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STEM Outreach to Underresourced Schools: A Model for Inclusive Student Engagement

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ABSTRACT: Diverse backgrounds, viewpoints and experiences in science, technology, engineering and math (STEM) are vital for innovation and creativity in STEM; and yet, racially minoritized groups, such as African Americans and Hispanics, remain underrepresented in the STEM K-12 and career pipeline. Studies show that exposure and access to STEM experiences in the early years are especially effective for increasing interest in STEM careers and intentions to major in STEM. However, these opportunities are often unavailable and inaccessible to underrepresented racialized minority students, particularly those from majority minority schools in low income communities. We describe a model for accessible and inclusive exposure to STEM experiences, enabled by a partnership between elementary schools from low income under resourced, predominantly racialized minority K-5 schools in North St. Louis County, Missouri, and scientists at a non-profit plant science research institution, to provide STEM activities for all students over the course of a single day. The goal was to stimulate students' interest in STEM and related careers, and enrich students and teachers' STEM knowledge. Five "STEM Days" were held at four elementary schools from 2017 to 2019. Feedback from teachers and students revealed positive outcomes, including increased excitement and knowledge gains. Students showed increased STEM interest, and teachers indicated that the new approaches to classroom STEM instruction, despite the brief exposure, were beneficial. Unexpectedly, participating scientists also noted numerous benefits. We share lessons learned and suggest recommendations for practitioners in STEM.

INTRODUCTION

Racialized minority groups, including African Americans, Hispanics, Native Americans, and Pacific Islanders, are steadily growing in population, in the United States, yet remain underrepresented in the STEM training pipeline and workforce (Strauss, 2011; Leonard et al., 2016; Jones et al., 2018; Bevan et al., 2018). African Americans/Blacks make up 11% of the U.S. workforce overall but represent only 9% of STEM workers, while Hispanics comprise 16% of the U.S. workforce but only 7% of all STEM workers (Funk and Parker, 2018). STEM degree attainment continues to be characterized by persistent racial inequalities that disadvantage racialized minority groups (Riegle-Crumb et al., 2019). According to the National Center for Education Statistics (NCES), African Americans, followed by American Indians/Alaskan natives, earned the fewest STEM bachelor's degrees in 2015-16 (National Center for Education Statistics, 2019). Even before college, racially minoritized students, including Black, Hispanic, and low socioeconomic status students, are less likely to maintain an interest in, or aspire to STEM careers during the high school years (Saw et al., 2018). Researchers attribute this underrepresentation in part to a lack of access to STEM exposure and experiences during the students' K-12 years (Flynn, 2016; London et al., 2021). African American students are often inadequately prepared in STEM, often excluded from school STEM enrichment opportunities during the K-12 years, through gate-keeping requirements such as academic achievement, student tracking and teacher biases (National Research Council, 2011; Farinde and Lewis, 2012; Eisenhart et al., 2015; Avendano et al., 2019). Barriers to STEM academic

and career trajectories for historically underrepresented racial groups, including inequities in school funding, derive from slavery, racism and racial segregation (Blaisdell, 2015; Cambria et al., 2018; Avenado et al., 2019).

Schools that serve predominantly racialized minority students from low-income households are often under-resourced, and struggle to provide students with qualified, well-paid teachers, tutors, mentors (Cambria et al., 2018; Purnell et al., 2015). Additionally, these schools also tend to have reduced access to STEM resources like supplies, field trips, school events and Advanced Placement courses (Clotfelter et al., 2005; Mickleson, 2003; Cambria et al., 2018). These schools are thus often characterized by low academic achievement, low teacher expectations, and limited access to classes required for entry into the STEM training and career pipeline (Strauss, 2017; Hogrebe and Tate, 2019; Cambria et al., 2018; Shtivelband et al., 2016). For example, the North St. Louis County, Missouri, region has historically struggled with educational inequality across socially and economically segregated communities that disadvantage predominantly African American communities (Cambria et al., 2018). The lack of exposure to STEM, limited STEM experiences, and few STEM role models prevent students in these communities from understanding the possible STEM career paths available to them (Crouch, 2011; Strauss, 2017; Purnell et al., 2015; Goodman and Gilbert, 2013). Researchers recommend increasing access to, and availability of, STEM extra-curricular experiences for students from racialized minority groups that are underrepresented in STEM to improve interest and intentions to major in STEM (Bottia et al., 2015).

Informal education outreach events are great platforms for increasing exposure of racialized minority students to STEM careers. These STEM outreach activities increase awareness about STEM and motivate students to pursue a career in STEM by connecting applied STEM with school science learning (Vennix, 2018; Kesidou and Koppal, 2004; Packard, 2012; Heise et al., 2020). These activities also allow students to explore their interests without the anxiety associated with formal assessments (Suter, 2016; Aslam, 2018). STEM programs and outreach in schools have been shown to develop students' STEM interest and self-efficacy (Feldhausen et al., 2018). Implementing STEM outreach events in under-resourced schools with predominantly racialized minority populations provides opportunities for students who would not typically be exposed to scientists, STEM activities, and careers (Tischler, 2016; Wickliffe et al., 2020). These in-school STEM events have also been shown to positively impact students' science-related attitudes, content learning, understanding of the scientific community (Gall et al., 2020; Laursen et al., 2007; Vennix et al., 2018) and engagement (Fredricks et al., 2004; da Rocha Seixas et al., 2016). Studies show that STEM outreach events, while focused on students, also benefit participant teachers and the visiting scientists, providing them with numerous career, personal and academic gains (Carpenter, 2015; Munn et al., 2018: Laursen et al., 2007). Opportunities for STEM experiences and exposure are however often scarce where there is greatest need, particularly among urban, low income, predominantly racially minoritized school communities that are historically underserved (Avendano et al., 2019).

The Donald Danforth Plant Science Center (DDPSC) in St. Louis, Missouri, an independent, nonprofit plant science research facility, partnered with four self-selected local elementary schools to conduct school-wide STEM outreach events (STEM Days) using the "scientist in the classroom" model, from 2017 to 2019.

The goals were to contribute to improving student academic outcomes including interest in STEM and related careers, enriched STEM knowledge, and to mitigate deficiencies in hands-on learning resources in predominantly racialized minority schools in low-income communities of North St. Louis County, Missouri. The main objectives of the STEM outreach events were to:

1. Enrich students' STEM learning and stimulate interest in STEM through exposure to the excitement of hands-on STEM learning;
2. Provide students with opportunities for educational interactions with STEM professionals for role modeling to increase interest in STEM and expose them to various STEM career opportunities;
3. To equip teachers in schools serving low income racially minoritized students with STEM resources and enriched STEM knowledge; and
4. To explore the outcomes of STEM events on the participating scientists.

