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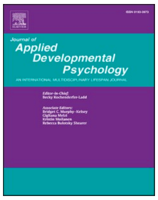

From opportunity gap to opportunity yield: The benefits of out-of-school authentic mentored research for youth from historically marginalized communities in STEM

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ABSTRACT

Our longitudinal, mixed methods study explores the experiences of over five hundred youth in long-term mentored research experiences outside of school, paired with data on their reports of plans to pursue STEM. Our participants, youth from historically marginalized communities, represent the most promise for diversifying STEM: 81% are students of color, and almost half are multilingual. This paper shares an analysis of a cross-section of quantitative data collected from this large-scale study as well as qualitative data in the form of participant interviews. Drawing from our quantitative data, we find that in stark contrast to the opportunity gaps that youth like our participants encounter, participating in out of school research generates a 'yield' of opportunities to engage in science practices–significantly more than in school– and to contribute meaningfully to a science community of practice. Our qualitative data suggests that this 'opportunity yield' may also contribute to their continued pursuit of STEM. Taken together, these findings underscore the critical role that learning in out-of-school mentored research settings can play for students revealing its important, complementary role in a STEM ecosystem.

In a decade of work with youth through our museum's in-depth mentored research program, we witnessed a heartening phenomenon: youth we've worked with are pursuing undergraduate degrees, advanced degrees, and careers in STEM. Alumni of the American Museum of Natural History's mentored research program—the majority of whom are from historically marginalized communities—regularly reached out to share the news that they were working in scientific fields and even pursuing advanced degrees. One young person reported that they had been accepted to be a STEM scholar at a local university and would be "working on a project on conservation biology." Another reached out to report that she had completed a double major in Biophysics and Applied Mathematics and was beginning a Ph.D. in Biochemistry. Consistent in their reports was the important role the mentored research program had played in preparing them for new opportunities. As one program alumnus noted: "The opportunities given to me from my experience were vital to helping me eventually get into my PhD program." Another reflected, "I'm pretty sure I was chosen because I mentioned my experience with the Science Research Mentoring Program." Another wrote: "Wanted to let you know that I've been hired by my college as the assistant director of STEM afterschool; the senior director really loved the fact that I'd previously been engaged in research in STEM."

Yet the national and local picture of the experiences in STEM of youth from historically marginalized communities reveals a starkly inequitable picture. This inequity exists at all levels of student experience and accumulates in impact over time. Vast disparities plague every

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stage of K-12 STEM education, including the amount of science instruction students receive (Smith et al., 2016); the lack of teachers of color in science and mathematics (AACTE, 2021; Plumley, 2019), the level of preparation of science teachers (Cardichon et al., 2020), access to advanced STEM coursework (Lewis & Diamond, 2015; MacPhee et al., 2013) and availability off after-school or advanced learning opportunities (Wai & Worrell, 2020). In turn, inequities emerge at the post-secondary level (McGee, 2020); for instance, across the demographics of college majors in STEM (National Science Board, 2022). Because students from historically marginalized communities experience less time on science instruction and fewer out-of-school opportunities, they are less likely to major in STEM, making it even harder to achieve a more equitable and diverse STEM workforce (Pew Research Center, 2021). However, in the face of this unacceptable national picture of STEM inequities, we were hearing vital, empowered stories of persistence, passion, participation, and success. Of course, we also heard about challenges, and continued inequitable treatment of our alumni, but our alumni seemed to be maintaining their strong interest and commitment to STEM.

The kind of large-scale research that would help us understand the nature and impact of these out-of-school experiences, however, is rare (Chi et al., 2015; Nguyen, 2023; Weiss & Chi, 2023). While considerable research explores and documents youth pathways into STEM in formal, academic settings (e.g. Godwin & Potvin, 2016; Weeden et al., 2020), far fewer studies examine the relationship between participation in out-of-school programs like ours, and youth pathways into STEM.

Our longitudinal “Staying in Science” study, funded by the National Science Foundation, was designed to help us examine the nature of mentored research program participation and to follow a large sample of youth into college as they chose their majors. Aware of this need in the research literature, we designed this study to help provide deeper insight into the importance of out-of-school learning, and to investigate the potential relationship between these out-of-school time (OST) mentored research experiences and students’ pathways into STEM.

