staff member rephrased her bid. Different types of dialogic structures emerged depending on who was present in the meetings and what the design constraints were. We attribute differences in dialogic structure to the positioning of lab staff as authoritative figures with institutional constraints (such as compliance with IRB and scientific rigor) in study design.

Perhaps most interestingly, regardless of how community scientists' in-person and electronic bids were received, they frequently expressed satisfaction with their participation in study design during these meetings and in interviews afterward. Thus, individual agency and reward from contributing to a scientific study were major motives for community scientists joining and continuing in the design team. Samuel's case illustrates part of this dynamic.

BIDDING FOR SAFE ADVANCES IN PARTICIPATION

Samuel was a retired medical professional who had worked in the lab as a community scientist for almost 10 years. He described his time in the lab as fairly routine and his day-to-day duties as not particularly stimulating. He primarily enjoyed working in the lab as a way of spending quality time with friends he had met volunteering (Hinojosa 2020).

Samuel found that occasional opportunities for expanded participation helped keep his volunteer experience fresh, although he was adamantly not interested in participating outside of his regularly scheduled shift. For him, successful bids for expanded participation were those that could take place over the course of just a few weeks, such as working on the enrollment script. For the "Genes and Grains" study, he worked on the enrollment script over several weeks in summer 2018. Mirroring statements made by the lab manager, he noted the staff counted on him for providing honest feedback: "I think that's one of the reasons they keep me around. It's for bouncing ideas off of them" (interview, September 7, 2019). He pointed out the draft script had several of his comments on it. For instance, he made notes on protocol, pointing out where community scientists would need additional information to complete enrollment. Some of those requests for background information and clarification were incorporated into a FAQ for the volunteer scientists to use during enrollments. Even when his comments were not accepted, he noted they were appreciated. Speaking of the lab manager, he said, "Oh, yeah. She appreciates our input and vice versa" (interview, September 2019). He enjoyed providing feedback and said

that intellectual discussions of the lab's work made for unusually positive lab experiences.

In contrast, Samuel's lack of genetics knowledge may have limited his ability to participate more fully in more complex practices like writing a journal article. He remarked it would be helpful if the PI gave a "chalk talk" to community scientists about the study and the genetics involved, since he did not have the background in genetics he would like. This view of himself differed from the way the lab manager positioned him as an "expert" during his shift who "[kept] her on her toes" (observation, February 15, 2017). Nonetheless, Samuel desired a chance to participate in the lab in more agentic ways in which he felt heard and appreciated.

The lab manager invited Samuel to participate in some preliminary data analysis and manuscript drafting. Despite Samuel's education, he did not have the foundational content knowledge necessary to push such data analysis forward. Although retired science and medical professionals fall under the category of people with scientific backgrounds, Samuel's expertise was outside of genetics. Therefore, the lab manager's positioning of him as a more-skilled participant sometimes appeared to cause him discomfort due to low levels of appropriation (i.e., taking up and "making one's own" Wertsch 1991) of genetic knowledge and practices. More extensive scaffolding of Samuel's work would have been necessary for more in-depth involvement in expanded participation.

In retrospect, it appears that some of Samuel's bids for increased participation were ambivalent. For instance, during preparation for writing the article, the lab manager provided an article for him to review. While others were reading, the observer noted Samuel getting up to look out the window. We interpreted a contradiction between how he repeatedly asked for additional opportunities but did not always take advantage or stay engaged. Since he did not act to expand his genetics knowledge even when offered, it "saved face" for him to minimize time and attention on the more challenging work contributing to a paper, and maximize focus on activities like the enrollment script for which he felt more qualified. Another reason Samuel gave for sometimes neglecting offers for expanded participation that responded to his own request was that he chose not to work on a manuscript during his own time. He was only in the lab once per week, and those shifts did not always overlap with when the lab manager was present. This structural limitation made it more difficult for Samuel to keep up with manuscript progress.