METHODS

Target Population. Participants in the STEM Days were four K-5 schools that serve predominantly racialized minority students from low-income households (Table 1). Participant schools, located in North St. Louis County, Missouri, self-selected through their teaching and administrative staff, by requesting the DDPSC for educational enrichment opportunities to improve students' academic outcomes at their schools. STEM Days were therefore a response to requests from participant schools, and were well-received, as they easily are inclusive of the entire school's student population. Moreover, for a majority of schools with a predominantly racialized minority student population, STEM Days were a novelty. The DDPSC Education Research and Outreach Lab (DDPSC-EROL) and school educators scheduled STEM Days immediately prior to the annual Missouri public

Table 1. *Total number of students and teachers that participated in STEM Days (n=1803). A student population of 70 -100% qualified for a free/ reduced lunch at each school.*

Pseudonym	Jolly Elementary	Jolly Elementary	Merry Elementary	Maker Elementary	Delight Elementary
Month/ Year	3/2017	3/2018	5/2018	3/2019	5/2019
Total student population	441	411	265	372	314
Number of teachers	20	20	14	19	15
Racial composition of students	96 -99% African American	96 -99% African American	40% African American, 20% Hispanic, 30% Caucasian	96 -99% African American	96 -99% African American

schools' mandatory statewide testing that occurs in the spring semester to aid students' preparations for test-taking. STEM Days were piloted on March 30, 2017, and held March 29 and May 15, 2018, and March 28 and May 3, 2019, at four different elementary schools (Table 1).

Preparation for STEM Day Outreach Events. To facilitate hands-on instruction of STEM activities at these events, participating scientists were recruited from the DDPSC community through emails and by word of mouth. Volunteers included college professors, postgraduate researchers, graduate students, undergraduates, rising college freshmen, and high school seniors of mostly Caucasian ethnicity (Table 2). Unfortunately, the narrow pool of racialized minority scientists at DDPSC impacted efforts to recruit larger numbers of scientists of similar demographics to the students.

All volunteers were provided the option of designing their own hands-on STEM activities or selecting from the DDPSC-EROL's repertoire of STEM activity kits (Figure 1). Prior to the STEM Day, all volunteers met with the DDPSC-EROL team to discuss the STEM Day itinerary, share ideas for STEM activities, and review state learning standards for science and math, in order to guide activity selection and preparation. At these meetings, volunteers also selected grade levels of students they felt comfortable interacting with, and shared and rehearsed their ideas for a STEM Day activity (ies). The grade level appropriateness of the STEM activity choices were reviewed by the DDPSC-EROL team and a STEM Day coordinator team of teachers and administrators from the host school to ensure grade level suitability. Immediately prior to the STEM Day, the DDPSC-EROL team conducted reconnaissance visits at each host school to assess space/facility provisions and allocate them to volunteers. Each participant school provided classrooms, the gymnasium, cafeteria and library facilities to accommodate STEM Day activities, as well as a lunch meal for all visiting scientists on the STEM Day. Nearly all STEM Day expenditures for supplies, equipment and transportation to the school were covered by grants from the DDPSC-EROL program; one or two host schools offered office supplies as needed. The DDPSC-EROL team and host school coordinator team met two to three times prior to STEM Days to discuss design, schedule and execution.

Designing STEM Day Outreach Events. The STEM Days were designed to take place at the host school during the

Table 2. *The composition of participant scientists that participated in the STEM Days.*

	Jolly Elementary	Jolly Elementary	Merry Elementary	Maker Elementary	Delight Elementary
Faculty	3	1	1	1	1
Research scientist	2	2	1	2	2
Postdoc	2	5	0	6	4
Graduate student	1	3	2	7	0
Post baccalaureate	7	4	1	3	3
Undergraduate	1	0	1	0	1
High school senior	1	1	6	0	5
Total	17	16	12	19	16
Racial composition					
Caucasian	65%	56%	75%	74%	75%
Black/African American	18%	13%	17%	11%	13%
Latina	6%	6%	0	5%	6%
Asian	12%	25%	8%	11%	6%

Figure 1. STEM Day hands-on activities (clockwise): searching for soil critters, learning about microcomputers with a fruit piano, engineering design with spaghetti and marshmallows, grocery store botany, robotics with Ozobots, planting a seed to-go station, strawberry DNA extraction and light transmission.

course of the school day, and to involve the schools' entire student population at no cost. The purpose of this structure was to foster inclusivity and to eliminate common gate-keeping barriers such as entry fees and transportation costs that often hinder participation of students from low income, racialized minority communities. The exception to inclusion of all grades was at Merry Elementary (pseudonym) in 2018, when the event coincided with state testing for grades 3-5, thus excluding those students from participating. To facilitate STEM Days, students at the host schools were divided into three batches by grade level (K-1, 2-3 and 4-5) (Figure 2). Each batch of students was then assigned to rotate among three to five stations, with one to four volunteers conducting hands-on STEM activities (Table 3) (Figure 2). A rotation model was devised in which the three grade-level batches of students were further divided into smaller groups of 15-20 students by classroom/homeroom that rotated through assigned STEM activity stations for 15 minutes per station, supervised by one to two teachers (Figure 2). The total duration of the STEM Day was about four hours of the school day.

SCHEDULE for STEM DAY Friday May 3rd 2019 10 a.m. -1:30 p.m.