Literature review

Although scholars widely recognize the challenges related to persistence in STEM, few studies of youth pathways focus on out-of-school learning and the role it might play (National Research Council, 2015). Longitudinal research that systematically explores the nature and impact of out-of-school STEM experiences is rare (Chan et al., 2020; Chi et al., 2015; Falk et al., 2016; Nguyen, 2023; Weiss & Chi, 2023). Unlike long-term studies in formal school-based environments with compulsory attendance and standardized curricula for all students, OST programs are uniquely designed and tailored to individuals or groups of diverse socio-cultural backgrounds who choose when and how long to participate in program activities. Often, these programs are small, short-term, and lack the infrastructure to maintain contact with individuals once they move on; these factors complicate the ability to attribute learning outcomes to program experiences and track individuals over time (Falk et al., 2018). Compounding these complications are methodological limitations to capturing the ways learning takes place within and across multiple contexts over time (Staus et al., 2021) and the challenge of attributing knowledge, interest or behavior outcomes to programmatic experiences (Falk et al., 2018).

While a handful of studies examine the trajectories of youth within informal STEM programmatic experiences (e.g., Shaby et al., 2021; Tan & Barton, 2020), such studies have not tracked participants beyond high school. A few studies have explored the potential impact of out-of-school STEM programs on participants’ college and career interests and pathways (Chan et al., 2020), finding that OST STEM program design principles and features contributed to participants’ persistence in STEM majors and STEM careers (Habig, Gupta, Levine, & Adams, 2018), and that program participants aspire to pursue STEM degrees at significantly higher rates than peers in control groups (Kitchen et al., 2018). Additionally, retrospective studies, including McCreedy and Dierking (2013) study of potential impacts of six OST STEM program experiences on 174 female participants, revealed that participation shaped participants’ identification with science and science careers.

While the findings from longitudinal studies confirm that youth who participate in OST STEM programs are likely to express aspirations to major in STEM in college or pursue a STEM career (Carrick et al., 2016; Rahm & Moore, 2016), these studies are often not large scale or cross-context. This study aims to contribute to our understanding of OST STEM experiences and youth trajectories in STEM by documenting the features of 24 OST STEM programs with over 560 participants as they moved from high school through college and into their early careers.

Study context

The findings in this paper were drawn from data from the first four years of our longitudinal study of youth who participated in an OST STEM mentored research experience. We are continuing to follow the trajectory of these participants, ultimately over the course of ten years. The youth participated in one of 24 different programs across New York City. The mission of these programs—part of a larger consortium—is to provide youth from communities that have historically been excluded or marginalized from entering STEM professions access to research internships that will support them in college and career pathways. This study is designed to follow the pathways of students who have had these research experiences. The first four years of our research design focused on the relationship between OST programs and persistence in STEM. The quantitative data shared in this paper represent a cross-sectional analysis of data from this larger study; and the qualitative data are drawn from yearly interviews we conduct with a sample of participants in this larger study.

We authors are a multidisciplinary team of researchers based in four research organizations. Our team includes established and emerging qualitative researchers and quantitative researchers, youth educators, science educators and alumni co-researchers pursuing STEM careers. Eight program alumni were youth co-researchers during the first four years of the study (two of whom have continued with us into the next leg of the project and are joined by four more alumni in the second round of the study, all of whom are now in college, graduate school, or working). Alumni co-researchers are a representative pool of individuals from the larger study sample composed of students of the same cohorts and age-range of our participants. Involving alumni as co-researchers ensures that our research is developmentally and culturally sensitive, as well as reflects their lived experiences, voices, understandings and concerns (Chaffee et al., 2024). In the second stage of our longitudinal study, we have expanded our measures to include items related to belonging and flourishing, as a way to continue to account for and recognize key socio-emotional features that matter for development and persistence in STEM. Our youth co-researcher partners are now new adults (in our new round of funding, we refer to them as “alumni researchers”) (see Chaffee et al., 2024).

Given the focus of the special issue on equitable learning and socio-emotional learning, we focus on data from our larger study that reveals features of the mentored research experience that do (or do not) reflect the characteristics of a strong community of practice, including socio-emotional support. And given the focus of the special issue on pathways, we share an analysis of a cross-section of quantitative data on what students report upon finishing their experience at their research site and qualitative data related to their plans to major in STEM.