Samuel's case underlines that even brief periods of expanded participation, such as the editing of the enrollment script, can help to keep the volunteer experience interesting

and exciting. It is also important to recognize limitations of expanding opportunities to volunteers; because they are volunteering their time, they may not be able or interested in spending effort outside their shifts, in particular when that work does not connect to outside interests or ambitions on a longer time scale in their lives. It is worth noting desires to limit one's time commitments were a common sentiment among the other eleven retired community scientists who responded to the 2017 survey, and they recognized this could limit their opportunities for learning and engaging in new scientific practices. Thus, major barriers for expanded participation include time commitment (from both volunteers and staff), knowledge of genetics and genetics practices, the desire to avoid face threat, and interest in pursuing projects outside volunteer shifts.

SUMMARY

Our analysis of these groups and individuals participating in the lab over time revealed how volunteers took up expanded practices in the lab. **Figure 1** shows the activities and practices for the individual cases, which intersect with the group cases. Next, we use **Figure 2** and three case studies to describe community scientists' involvement in various scientific practices.

As with the other scientists in the lab, the most foundational practices that Samuel, Summer, and Breana participated in were lab maintenance, communication with the public, and data collection. Maintenance, which

included tasks such as washing dishes and restocking the exhibit experiments, commenced as soon as each began volunteering. They also immediately began communicating with the public by talking with museum guests in the exhibit outside the lab. These activities were typical of all community scientists in our study, not just these case studies. When studies were open for enrollment (November–August), these community scientists enrolled guests, which included communicating with the public to help them understand the genetics studies as well as collecting their DNA samples for the studies. We designate a gap in the data collection practices in the timeline to show enrollments were conducted for part of the year during each study. Beyond these individuals, most community scientists who volunteered in this lab enrolled museum guests also, unless they were too young to do so. Sometime after they had been volunteering in the lab for a period, Samuel, Summer, and Breana began data processing of the collected DNA samples by doing DNA extraction. This was also typical of most volunteers.

All three of these individuals were involved in communication with the science community through work on journal articles, with Breana's and Summer's contributions more sustained and Samuel's brief due to his own decisions. The two who had less knowledge, Samuel and Breana, contributed to preliminary data analysis and background research respectively, while the community scientist with the greatest level of prior preparation and