	K -1st grade						2nd - 3rd grade					4th - 5th grade					
STEM Activity	Soil organisms	Coding with colors - Ozobots	Exploring Seeds and math	The density tower	States of matter, CO_2 and popping baggies	PLANTING AND ALGORITHMS	Light and The ice cube tray battery	Micro computers and the fruit piano	Weather and states of matter: engineering a wind vane	Fractions and fruits	PLANTING AND ALGORITHMS	Minecraft, DNA, Digestion, Proteins, Enzymes and Saliva	Math fun with circles and Pi	Robotics, plant phenotyping	Biomedical engineering applications	Technology, robotics, microcomputers	PLANTING AND ALGORITHMS
Scientists (pseudonyms)	A	B	C	D	E	F	group 1	H	I	J	K	L	M	N	O	P	K
Location	Room 1	Room 2	Room 3	Room 4	Room 5	GYM	Room 6	Room 7	Room 8	Room 9	GYM	Room 10	Room 11	Room 12	Room 13	Room 14	GYM
10:00 - 10:25 am	*group 1 = about 34 students	group 2	group 3	group 4	None	group 5	group 1	group 4	group 3	None	group 2	group 1	group 2	group 3	group 4	None	group 5
10:30 - 10:55am	group 2	group 3	None	group 5	*group 1	group 4	group 2	group 1	None	group 4	group 3	group 2	group 3	None	group 5	group 1	group 4
11:00- 11:25 am	None	group 4	group 5	*group 1	group 2	group 3	None	group 3	group 1	group 2	group 4	None	group 4	group 5	group 1	group 2	group 3
11:30:00 - 12:00	Lunch						Lunch					Lunch					
12:00 - 12:25pm	group 4	group 5	*group 1	None	group 3	group 2	group 3	group 2	group 4	group 1	None	group 4	group 5	group 1	None	group 3	group 2
12:30 - 12: 55pm	group 5	None	group 2	group 3	group 4	group 1	group 4	None	group 2	group 3	group 1	group 5	None	group 2	group 3	group 4	group 1
1:00 - 1:25pm	group 3	*group 1	group 4	group 2	group 5	None	ENGINEERING DESIGN WITH SPHAGHETTI AND MARSHMALLOWS	ENGINEERING DESIGN WITH SPHAGHETTI AND MARSHMALLOWS	ENGINEERING DESIGN WITH SPHAGHETTI AND MARSHMALLOWS	ENGINEERING DESIGN WITH SPHAGHETTI AND MARSHMALLOWS	None	group 3	group 1	group 4	group 2	group 5	None
	Departure						Departure					Departure					

Student population		
Grade Level #s:	Total number of students per grade	# of classrooms or student groups
K	51	3
1st Grade:	49	3
2nd Grade:	57	2
3rd Grade:	41	2
4th Grade:	58	3
5th Grade:	58	2
Total student population	314	15

Figure 2. Sample of an inclusive STEM Day event schedule for an entire K-5 school's student population.

Table 3. *Sample of STEM Day hands-on activities.*

Subjects	STEM Activities
Pre K -1st grade	
Science	Soil critters; Seeds Carbon dioxide and dancing raisins
Technology	Robotics and Ozobots
Engineering	Rainbow in a jar/ Density tower
Math	Flower petal math; Seeds and math
2nd - 3rd grade	
Science	Strawberry DNA Acids and bases from red cabbage Weather and states of matter
Technology	Robotics and Ozobots Microcomputers and the fruit piano
Engineering	Engineering a wind vane Electricity using the ice-cube tray battery
Math	Circles and Pi Fractions and fruits
4th - 5th grade	
Science	Dichotomous keys in stream ecology, Minecraft, digestion, proteins and enzymes Plant structures; dissecting plants
Technology	How to program a microcomputer Robotics and plant phenotyping Technology
Engineering	Electricity and magnetism Biomedical engineering applications
Math	Measuring earth, spheres, space Measuring speed; Circles and Pi

Evaluation and Data Analysis. Student outcomes from the STEM Days were obtained through written responses to two open ended question prompts in a paper survey questionnaire: *1. What new things did you learn today that you did not know before? 2. What else would you like to share with us [about STEM Day]?* (Figure 3). The student survey questionnaire was designed by the DDPSC-EROL team and given to teachers at the conclusion of each STEM Day to distribute to students.

Additionally, student outcomes were gathered from participant teachers using a teacher survey questionnaire designed by the DDPSC-EROL team and distributed to teachers immediately following the STEM Days, (surveys available on request). The teacher survey questionnaire comprised open ended questions on perceptions of gains from the STEM Day for their students and themselves. E.g. *"What "new" responses or changes did you observe from your students on STEM Day and afterwards that you could directly attribute to the STEM Day experience?"* And for the teachers, *"Did you as an educator learn new information or participate in new activities? Please share what you got out of STEM Day"* (Tables 4-7). Students and teacher completed surveys were returned between one and four weeks after the events. The teacher survey response rate was (80%, 36%, 76% and 100%) for Jolly, Merry, Maker and Delight Elementary respectively. Therefore, except for Merry Elementary, where only grades K-2 participated in the STEM Day, teacher responses were evenly distributed between schools.

For each question, teacher and student survey responses were entered into Excel, analysis followed open coding methods as appropriate such as structural coding and *in vivo* coding to identify emergent themes, which were then grouped into categories and each quantified (Saldana, 2016).

Feedback from the visiting scientists was gathered through informal debrief discussions, a few days after event, and formally requested in 2020 to assess long term impacts, using a survey questionnaire adapted from protocols by Laursen et al. (2007). The survey questionnaire was sent by email to all visiting scientists that participated in STEM Days from 2018 to 2019, via the online survey tool Qualtrics (Qualtrics LLC, Provo, UT). The survey questionnaire collected respondents' quantitative ratings on close-ended question prompts and written responses to open ended prompts such as;

"Did the STEM Days provide you any gains in skills, professional/career-related, practical or personal? e.g., presentation skills" [Select one:]

- *Not at all*
- *Only a little*
- *A lot*
- *A whole lot*

"Looking back at your participation in STEM Days, what benefits or gains have you observed for yourself out of the experience?"

A total of 48 scientists volunteered for STEM Days from 2018 to 2019, and of these, 16 provided written responses of their experiences (Table 8). Although it was beneficial for obtaining long term impacts, the time lag between STEM Days and formal solicitation of feedback from visiting scientists might have negatively affected the survey response rate as several of the scientists had transitioned out of employment/ affiliation with the DDPSC. Quantified survey responses were analyzed in Microsoft Excel. Responses to open –ended prompts were analyzed using thematic analysis, themes were identified using iterative coding and re-reading of the data (Saldana, 2016, Daly, Kellehear, and Gliksman, 1997).

RESULTS

Student Outcomes. Of 1362 students that participated in STEM Days from four elementary schools, over 40% provided feedback through written survey responses. It is highly likely that the reading and writing requirements of the written survey affected the survey response rate particularly from students in the lower grade levels. A total of 580 students provided written responses to the open-ended prompt

Table 4. *Teacher feedback on student gains from STEM Days in 2018 (n= 21) and 2019 (n= 27).*

Common responses to: What "new" responses or changes did you observe from your students on STEM day and afterwards that you could directly attribute to the STEM day experience?	Number Giving the Response	Sample Quotes
Increased student engagement- behavior, cognitive, emotional (excitement, enjoyment), and learning gains	30	"My students were so excited to share their favorite stations and what they learned" "My students immediately started naming traits related to our DNA and speed. They want to measure their speed while running"
Student interest and curiosity in STEM sparked	9	"Some students seemed more interested in science than they were before" "The students asked more questions about science related concepts without being prompted"
Students more engaged in STEM career discussions	1	"They are figuring out their future careers and didn't know that STEM day would help them do that"