Drawing primarily from this cross-sectional analysis of survey data and supplementing with qualitative interview data, we answer three research questions: 1.) What were key features of the mentored research sites? 2.) To what degree did youth report learning science practices? 3.) What did youth report about their plans to major in STEM?

The mentored research programs: 24 sites

All 24 OST mentored research programs which youth participated in are part of the New York City Science Research Mentoring Consortium (NYCSRMC). NYCSRMC is a partnership among academic, research, and cultural institutions, including the American Museum of Natural History that share the goal of engaging high school youth in STEM research experiences working alongside scientists. The mission of the initiative is to provide youth access to research internships that will support them in college and career pathways. The program is spread across the five boroughs of New York City. During this first round of data collection, the program had 11 sites in Manhattan, 4 sites in Brooklyn, 4 in Queens, 3 in Bronx, and 1 site with placements all over New York City. Of the total, 15 are universities, 3 are museums, 4 are community-based organizations, and 1 is a hospital. Each site reaches between 10 and 60 youth; collectively 500 youth who are either sophomores, juniors, or seniors in high school complete one of the science/engineering research programs in the NYCSRMC every year. Although the programs are offered at different institutions, all of the sites share the following program features: 70 h of free preparatory coursework to introduce youth to needed scientific concepts, software, and technologies, over 100 h of mentored science research, academic and career guidance for science success.

While the sites share those principles of youth learning and elements of program design and delivery, the research focus at each site reflects each institution's scientific expertise. Youth working with scientists at the American Museum of Natural History may focus on astrophysics, genomics, or cultural anthropology. Those paired with researchers at Mt. Sinai School of Medicine focus on medical topics, and those at Wave Hill Botanical Gardens work in conservation biology. This variation in disciplines and settings (i.e. laboratory or field) offers different opportunities to engage in science practices. A site with more field work may have more data collection, background research, and analysis, while a laboratory-based project may involve more analysis and synthesis.

Conceptual framework

Our pathways study provides an alternative approach that takes into account the concerns about the prevailing metaphor of the "STEM pipeline" (Lykkegaard & Ulriksen, 2019; Metcalf, 2014). The critique of the pipeline metaphor is that it conceptualizes the journey to a STEM career as a single, linear path which loses participants as they "leak out" at various points along the way. The pipeline is faulty, deficit-minded, and does not accurately capture the heterogeneity of pathways or the cultural or contextual features of youth's lived experiences that serve as assets and resources (Cannady et al., 2014; Lykkegaard & Ulriksen, 2019; MacPherson et al., 2024; see also Yosso, 2005). In the study, we take a youth development perspective, informed by socio-cultural theory and research on communities of practice and conceptions of learning ecosystems. A lens from critical theory is also important in our work as our study intends, over time, to account for and understand the experiences of youth from historically marginalized communities in STEM, and to examine the experiences they have in the varied settings as they pursue their pathways.

As an overarching theoretical perspective, Lave and Wenger (1991) view of learning as a "trajectory of participation" (O'Connor, 2001, p. 228) has been an important conception to capture the ways that youth could gradually shift from "legitimate peripheral participation" to full participation in the practices of the community. Core members of the CoP in the research site (like their mentors, often senior scientists and postdoctoral fellows) help guide new members through participation in the authentic practices of the CoP, and through this process, newcomer's identities evolve in relation to the CoP. We hypothesized that community cohesion and a sense of co-responsibility between participants emerges (Wenger, 1998), meaning that youth and more experienced scientists both provide valued work in the community. These frameworks enabled us to focus on the process of learning and becoming a participant in a community of practice–in this case, the mentored research site–as intricately linked to the learning of science practices and in turn, to identity formation and decisions such as a college major (Chaffee et al., 2023).

However, specifically to understand the mentored research experiences, the conception of communities of practice (CoP) reflects well the goal and aims of the research site (Lave & Wenger, 1991). The theoretical idea of communities of practice captures how a group of people with a shared goal, set of practices, and shared interests interact on an ongoing basis with the goal of deepening their knowledge and expertise and collectively learning from each other (Wenger et al., 2002). Practices are what members "do" when they interact and can include shared beliefs, values, ways of acting and interacting, as well as activities and tasks (Barab et al., 2002; Irving & Sayre, 2016). The focus on sets of practices is also consistent with current conceptions in education of how scientists work, and with how people learn science (NGSS Lead States, 2013).