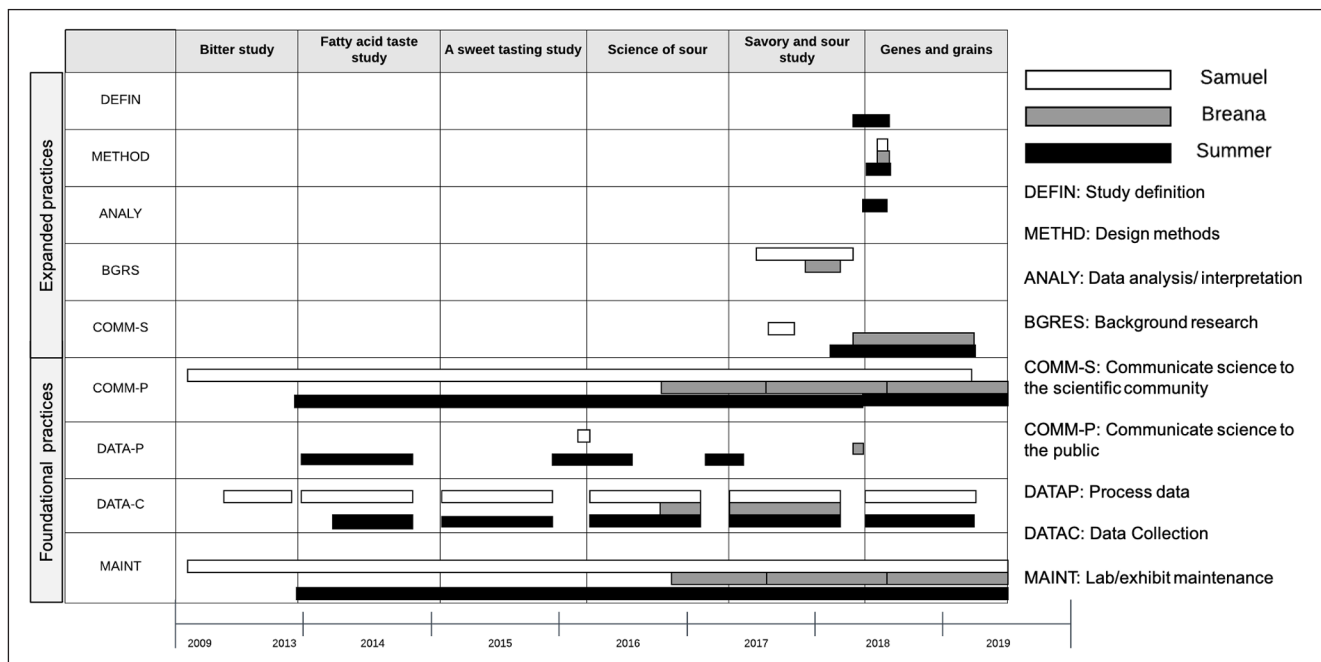


Figure 2 Participation in practices among focal participants. Three individual case studies (Samuel, Breana, and Summer) indicate the types of practices participants engaged in over the course of six genetics studies. The scientific practices with examples are shown in Table 2, and a summary of the participation frequency across all scientists is in Figure 1.

knowledge, Summer, contributed significantly to data analysis. Involvement in journal writing and preparation was not common among community scientists in general, and was explicitly calibrated to the levels of knowledge and time commitment of the participating volunteers. All three of these community scientists (and 11 others) were involved in specification of and refinement of research methods, explicitly facilitated by the lab's creation of a designated design team that reviewed and revised the enrollment script; in studies prior to "Genes and Grains," such contributions were present though less extensive. Finally, involvement in the next study definition and scope was made possible for a small number (4) of community scientists, including Summer, by the lab's creation of a small feasibility team that functioned as a review panel.

DISCUSSION

We sought to answer the following research questions: How are opportunities for expanded participation in the scientific process offered and then accepted or rejected in this community science program? What might expanded participation look like? And what influences expanded participation? Through interpretive case study research, we examined how community scientists exercise agency and respond to opportunities for expanded participation (i.e., bids for study design, data analysis, and dissemination of scientific findings through work on scientific articles). Findings show first that community scientists were offered opportunities for expanded participation and negotiated their contributions and collaborations with lab staff; however, community scientists' expanded participation was a result of more than providing opportunities for involvement. Volunteers in early-to-late career stages tended to exercise more agency in higher-level lab tasks and practices. Second, dialogic negotiation of participation was necessary, through bids and responses to bids, and through proffered guidance and guided participation. Committed involvement to expanded participation thus entailed deep cultivation and nurturing by both the museum staff and (at times) other more knowledgeable volunteers. Expanded participation was also bolstered by the volunteers' capacity and motives for pursuing those opportunities that align with past, present, or future interests and identifications. Such interests and identifications contributed to community scientists' willingness to overcome barriers and time constraints when they arose.

The five focal cases reported here demonstrate how offers and bids for expanded participation were received in the lab. Bids were extended from lab staff and volunteers; however, bids were not always accepted or sometimes fell

short of intended goals. Successful bids for participation were generally linked to availability of volunteer and lab staff, knowledge of background information and scientific practices, and when necessary, willingness to pursue projects outside of volunteers' shifts; also, motives for committing were linked to current or future desired careers or skills and often took extended periods of time to come to fruition. This demonstrates how expanded participation can be scaffolded as it is in a traditional lab, with distinct differences, such as the motives behind volunteering for expanded participation and the need for low risk to volunteers and for the program if they decline or circumvent efforts for expansion. During the "Genes and Grains" study, lab staff recognized the need for additional scaffolding of volunteer participation, in particular, support with manuscript writing. Now, when someone is invited to work on a paper, staff share a worksheet that includes the steps involved in working on a paper, notes responsibilities and expectations, and details an anticipated timeline.