Table 5. *Teacher feedback on the impact of STEM Days on their students from STEM Days in 2018 (n= 21), and 2019 (n= 27).*

Common responses to: Do you think today's experiences with your students were meaningful?	Number Giving the Response	Sample Quotes
Provided learning aids like visuals and opportunities for hands-on experiences to enrich STEM learning	14	"It was a chance to experience hands-on things we usually only talk about, they received a nice visual on solving fractions"
Enhanced student engagement and enjoyment of STEM learning	10	"Yes the students had a lot of fun and were making connections to their learning"
Stimulated STEM curiosity, interest	7	"Absolutely! Many of my students took a greater interest in coding"
Exposure to new STEM concepts	5	"I think exposing them to new science and technology was beneficial at this stage" "new activities taught by new people create more memories in the brain"
Exposure to science related jobs	2	"STEM experience was meaningful for students to see and learn about science related concepts/jobs"
Helped prepare students for upcoming state assessments and higher grades	2	"We need more outside activities in order to prepare our students for middle school"

Table 6. *Teacher feedback on the impact of STEM Days on themselves from STEM Days in 2018 (n= 21), and 2019 (n= 27).*

Common responses to: "Did you as an educator learn new information or participate in new activities? Please share what you got out of STEM day?"	Number Giving the Response	Sample Quotes
Learned new STEM concepts, new experiences with STEM	22	"Learned how to measure speed/about a strawberry DNA" "The electricity and fruit demonstration the fruit piano was new"
Enjoyment and fun	6	"I enjoyed the artificial hand and insulin activities" "I loved helping kids with the robots and digging for organisms"
Student related: activities were age appropriate, engaging, introduced advanced concepts, allowed critical thinking and promoted learning in an engaging way	5	"...my students continued questions they were eager to know more" "it introduced them to algebra"
Provided hands-on learning activities and opportunities to engage in them	5	"STEM provided a lot of hands on activities in a short amount of time" "Was able to participate in all the hands on learning activities along with my students" "The tower of materials, I have seen it before and have always wanted to try it"
Gained ideas for new STEM activities	4	"STEM day gave me some ideas for new science experiments" "...strawberry DNA extraction new and fun activities to do with students"
Learned new approaches to teaching STEM	2	"I learned new quick ways to teach speed and traits some fun ideas about how to incorporate math and science"
Experiences with real world applications of STEM	2	" I enjoyed learning about real life science applications"

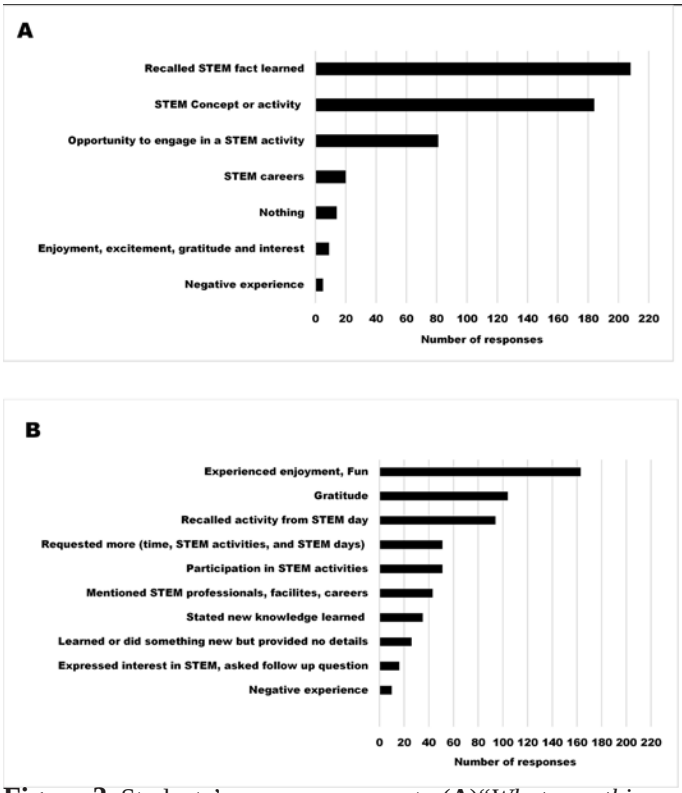

Figure 3. Students' survey responses to (**A**)"*What new things did you learn today that you did not know before?*" (**B**) "*What else would you like to share with us about STEM Day?*" from the 2018-2019 STEM Days.

"*What new things did you learn today that you did not know before?*" (Figure 3A). These responses were coded and grouped into themes such as STEM facts learned, STEM techniques and STEM disciplines (Figure 3). Majority of responses were specific STEM facts that students learned from the STEM day as illustrated by students' quotes below;

"… that I didn't know that fruit has DNA";

"that code needs to be really specific"

"bacteria are all shapes and sizes"

A total of 628 students responded to the open ended prompt "*What else would you like to share with us about STEM Day?*" (Fig 3B). Responses were coded and grouped into themes as described previously. Students' most common responses to this prompt were; enjoyment/fun, gratitude, and recall of a STEM event hands-on learning activity (Figure 3B) as shown by the exemplar quotes below;

"I would like to share how I was being so happy and joyful to learn how strawberries had DNA."

"I enjoyed learning about robots and baking soda and particles turning to gas"

Students' responses also suggested that STEM Days, despite being of short duration, sparked curiosity about STEM and stirred up interest in STEM professions as illustrated by the quotes below:

Table 7. *Teacher responses to "What advice might you give our scientists in their teaching efforts today?" from STEM Days in 2018 and 2019 (n=30).*

Theme	Sample Quotes	Responses
Hands-on activities	"The only suggestion I have is to make the activities more hands on especially the Programming activity".	27%
Classroom instruction strategies	"Teach an attention getting strategy to start"	27%
Duration of STEM activities	"Next time maybe make the lessons shorter or more kid friendly"	13%
Student participation strategies	"Use a student helper to model a task before asking the entire class to complete the task"	13%
Planning and design of STEM activities	"Frontload students with expectations and structure lesson so students know what's going to happen"	13%
Frequency of STEM events	"Please come more often"	7%

"I would like to learn about space and learn about stars and how earth was made. Hmm I wonder how earth was made?"