Communities of practice features

In our study, we considered research sites as the communities of practice, and we examine the presence of these features, as well as the potential relationship between the features of these communities, including the practices youth learn. Key features of the community of practice that we were interested in included: problem solving with members of the community; getting feedback on one's ideas; and considering alternative explanations for phenomena. We were also interested in the socio-emotional aspects of the research site, including ways that the research site community might provide youth with feelings of support on their pathway and feeling valued and important to the community. Were youth experiencing these features? Which ones?

Opportunities to engage in science practices

For youth to shift from novice to expert, they must have opportunities to engage in the community's authentic practices (Lave & Wenger, 1991). In the mentored research programs, youth start at the "periphery." They learn the rationale of the project that the scientist is leading, read background papers, learn basic lab techniques—and then slowly become more independent with scientific tasks related to data collection and analysis. Examining the degree to which youth reported these opportunities to engage in science practices was a key component of our study. We were especially interested in whether youth reported, for instance, opportunities to design and plan investigations; collect and analyze data; read published research and develop explanations. We were also interested in the degree to which youth had opportunities to learn about the value of their work to the larger community–intersecting again with our interest in the socio-emotional elements of the community.

In and out of school settings

Finally, our conceptual framework also draws from Bronfenbrenner (1977) ecosystems perspective which acknowledges the multiple contexts and learning environments of youth learning (Bronfenbrenner & Morris, 2006; see also Allen et al., 2020); such as high schools and afterschool programs. Critical theory, however, requires that we recognize that these spaces are not neutral (Baldridge, 2020; O'Hara, 2020). Policies and practices enacted within institutional contexts–especially scientific institutions– have systematically excluded students like those in our programs, at all levels of participation (Chaffee et al., 2021; Dawson, 2014; Philip & Azevedo, 2017). For this reason, we gathered data on youth reports about opportunities to learn practices not only at their research site but also at their school site, to see if we found any differences in opportunities in the two contexts.

Methods

In this paper, we focus on findings from three sections of a yearly survey we administer as part of our longitudinal study. Given the focus of this special issue, we report on findings related to features of the community of practice, opportunities to learn science practices, and reports of intention to major in STEM. To explore the nature of youths' program experiences in the first year of the study (2017), we surveyed youth immediately after they completed the program in a "Current Student Survey." In year two of the study (2018), we designed an "Alumni Survey" and administered it to all youth who were one year beyond their mentored research experiences (the 2017 cohort, and then the 2018 cohort). Each year, roughly 500 students participate in the mentored research program and roughly 40% of the students in the program responded to our surveys yearly. We also focus on findings from our interviews, which we conducted with a subsample, and case studies of three youth. (This data is drawn from the data set of a larger, longitudinal study which includes these yearly surveys of our participants, social network surveys, interviews with a sub-sample ($N = 24$), and case studies ($N = 12$).)

Participants

Participants are youth from twenty-four different NYCSRMC sites across the five boroughs of New York City who responded to our surveys ($N = 566$). Participants had either just completed a mentored research program at one of the consortium sites in 2017, 2018 and 2019 ("current students") or were alumni of the program one year out ("alumni"). All students who were participants in the programs across these sites were invited to participate through emails from their program directors.

Table 1 shows our sample demographics for the three years of survey data. Students ($n = 566$) were all in high school when they took this survey. Thirty percent of all participants took the survey in 2017 while 35% of participants took the survey in 2018, and another 35% took the survey in 2019. Related to gender identity, 64% of our participants across the three years identified as female, 34% identified as male, 2% identified as gender non-conforming or non-binary, and 1% preferred not to state.

As shown in Table 1., 32 % of our sample identified as Hispanic or Latino, 67% identified as non-Hispanic or non-Latino and 1% declined to state. In relationship to ethno-racial identity, 19% of our sample identified as White, 19% identified as other (i.e., their preferred ethno-racial identity was not listed), 17% identified as Black or African American, 17% identified as South Asian, 16% identified as East Asian, 7% percent identified with more than one ethno-racial group, 2% preferred not to state, 1% of participants identified as Native Hawaiian or Pacific Islander, and <1% of our sample identified as American Indian or Alaskan Native. 77% of students had one or more parents born outside of the US, and almost half are multilingual (46%), communicating with their families in languages other than/in addition to English.