On the basis of our analysis of our complete case study data corpus, we concluded that enjoyment of expanding participation was not solely a matter of being provided new or deeper opportunities to volunteer. While successful expansion required frequent and consistent nurturing by museum staff, and in some cases more knowledgeable volunteers, there were also motives from the volunteers at play, such as Samuel's enjoyment of being a thought partner. Our finding on motives for participating in citizen science is consistent with other research. In a review of 32 qualitative and quantitative papers on citizen science, enjoying a built-in reward to participating in a valuable way, such as contributing to scientific output, was found to be a major motive driving participation; while a lack of finding satisfaction from participation had a negative effect on continued participation (DeVries, Land-Zandstra, and Smeets 2019).

We also found expanded participation was associated with correlative prior interests and experiences—i.e., community scientists' past trajectories—as well as current interests and availability or capacity for involvement in a given role or project. Important issues with capacity were saving face and safety (Goffman 1967): We interpret Samuel as resisting positioning as an expert, and limiting his contribution to a paper to minimize instances where genetics expertise, or lack thereof, could be confronted, thus making the space feel safer. He instead gravitated to positions where he felt more confident. Resisting certain positionings and relating one's resistance to lack of background knowledge and to certain levels of perceived scaffolding deserves more attention in future research.

Expansion also reflected prior interests and experiences of museum staff, who modeled scientific practices and

interests that were collaborative and generative. We saw this when Summer's comment re-ignited interest in the museum staff's prior work. In addition, for early-to-mid-career individuals, expanded participation often linked to their intended future trajectories, as in Breana's aim to become a nurse. This may occur through scaffolded processes of building new skills, gaining new practical or conceptual knowledge, and/or adding valuable items to their resumes. Because providing scaffolding toward complex scientific practices is resource and knowledge intensive, it cannot be proffered to all community scientists, but instead needs to be calibrated to their "zones of proximal development" (Vygotsky 1978).

The expanded participation we report here also changed the lab's culture, as lab staff asked more often for expert advice from volunteers, and took up volunteers' expertise through new forms of participation, such as publication of scientific knowledge from data thought to be previously useless. This positioned volunteers engaging in genetics research—especially those with science backgrounds—as contributing valuable expertise. Lab staff were positively receiving scientific contributions community scientists made, and the lab's genetics research was benefiting in ways not foreseen by lab staff (for example, staff delegated projects to share the burden of the overwhelming amount of work in the lab). This has implications for similar volunteer and citizen science programs, which can involve their participants in scientific practices beyond observation and data collection.

These findings are generated from adults in their early to late careers with science expertise who sought to be involved in the community and to contribute meaningfully to science in ways that were personally satisfying and professionally rewarding (such as building upon knowledge and skills related to school and career). Nonetheless, the findings from this research have clear pragmatic implications for other types of informal science education spaces that use guided learning and participation; the study also contributes to theory on broadening public participation in scientific research.

Theoretically, the intersection of participants' life history, the length of time they are with the program, and the program's history, is a nexus for agentic opportunities. Between 2017 and 2019, the museum lab began to offer opportunities for higher levels of participation in scientific practices, which further provided space for intersections with community scientists' life histories and identifications, and provided support for their agentic participation. Individual agency became the firing point for expanded participation to be taken up in bids. Thus, trajectories of identification, life courses, and the historical and present structure of a science learning program can foster agency

moments that act as key pivots toward expanding expertise or desired learning initiatives. Using this unique array of theoretical concepts, program designers can pragmatically structure support and galvanize participants' motivations to allow for enactment of individual agency. For instance, others interested in expanding participation in citizen science may find it useful to offer a variety of opportunities with a range of target participants' life and career stages in mind, as well as structuring those opportunities to include appropriate scaffolding, and chances for both community and professional scientists' agency to shape the study. Our findings thus frame how identity and life course theory can inform practice in building more expansive science-learning environments, such as how to structure spaces where scientists and community scientists collaborate in deeper and more connected ways.