"How do the robot know if you didn't color in the lines and how do it know if you did color in the lines because I think that robot is smart"

"I want to work with computers when I grow up"

Additionally, teachers provided feedback on their perceptions of student outcomes through written responses to open ended prompts such as "*What "new" responses or changes did you observe from your students on STEM Day and afterwards that you could directly attribute to the STEM Day*

Table 8. *Demographics of participant scientists survey respondents.*

Education Rank/Status	Gender	Ethnicity	Number of Respondents
Research Scientist with a doctorate	Female	White / Caucasian	2
Post doc	Male	Asian, Asian American	1
Post doc	Female	White / Caucasian	1
Post doc	Female	Asian, Asian American	1
Post doc	Male	White / Caucasian	1
Post doc	Male	Black / African-American	1
Graduate Student	Male	White / Caucasian	2
Post Baccalaureate	Female	White / Caucasian	1
Undergraduate student	Female	White / Caucasian	1
Master's degree	Male	White / Caucasian	3
High School Senior	Female	White / Caucasian	2

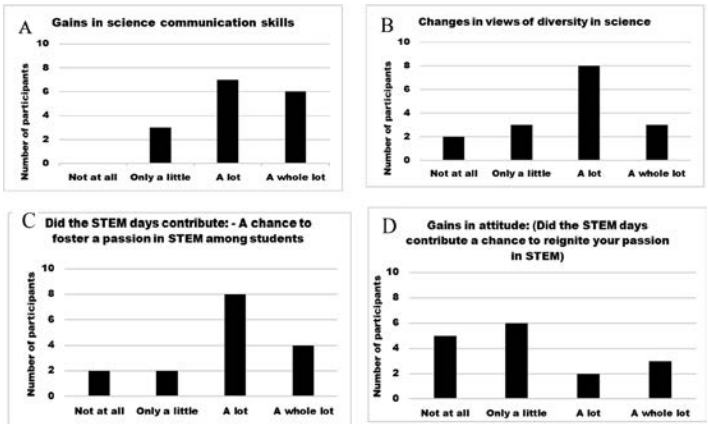

Figure 4 (A-D). Feedback from participant scientists on their gains from the STEM Days 2018-2019 (n= 16).

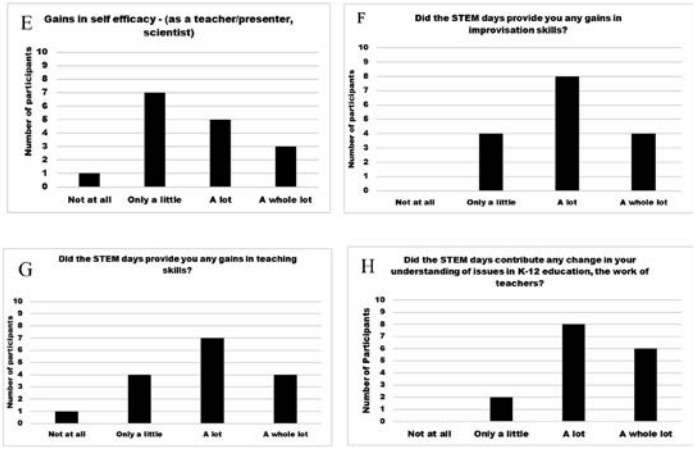

Figure 4 (E-H). Feedback from participant scientists on their gains from the STEM Days 2018-2019 (n= 16).

experience? Please explain."

The majority of responses to this prompt were observations of increased engagement among students. Teachers appreciated the hands-on learning opportunities for their students that the event provided (Table 4). Additionally, several teachers remarked about gains for students, such as activities with advanced-level STEM content. Teachers also noted that students benefited from the opportunity for exposure to new STEM concepts and STEM careers, as well as learning about topics above their grade level and from activities that assisted with preparation for state assessments (Table 4).

Teacher Outcomes. A total of 48 of 88 teachers who participated in the events from 2018 to 2019 provided feedback on outcomes from the STEM Days for themselves and their students through written survey responses (Tables 4-7). In response to prompts such as "*Did you as an educator learn new information or participate in new activities? Please share what you got out of STEM Day,*" a majority of teachers reported learning about new concepts in STEM, such as robotics, DNA properties, and attributes of dry ice, from the hands-on activities presented to students (Tables 5-6). Several teachers also mentioned enjoyment of the event and expressed appreciation for the abundance of accessible and engaging hands-on learning activities that the STEM Day provided, some of which they had always wanted to try out. Teachers also remarked that they learned new, fun and quick approaches to teaching STEM concepts, as well as new ideas for science experiments (Table 6).

Teacher feedback also included advice for scientist volunteers in responses to the open ended question prompt " *What advice might you give our scientists in their teaching efforts today?*" The majority of the advice was in regards to "making all the STEM Day activities more hands-on." Teachers also advised scientists to incorporate classroom instruction techniques, such as use of student friendly vocabulary, attention garnering strategies, and in the implementation of their STEM activities (Table 7).

Participant Scientist Outcomes. Feedback from participating scientists revealed unexpected gains from STEM Days such as science communication skills, views of diversity issues in science, and opportunities to influence students' attitudes towards STEM (Figure 4). Scientists also reported gaining teaching skills, an understanding of education issues related to curriculum, teachers, and pedagogy as well as emotional rewards like seeing students excited about science and enjoyment of role-modeling (Figure 4).

Participation in STEM Days also helped clarify career paths for some scientists (Figure 5). Responses to the open-ended prompt; "*Did the STEM Days have any influence on your career path or career decisions?*" included statements about confirmation to pursue teaching or education related careers. One respondent stated, "*Yes. Confirmed that I want to go into science education, made me reconsider the way that I want to do it (specifically made me consider K-12 sci. ed.*") (Figure 5).

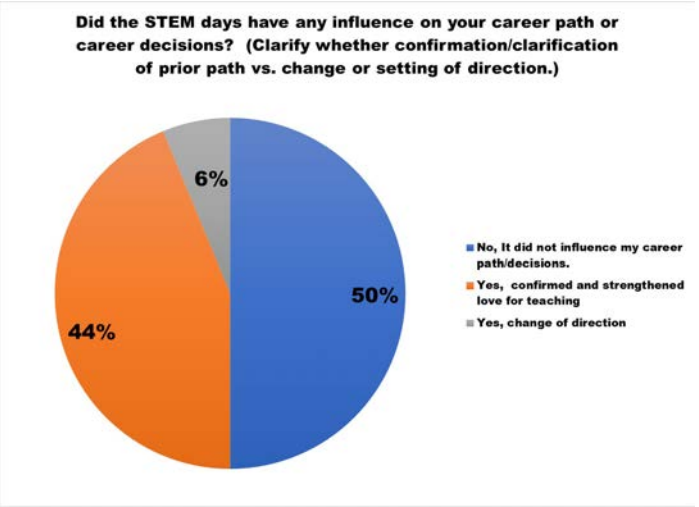

Figure 5. Participant scientists' responses to "*Did the STEM Days have any influence on your career path or career decisions (Clarify whether confirmation/clarification of prior path vs. change or setting of direction.)?*"

When asked to reflect on long term gains from participating in STEM Days, through the open-ended prompt:"-*Looking back at your participation in STEM Days, what benefits or gains have you observed for yourself out of the experience?*" responses from the volunteer scientists corresponded to four general themes: science communication skills and career motivation; knowledge of pedagogy and academic learning standards; enhanced experience working with younger children; and exposure to teacher experiences and beliefs as detailed below.