The three case studies we present include: Manuel, who identifies as a Black and Latino male, first-generation student; Tomas, who identifies as a Black male; and Julietta, who identifies as a Latina female, first-generation student. (All names are pseudonyms.) All three are from families with one or more parents born outside the US. All participated in mentored research in 2017 or 2018.

Survey items

In addition to gathering data on demographics and background information, both current student and alumni surveys included sets of questions about: 1) the features of the lab or site that helped us understand the degree to which students were participating in a community of practice; 2) the science practices students had opportunities to learn and 3) their future plans.

Table 1
Demographics for cs17-cs19 Participants ($n = 566$).*

Variable	Percentage of participants
Year participant took the survey	
2017	0.30
2018	0.35
2019	0.35
Do you plan to major in STEM in college?	
Yes	0.80
No	0.03
Unsure	0.17
Gender identity	
Female	0.64
Male	0.34
Gender nonconforming or non-binary	0.02
Prefer not to state	0.01
Hispanic or Latina/o	
Yes	0.32
No	0.67
Prefer not to state	0.01
Racial Identity	
White	0.19
Other	0.19
Black/African American	0.17
South Asian	0.17
East Asian	0.16
More than one group	0.07
Prefer not to state	0.02
Native Hawaiian or Other Pacific Islander	0.01
American Indian or Alaska Native	<0.01

Note: Some categories will not add up to 100% due to rounding.

* A first-generation college student is a participant where neither parent has completed a 4-year college degree.

Community of practice

We created seven survey items to explore different facets of participation in a strong community of practice. We based our items on the work of Lave and Wenger (1991) and Wenger (1998). Moreover, we developed these items to capture practices and experiences that we deemed important for students to have in our mentored research program (Table 2).

Opportunities to engage in science practices

We created seven items to explore the different types of opportunities participants had to engage in science practices (Table 2). At the time we developed our survey, there were no scales that we knew of that captured science practices. To that end, we developed a set of items based on the *Next Generation Science Standards* (NGSS Lead States, 2013) as well as the six strands associated with informal STEM learning delineated in *Learning Science in Informal Environments* (*LSIE*) (National Research Council, 2009).

We prioritized items in particular that we deemed important for students to have in the mentored research program. Because we were interested in the degree to which students experienced these features not only out of school but in-school, to see if there were any distinctions between settings, we asked about students' opportunities to engage in practices in and out of school: students were asked to rate how often they had the opportunities to engage in the same set of practices at their research site and at their school site.

Interviews

We conducted interviews with a subset of alumni ($n = 26$) to delve deeper into youth's experiences in their mentored research community. We gathered details regarding the nature of their mentored research experience, the ways in which relationships with mentors and peers formed and were (or were not) sustained after youths' research programs, and how those relationships shaped youths' perspectives of science research and their own next steps in their academic careers. We wrote brief analytic case studies of all participants as well as longer case studies of three focal participants.

Analysis

Quantitative

Our descriptive analysis of our data reflects data from each of the three years of the survey. We first analyzed youth responses to the community of practice items. We displayed the results by showing the percentage who "agreed" or "strongly agreed" with each community of practice item. We then explored the items measuring students' opportunities to learn science practices in their mentorship sites and at their school. We examined the means of the items and compare the differences between the frequency of practices at school and at their mentorship site using a Wilcoxon Signed-Rank Test for paired data. Since each item was measured using an ordinal scale, the Wilcoxon Signed-Rank Test was the best test to compare the difference between school and mentorship site on each item.

Then, to further highlight the differences between the opportunities to practice science at school and at their mentorship, we determined the percentage of participants who stated that they participated "often" in the practice at each site. Finally, we drew from survey data that we collected from the same students in 2020, to examine the number of participants who said they planned to major in a STEM field in the 2017–2019 current student surveys and the number of those students who, in 2020, were actually majoring in a STEM field or who still planned to major in a STEM field.