This study also makes clear the need for additional research. In particular, we see a need to look more closely at how trajectories of identification play out; to examine the cultural, linguistic, and pragmatic barriers to participation, particularly among pre-professionals; and to investigate how a caring lab community facilitates community scientist engagement (see also Hinojosa 2020). Inspired in part by this study, we conducted research focusing on how pre-professionals are guided in their participation, and on barriers, both perceived and encountered, to continued and expanded participation in the lab (Hinojosa, Swisher, and Garneau 2021). Additionally, future design-based implementation research can draw from our theoretical and pragmatic results to examine how design principles can generalize to other settings.

CONCLUSION

With interpretive case study research in one program, we examined how community scientists exercised agency during bids for expanded participation. Our study showed the pivotal aspects of agency and expanded participation were: offered opportunities for expanded participation, negotiation, and encouragement and support by both professional staff and other volunteers. Other major findings were that in contrast to pre-professional participants, those in early-, mid-, and late-career stages exercised more scientific agency in utilizing existing expertise or in seeking to build up expertise. This is not to say pre-professionals did not exercise agency in the lab, it was just not with respect to expanded scientific participation.

Through increased levels of participation, community scientists in this program were observed contributing to scientific goals of the lab beyond data collection and began to collaborate and co-design with lab staff in other

scientific practices. These practices included background research (13%), defining the study (9%), designing and critiquing study design and methods (31%), data analysis and interpretation (7%), and collaborating on manuscripts with lab staff and outside scientists (9%). During observed expanded practices, the community scientists were frequently positioned as having expertise. In the instances we studied, the majority of offered bids and accepted bids were among those already established in their career paths or aiming for a career in science; however, the majority, if not all, volunteers in the lab were interested in science and tended to either have had a science-related career in the past, be on a pathway toward or already be in a science career, and/or have a desire a future profession in science.

Lastly, findings contribute to theory and practice. At the nexus of individual trajectories of identifications and program history, alignments in timing and individual agency operate to allow program practices and activities to be taken up in different ways. Program design implications therefore include how to use program and institutional past and present, as well as participants' life-courses and trajectories, when designing opportunities for agency and expanded learning. Using this unique array of theoretical concepts, program designers can pragmatically structure support and galvanize motivations to allow for the enactment of individual agency.

NOTE

- 1 The museum uses the terms “community science” for the genetics of taste research, and “community scientists” for the volunteers who participate in the conduct of the studies, because the museum (and other researchers in the area of citizen science such as Eitzel et al. (2017)) have found that some people, particularly in their local Latinx community, feel excluded by the term “citizen science.” We will use these terms throughout this paper, because it is the local term, and especially for persons of Chicano/a and Hispanic identification in the United States, the term “citizen” is strongly associated with holding papers documenting citizenship.

SUPPLEMENTARY FILE

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

- **Supplemental File 1.** Appendix. DOI: <https://doi.org/10.5334/cstp.292.s1>

ETHICS AND CONSENT

All 59 study participants consented to participate in the learning science research study (protocol: 16-0329) approved by the researchers' Institutional Review Board on May 6, 2017. Pseudonyms are used in this paper for all

participants; researchers also changed or masked some details about individuals to maintain confidentiality.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR AFFILIATIONS

Leighanna Hinojosa  orcid.org/0000-0003-2852-962X

University of Colorado Boulder, US

Robbin Riedy  orcid.org/0000-0003-3892-2564

University of Colorado Boulder, US

Joseph Polman  orcid.org/0000-0001-9513-2783

University of Colorado Boulder, US

Rebecca Swanson  orcid.org/0000-0003-0411-5211

University of Colorado Boulder, US

Tiffany Nuessle  orcid.org/0000-0003-4489-896X

Denver Museum of Nature and Science, US

Nicole Garneau  orcid.org/0000-0002-5247-1547

Denver Museum of Nature and Science, US

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