Science Communication Skills and Career Motivation. Participating scientists noted that they gained skills to better communicate science particularly to younger audiences, e.g. *"I feel like my science communication skills have seen the greatest improvement. Working with the kids at the STEM Day experiences helped me to understand how to simplify complex ideas into something more digestible."*

Knowledge of Pedagogy and Academic Learning Standards. Several scientists remarked about gaining skills necessary for effective classroom teaching, for example, patience, quick thinking, flexibility in teaching style, and the need for multiple teaching approaches. One of the scientists stated: *"I gained an appreciation for how difficult it can be to actively engage a large group of students at once. I think that I would work to simplify the presentation I give for the next time."*

Enriched Experience Working with Younger Children/Students. Volunteer scientists also mentioned that STEM Days provided them with opportunities to work and interact with children, particularly from diverse communities and ethnicities from theirs, which for some were new but enjoyable experiences. One respondent stated: "*Working with groups of children is outside my comfort zone and this taught be that it is not that bad and can be a lot of fun.*"

Exposure to Teacher Experiences, Beliefs, Backgrounds. The STEM Days also afforded the participating scientists opportunities for interaction with teachers, through which they were able to gain insights about teacher beliefs about science, and about the teaching profession, as exemplified by the quote: "*I realized that some elementary school teachers may be of a background that may not agree with certain scientific conclusions, and that outreach may require more finesse in these environments.*"

Participating scientists responded to the notion that short duration events like STEM Days have a lower likelihood for producing long term impacts, through the open ended prompt: "*One criticism of programs such as the STEM Days is that they are 'one-shot,' short-term interventions without the longevity to make much of an impact. Having been on the inside of the program, how would you respond to that criticism?*" Their responses were categorized into the following themes.

STEM Days are Memorable and Impactful. Respondents asserted that STEM Day experiences are impactful because of the excitement they recalled witnessing during hands-on activities with the students. Volunteer scientists also shared personal memories of STEM Day experiences from their own educational journeys, as exemplified by this quote, "*When I was in grade school, we had guest speakers come and talk about STEM. In college now, I still remember those fun projects. So I do not think it is a one shot because these special days are what kids will remember years to come.*"

STEM Days Increase Enthusiasm and Motivation for STEM. Respondents noted that STEM Days provide much needed breaks from "standardized education," consequently generating excitement and motivation for learning. One scientist remarked "*even one-shot activities that can increase enthusiasm for science are valuable*."

STEM Days are an Easier Fit for Organizers, Schools and Volunteers. Participating scientists also noted that the short duration nature makes STEM Days easier to implement and commit to for both schools and volunteers. Example quote: "*I think that the one-shot programs are sometimes easier for people to volunteer at the beginning as they are a smaller time commitment.*"

STEM Days are a Necessity for Students in Underprivileged Communities. Respondents noted that despite being short duration, STEM Days provide rare opportunities for students in underresourced communities to interact with actual scientists, and to gain exposure to hands-on STEM learning that might be missing from their standardized school curriculum. Example quote: "*Any chance to connect with underserved student populations and expose them to science is a win*."

STEM Days Require Sustained Engagement. Some respondents however argued that longer-term school partnerships that entail multiple visits and events have a higher likelihood of yielding impact than single STEM Days. One respondent stated:

> *While I really think the students love and enjoy to have fun with experiments with real scientists (and a few may remember this for quite some time), I don't think it's going to impact most of them long-term. What I think would help is to instead have these STEM days re-occurring throughout the year (four*

times a year; ideally the same people at each school) in order to build a relationship with the students that will likely stick in the long-term.

Another respondent added, "*Continued yearly involvement is key. Continued interactions with underserved populations is important to increase the number of people of color in science.*"

For the volunteer scientists, the major challenges of participation in STEM Days were the time it took away from work (> 50%), stress and nervousness prior to the day, classroom management during the event, and exhaustion of the event.

DISCUSSION

The main objectives of the STEM Days were to enrich students' learning, stimulate interest in STEM, and to introduce students to various STEM career opportunities in an inclusive format. We also sought to provide students with opportunities for educational interactions with STEM professionals to increase their interest in these professions and to equip teachers in schools serving low income URM students with STEM resources and enriched STEM knowledge. Moreover for our participant students, majority racialized minorities from historically underserved schools, the STEM Days were vital for addressing persistent inequities in academic resources, increasing availability, access and exposure to STEM experiences. This increased access and exposure has been shown to predict intentions to major in STEM and interests in STEM careers (Bottia et al., 2015; Avendano et al., 2019). Based on informal and formal feedback as well as our own observations, the STEM Days achieved these objectives and produced lasting impacts, on students, teachers, and participating scientists.

For the most part, it was felt that these events were a celebration of learning in different areas of study for teachers, students, and scientists. Student survey responses revealed a recall of specific STEM facts learned at the STEM Days, as well as recollection of the unique STEM activities they engaged in. Previous researchers similarly reported learning gains by K-12 students following STEM outreach (Vollbrecht et al., 2019; DeWilde et al., 2019). Students' feedback responses also indicated that the STEM Day generated an interest in STEM professions. Moreover, students' responses were corroborated by teachers' feedback that STEM Days not only stimulated interest in STEM learning, but also elicited discussions about STEM careers among students, in agreement with previous studies (Clarke et al., 2019; Angle et al., 2016). This is probably because STEM Days provided opportunities for students to be exposed to the "excitement of science," and STEM professionals, that might be lacking in their regular classroom instruction. STEM outreach events are also known to provide opportunities for students to interact with professional scientists in the STEM college and career pipeline, further personifying and informing young students about STEM careers. This "early access, exposure, and exploration of opportunities" during elementary and secondary education has been shown to predict students' career paths (Daugherty et al., 2014; DeJarnette, 2012; McClure et al., 2017; London et al., 2021).