Qualitative

To analyze the interviews, we conducted a content analysis and identified key themes and patterns. Next, we wrote case studies of the twenty-six students, and analyzed case study qualitative data using a deductive approach to surface categories, which we developed into codes, as well as key themes and patterns. Codes involved in analysis of these interviews included items such as "science practices" and "future plans." For this paper, we draw primarily upon our four focal case studies to elaborate and deepen our understanding of our survey findings, and to help triangulate emerging findings.

Findings

Our quantitative survey and case study qualitative data provide insight into the key features of the mentored research programs that youth experienced. They highlight the vibrancy of the community of practice they participated in, underscore the variety of science practices youth learn, and provide a glimpse into the intentions and even the subsequent choices of STEM majors of our participants.

Table 2
Items used to Explore Community of Practice and Opportunities to engage in Science Practices.

Community of Practice Items[1]

1. I feel like I understand the language used by my mentor and others in my science research site without needing a full explanation every time terms are.
2. I have the support from my project site that I need to successfully participate in my program.
3. I am part of a community where we are all working on the same goals.
4. My contributions matter.
5. When I'm doing my research, I can get feedback from my mentor.
6. My peers and I problem solve together.
7. I view what I do at my science research site as complex and challenging.

Opportunities to Engage in Science Practices Items[2]

1. Design and plan science investigations.
2. Analyze data or other material.
3. Learn about why my research is important to the larger scientific community.
4. Share my findings at an academic conference or science fair.
5. Read published research articles related to my research.
6. Collect data or other material for analysis.
7. Develop an explanation or representation of my research findings.

Table 3
Community of Practice Features of Research Site (2017 to 2019).

Community of Practice elements	Percent who agree or strongly agree that they do the following at their research sites		
	2017 ($n = 168$)	2018 ($n = 198$)	2019 ($n = 200$)
I use and understand scientific language	95.8%	97.9%	85.5%
I have support to be successful	96.4%	95.9%	96.0%
I feel like part of community	91.6%	89.4%	91.5%
I feel like my Contributions matter	94.6%	92.9%	94.4%
I receive feedback from my mentor	91.1%	89.8%	97.0%
I problem-solve with my peers	92.9%	92.4%	92.5%
I feel like my work is complex/challenging	89.3%	97.9%	89.0%

What features of a community of practice did youth report?

The results from each of our community of practice items for the 2017, 2018, and 2019 current student surveys show that 89% or more of students agreed or strongly agreed with each community of practice statement (See Table 3.). In 2019, 85% or more of students agreed or strongly agreed with all of these statements. The vast majority of students reported that their mentorships offered them a community of practice in which they felt supported, that they were part of a community, and that their participation mattered. They reported being able to work with peers, receiving feedback from their mentors, and doing work that they believed is complex and challenging.

What did youth report about opportunities to learn science practices?

We found that for every item—save developing explanations—participants reported having significantly more opportunities to engage in science practices at their mentorship site than at their school. For example, on the item that asked students about their opportunities to design/plan science investigations at their site, students reported an average score of 3.88 at their site and an average score of 3.26 at their school ($z = 7.62, p < .001$). The item with the largest difference between school and site was opportunities to analyze data with an absolute difference of 0.70 between school and site ($z = 6.68, p < .001$).

Next, in Table 4, Table 5, and Table 6 we show the mean score for each of the different items that measured how frequently students had the opportunities to engage in science practices in each year of the survey. We compare the means of their opportunities to engage at their mentorship site and at school using a Wilcoxon Signed-Rank Test. Table 4 shows the results from our 2017 survey. The 2018 student survey results were similar to the 2017 survey results (as shown in Table 5). On average, 2018 students also reported having significantly more opportunities to engage in science practices at their mentorship site when compared to their school (see Table 5). For example, students reported more opportunities to analyze data at their research sites (averaging a score of 3.76 at their sites) as opposed to school sites, where they reported an average of 3.20 ($z = 6.81, p < .001$).

One exception was that in 2018 students reported having more opportunities to develop explanations of their findings at their school site than at their mentorship site ($z = -2.16, p < .05$). The items with the largest difference between school and site were opportunities to design and plan investigations ($z = 7.57, p < .001$) and opportunities to read published articles ($z = 5.96, p < .001$) with an absolute difference of 0.62 between school and site for both items.

These results were also consistent with surveys of students in 2019

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[1] Items were rated on a Likert scale where 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree.