STEM outreach events easily generate excitement by interrupting the students' classroom routine, exposing students to new instructors and teaching styles, as well as new educational resources. Student survey findings revealed that students not only experienced excitement and enjoyment of learning and doing STEM, but also expressed a desire for more STEM events and activities. These experiences were echoed by teacher survey data, which noted perceptions of increased student engagement in learning; excitement, enjoyment, and active participation during the STEM Days; and in subsequent classroom discussions on STEM. Researchers have similarly reported an increase in students' STEM learning and enjoyment of STEM from experiences with STEM professionals in their classrooms (Ufnar and Shepherd, 2021; Laursen et al., 2007; Clark et al., 2016; Dubetz and Wilson, 2013).

For teachers, participation in STEM Days provided opportunities to acquire new STEM knowledge, new ideas for classroom activities, new teaching approaches, and a wide range of hands-on activities. Previous research conducted regarding scientists in classroom STEM outreach noted similar gains for teachers (Laursen et al., 2007 and Munn et al., 2018). These findings show the vital role of STEM outreach events in resourcing schools from low-income communities. Moreover, our findings also show that STEM Days also contributed to teacher professional development not only emotionally, through enjoyment, but also through enriching their STEM content knowledge. Dani et al. (2018) and Angle et al. (2016) also reported enjoyment and gains in teachers' understanding of science topics, effective teaching of science, and perceived value of informal STEM outreach events. However teacher feedback also included remarks about the perceived struggles faced by guest scientists in classroom management and instruction. Mason et al. (2018) also observed that classroom management skills, particularly of student behavior, are often lacking among post-secondary academic trainees running STEM outreach and recommended similar training initiatives. STEM Days could therefore be improved by training volunteer scientists on classroom management techniques.

Notably, STEM Days provided the participating scientists with an opportunity to elevate their understanding and appreciation of STEM education at the K-12 level while they shared STEM knowledge in fun ways with an enthusiastic au-

dience. For most of the volunteer scientists, the STEM Days provided opportunities for social interactions with students in communities that were economically, socially and culturally very different from theirs. Volunteer scientists therefore reported gaining an increased awareness of a lack of diversity in STEM, and the STEM learning challenges faced by students and teachers at under resourced schools in predominantly racialized minority low-income communities. Angle et al. (2016) also found that participating scientists benefitted from learning about students' and teachers' classroom experiences, concerns, and resources. The STEM Days also provided scientists with opportunities to improve their science communication and instruction skills, particularly with younger audiences, as observed from their feedback surveys. Previous researchers have reported similar gains in teaching and communication skills, networking, clarification of career paths and increased understanding of STEM concepts by scientists participating in STEM outreach events (Laursen et al., 2007; Dubetz and Wilson, 2013; Clark et al., 2016; Carpenter, 2015; Vollbrecht et al., 2019). STEM Days therefore are a plausible solution to the call for institutions of higher learning to equip undergraduate and graduate students with science communication skills to mitigate public misperceptions of science and enable informed policy decision making (Brownell et al., 2013). Furthermore, the STEM Days also provided participating scientists, including graduate students and post-doctoral associates, with opportunities to clarify their career interests. One volunteer scientist noted that STEM outreach events were a "*great opportunity, would be beneficial for any school to get to meet career scientists, and it's a great way to increase science enthusiasm.*"

Participating scientists reiterated the numerous benefits of STEM Days, despite their short duration, including providing excitement and motivation for learning, rare opportunities for exposure to scientific professionals for students in underserved communities, and the ability to produce lasting positive memories about STEM. Visiting scientists noted that the biggest challenge to participation in these events was the time investment required. A solution to this challenge might be to increase the relevance of STEM Days for the visiting scientists, possibly through work incentives or course credit for students. For the DDPSC-EROL staff, the organization of STEM Days required much time and effort, but they added strength to their ability to work with larger numbers of students at one time, and helped to build a larger cohort of working scientists at the DDPSC who enjoyed participating in outreach and were able to volunteer. Furthermore, STEM Days added significantly to the DDPSC-EROL networking capacity through its interactions with hundreds of students and teachers.

Lessons Learned and Recommendations.

Organization. Having one individual serve as the liaison between the school and the group of volunteer visiting scientists was vital for the success of the STEM Days. For all STEM Days, co-author RJK served as the event coordinator, organizer and liaison who established and maintained contact with the schools, coordinated room scheduling, planned the classroom rotation cycle, compiled a list of suggested topics for each grade level based on the school curriculum, and recruited volunteer scientists to work in the classrooms. The event organizer ensured that materials were on-hand, individual STEM activities were ready for presentation, and that additional arrangements were in place.

Additionally, it is important to coordinate with the schools to reserve classroom or school space for volunteer scientists for the entire day prior to the event. For each STEM Day, we utilized all of the classroom and school spaces made available by the school, including the gymnasium, library and cafeteria, for hands-on STEM experiences. We recommend that students rotate through STEM activities, as this allows a smoother transition than if the scientists move from classroom to classroom. Scientists stationed in classrooms and school spaces, were able to personally welcome rotating groups of teachers and students to their learning experience. We recommend an early arrival at the school for pre-event set up. On the day of the event, early arrival of all visiting scientists at the schools provided for a sufficient set-up time of the hands-on activities prior to the event, which was extremely important for implementation and crisis management. For example, at one of the STEM Days, when a scientist assigned to an activity was unable to make it, the earlier arrival of other scientists allowed for re-assignment of their classroom and activity to another scientist in a team teaching pair.

Volunteer Scientists. Organizations wishing to adopt this STEM Day model may want to boost volunteer recruitment by providing incentives such as course credits where relevant; or widen the volunteer scientists search to include local high schools and colleges to achieve an optimally high number of volunteers. We recruited high school seniors as volunteer scientists for some of our STEM Days, and found them to be resourceful and creative with developing hands-on STEM activities, enthusiastic, and more tolerant of students' classroom behavior. We also found that with STEM Day execution, the more volunteers the better. One volunteer advised, "*Always plan or attempt to have more than enough volunteers, sometimes have two people can make a situation much more manageable*." At the STEM Day where we had the largest number of scientist volunteers, we were able to increase the range of STEM activities, and to organize teaching teams (2-3 scientists per classroom). Team-teaching with two or more volunteer visiting scientists helped to

keep hands-on activities flowing, gave the opportunity for interaction with all students and provided "extra hands" to prepare for the next cohort of students.