[2] Items were rated on a frequency scale where 1=never, 2=rarely, 3sometimes, and 4=often.

Table 4
Opportunities to Engage in Science Practices at Research Site and at School 2017 (n = 168).

Science Practices at Site	Average of all participants at site and school		
	2017 Site	2017 School	Difference between means[1]
Design/plan science investigations	3.88	3.26	0.62***
Analyze data	3.70	3.00	0.70***
Learn why my research is important	3.57	2.98	0.59***
Share research findings	3.49	2.83	0.66***
Read published research	3.45	2.86	0.59***
Collect data	3.24	2.80	0.44***
Develop explanations or representations of my findings	3.08	3.20	−0.12

$^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$.
Note: Each item has a minimum possible score of 1(never) and a maximum possible score of 4 (0ften).

[1] We used a Wilcoxon Signed-Rank Test to test for significant differences.

Table 5
Opportunities to Engage in Science Practices at Research Sites and at Schools 2018 (n = 189).

Science Practices at Site	Average of all participants at site and school		
	2018 Site	2018 School	Difference between means[1]
Design/plan science investigations	3.81	3.19	0.62***
Analyze data	3.76	3.20	0.56***
Learn why my research is important	3.63	3.08	0.55***
Share research findings	3.53	2.92	0.61***
Read published research	3.46	2.84	0.62***
Collect data	3.32	2.88	0.44***
Develop explanations or representations of my findings	3.07	3.29	−0.22*

$^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$.
Note: Each item has a minimum possible score of 1(never) and a maximum possible score of 4 (0ften).

[1] We used a Wilcoxon Signed-Rank Test to test for significant differences.

Table 6
Opportunities to Engage in Science Practices at Research Sites and at Schools 2019 (n = 200).

Science Practices at Site	Average of all participants at site and school		
	2019 Site	2019 School	Difference between means[1]
Design/plan science investigations	3.39	2.79	0.60***
Analyze data	3.79	3.24	0.55***
Learn why my research is important	3.69	2.99	0.70***
Share research findings	3.20	2.37	0.83***
Read published research	3.52	2.87	0.65***
Collect data	3.76	3.09	0.67***
Develop explanations or representations of my findings	3.80	3.28	0.52***

$^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$.
Note: Each item has a minimum possible score of 1(never) and a maximum possible score of 4 (0ften).

[1] We used a Wilcoxon Signed-Rank Test to test for significant differences.

(Table 6). As with the other two survey years, students reported having significantly more opportunities to engage in science practices at their mentorship site when compared to their school. For example, the largest difference between opportunities at site and school was found in the share research findings item ($z = 8.46$, $p < .001$). This indicates that students reported having more opportunities to share their research findings at meaningful venues, like conferences or science fairs, at their mentorship site when compared to their school.

Finally, to highlight the discrepancies between site and school regarding opportunities to engage in science practice, we examined the percentage of participants from each year who reply that they “often” had the opportunities to engage in each of these science practices (see Table 7). In 2017, the item with the highest percentage was 89.9% of participants reporting that they often had opportunities to design and plan science investigations, compared to 47.6% reporting the same at their school. Similarly, in 2018 the item with the highest percentage of participants reporting “often” at their site was again design/plan science investigations (83.7%) compared to 48.7% reporting that they often had those opportunities at school. Lastly, in 2019 collecting data was the item with the highest percentage of participants reporting that they often had the opportunity to do it at their mentor site (81.5%) compared to 36.0% of participants reporting having the opportunity often at their school.

Overall, our analysis suggests that mentorship sites offered more opportunities for students to engage in science practices when compared to their schools. Mentorships afforded opportunities for youth to engage in meaningful science practices, which are likely to have a relationship with both persistence and desire to stay in STEM fields upon program completion and into higher education.

What did our qualitative data reveal about the nature of the community of practice and their opportunities to learn science practices?

Our qualitative data was consistent with our quantitative findings: we found students reported having these kinds of advanced science opportunities at their research site. For instance, in his description of the research Manuel was involved in, science practices are clearly part of what he engaged in, as part of a study of raccoon DNA:

> “We wanted to use eDNA to assess, see mammalian biodiversity. So we had different camera traps at different parks, at five different parks in New York City. We had camera traps determining—it was like sensory motion camera traps where they could identify any species that was moving during the area that the camera traps were pointing to. So… we used the data from the camera traps to see if we could assess— we took soil samples from the same area where the camera traps were located, to see if we get the same results, like we see in the camera traps. Or even … better results to assess the biodiversity in that area of the park.”