We recommend training of volunteer scientists particularly on techniques for classroom management. Prior to the STEM Day, train and adequately prepare scientists to handle diverse classroom scenarios like chaos, disorder, inattention, and student-led distractions, as well as on attributes such as creativity, passion, enthusiasm, and patience. An immediate challenge mentioned by volunteer scientists was classroom management. Some of the scientists found the STEM Days jarring, felt ill-equipped and overwhelmed after participation in the STEM Days, and mentioned struggling with overly excited students, and student and teacher disruptions. Unfortunately and regrettably, our preparation process with the volunteer scientists did not include training on how to handle classroom disruptions. Students left out of STEM Day activities easily resorted to becoming sources of distractions. It is therefore essential that volunteer scientists ensure everyone in the classroom participates, even in the smallest way. Further emphasizing the importance of volunteer preparation on classroom management techniques, one volunteer noted:

> *Almost every outreach I have participated in that was in a classroom setting includes one or several students who distract others in the class from learning. How do you handle this as a educator? If this situation arose for you, how did you respond? What did you do afterwards or prior to next outreach event? Did you research common practices in this area? Were you able to adapt or did it throw off your entire planned presentation/activity?*

Additionally, enthusiastic volunteers easily got the students engaged in learning, one scientist advised "*Be creative. Don't be business as usual. This is an opportunity to share your passion. If you come in there* [the classroom] *lacking energy, the students immediately sense that. If you don't care about what you are doing, why should they?*"

Teacher Involvement. At all STEM Days, the list of planned STEM activities was not shared with the teachers prior to the events to maintain an element of surprise and anticipation, thus the teachers were relegated to learner and/or chaperone roles at the events. This arrangement had advantages, like teachers responding to the STEM activities with excitement and interest; however, others felt ill- equipped to engage in the STEM Day along with their students. The preparation process for all STEM Days mostly engaged one to two teachers and school administrators, who were to communicate with teachers and the event liaison. The school administrators were tasked with ensuring that the schools were prepared to host the events. Perhaps due to the lack of involvement of all the schools' teachers in the STEM Day planning, several at each school appeared unaware and disinterested in the STEM Days. Thus, visiting scientists experienced a wide spectrum of teacher involvement and engagement in the STEM Day events, including excitement, disengagement, disruptive classroom management, and aggression towards students. While at some schools, teacher and classroom aides kept the classroom environment calm and monitored student behaviors, this was not the case in others. This was perhaps because teacher roles and responsibilities were not discussed and delineated during STEM Day preparations. One teacher suggested "*Give teachers a little more direction on what involvement you need from them.*" Therefore host schools need to be prepared and organized, with clear descriptions of roles and responsibilities of scientists and school staff prior to the STEM Day. Higher teacher involvement is helpful, so they can learn creative and inexpensive ways to encourage learning.

Activities. STEM Day activities that had a "wow" factor such as chemical reactions with color changes, were the most memorable, as observed from students' feedback on survey responses, e.g., a red cabbage acids and bases activity; carbon dioxide release from vinegar and baking soda mixtures "*I have fun playing with acids and bases.*" Technology based activities that integrated students interests and activities led by enthusiastic volunteers were popular too as illustrated by these students' quotes "*my most favorite was the programming because we could take selfey*"; "*my most favorite was measuring the earth because we did things fun and the people were funny.*"

Volunteer scientists suggested the development of a master list of activities that were successful for each grade be shared with presenters at each event, instead of letting scientists design their own. Event coordinators are key for making certain the STEM topic and activity are age- and grade-level appropriate, and for guiding scientists on activities that best fit the curriculum. For all STEM Days, activity selection was guided by the state learning standards for K-5 in math and science, and shared with the volunteer scientists during preparation of the activities. Furthermore, we shared the final selection of STEM Day activities by grade level with the host schools' STEM Day coordinator team, which often was comprised of a lead teacher or two, curriculum leader, and principal, and asked for feedback on grade level appropriateness. For all STEM Days, there were never any objections to any activity or concerns about grade level appropriateness. Flexibility and improvisation during STEM Day is critical; it also helps to start with easy steps of the activity and then build to the challenging. One volunteer scientist remarked,

> *I learned to be adaptable and to think more quickly on my feet. I had to work with so many kids on a*

difficult activity in a very short amount of time and kept tweaking my directions after each group, and with each group, the activity worked better.

Another respondent added, "*I would emphasize that improvisation and really driving home the points in ways that kids can understand is key to being successful, and preparation beforehand would be helpful.*" Always have a back-up plan(s) for activities; it is best to over-prepare, to practice activities and anticipate problems ahead of time; try to "fool proof" them as much as possible. We allocated time in the preparation meetings for scientists to rehearse and pre-test their activities; this allowed for adjustments and modifications to activities prior to the events. We recommend the inclusion of free stations or stations with giveaways, such as plant a seed-to-go, in the schedule as we did, so that volunteer scientists can take a break, replenish supplies, etc. Lastly, STEM Days are expensive to conduct, therefore, it is better if supplies can be bought in bulk, reused, or repurposed from event to event, or year to year, or if possible, share materials with the host school. At all STEM Days, host schools were happy to take care of office supply needs, and one even proposed pursuing a grant opportunity elsewhere to help offset STEM Day expenses.

Limitations and Conclusions. While some of the data presented is from very small sample sizes due to the low response rate, and makes drawing conclusions based on responses from one or two participants difficult, previous qualitative studies show that we can still "learn from small numbers" (Pawley, 2018; Ufnar and Shepherd, 2021). In addition to written surveys, additional data sources, including observations and student and teacher interviews, would have also enriched our findings.

The United States continues to grapple with an underrepresentation of racialized minority groups in the STEM college and career pipeline, which is attributed to various factors including exclusionary designs and approaches of formal and informal STEM learning systems. We describe a model for a STEM outreach partnership between a not-for-profit institution and under-resourced predominantly racially minoritized K-5 schools that fosters inclusiveness and could contribute to broadening the diversity of the STEM pipeline. This partnership was uniquely characterized by its inclusive design elements that engaged the schools' entire student population in STEM outreach, not just a select small group, and eliminated barriers to student participation such as costs/fees and transportation, by meeting students in their classrooms over the course of the school day. Despite their short duration (~ 4 hours) and once-a-year occurrence, the STEM Days proved beneficial to students, whose interest in STEM and related careers was sparked by opportunities to engage in hands-on learning, and to teachers, who acquired new approaches to teaching and new STEM knowledge. Furthermore, the STEM Days had lasting impacts for volunteer scientists, including clarifying career interests in STEM education and outreach, exposure to educational challenges in low income racially minoritized communities, and improving their communication skills. Lastly, while having scientists come into the school for a one-day STEM sharing experience and encouraging students to embrace STEM knowledge is valuable, additional emphasis should be placed on the notion that the STEM outreach could be the first step to building a more enduring educational partnership.

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Author Contributions

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ABBREVIATIONS

DDPSC: Donald Danforth Plant Science Center; DDPSC-EROL: Donald Danforth Plant Science Center Education Research and Outreach Lab; NCES: National Center for Education Statistics; STEM: Science, Technology, Engineering, and Math

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