Tomas, who was also involved in a DNA study of raccoons, also emphasized the support he had from his mentors in networking beyond the program; noting:

> “My mentors too, they were able to tell me *oh, look at this when you're finished with [our research program]. Or, look at this* …. They gave me connections as soon as I told them I got into my college. They were like, *I have connections there. I can help you if you're looking for a lab or anything.*”

Manuel emphasized that doing this kind of research was not only exciting, interesting, and enjoyable, but it also involved a set of challenging skills and practices that were entirely new to him. As he noted, “the most appealing part about it is the research that I did back in the research mentoring program, like I really enjoyed doing the eDNA sequencing. And it was something because I [had] never done something like that, like doing research. It was my first time.”

Similarly to Manuel's comments, Julietta, whose research focused on computer science, described how she was able to do not only new work but more advanced work at the research site than she had ever done before: “I did computer work beforehand, but not to that depth or to that extent. Now it was like computer science. It was coding, and it was analyzing data and everything else.”

Table 7
Opportunities to Engage in Science Practices at Research Site and at School 2017–19.

Science Practices at Site	Percent who reported doing these practices "often" at their site or school					
	2017 Site	2018 Site	2019 Site	2017 School	2018 School	2019 School
Design/plan science investigations	89.9%	83.7%	54.5%	47.6%	48.7%	31.5%
Analyze data	75.0%	81.6%	82.0%	39.9%	49.7%	47.00%
Learn why my research is important	63.1%	68.4%	71.0%	35.7%	41.8%	40.5%
Share research findings	58.9%	64.2%	43.5%	35.1%	37.6%	22.0%
Read published research	57.1%	57.4%	60.0%	32.7%	35.4%	35.5%
Collect data	45.2%	50.5%	81.5%	31.0%	36.0%	42.5%
Develop explanations or representations of my findings	43.5%	46.3%	80.0%	47.0%	51.9%	49.0%

Table 8
Students who said that they planned to major in STEM in the CS2017-CS2019 surveys and were currently a STEM major in the A2020 survey.

Are you currently a STEM major in 2020?	Do you plan to major in STEM in college (2017–2019)?		
	No or Unsure	Yes	Total
No or Unsure	18	31	49
	66.7%	23.3%	30.6%
Yes	9	102	111
	33.3%	76.7%	69.4%
Total	27	133	160
	100%	100%	100%

Tomas also explained that even his teachers at high school recognized that he was being asked to do advanced work in his mentored research site, underscoring the challenge it provided:

> "…my teachers, they would always ask, 'how is everything going. Is there anything we can do to help you?' Because they knew that as a high school student research is difficult for anyone, but as a high school student, it's going to be really difficult for you because you never think outside the box how research expects you to think."

What did youth report about their intention to major in STEM?

We asked current students if they planned to major in a STEM field in college in our surveys. We surveyed several participants again in 2020 to ask if they were currently majoring in a STEM field, or, if they had not declared a major, we asked if they still planned to major in a STEM field.

Our survey data show that 76.7% of students who said they planned to major in a STEM field in the 2017–2019 surveys were currently majoring in a STEM field in 2020, as shown in Table 8. And, 93.6% of students who said they planned to major in STEM in 2017–2019 still planned to major in STEM in 2020 as shown in Table 9. (Tables 8 and 9 show the proportions of students who responded to these questions in either 2017, 2018, or 2019 and then responded again in 2020.)

Again, qualitative data from our interviews not only were consistent with these findings but also help add depth and elaboration to these patterns. Julietta, who described feeling that she was able to do more sophisticated computational work in her mentored research site, reflected that this depth of work led her to discover her passion for computer science: "I think *that* was when I realized that I like computer work." She pointed to her research experience as a key factor in her decision to major in STEM. She explained that she had selected the technical university she was attending because they were "known for their computer science."

Table 9
Students who said that they planned to major in STEM in the 2017–2019 surveys and still plan to major in STEM in the 2020 survey.

Do you plan to major in STEM in college?	Do you plan to major in STEM in college (2017–2019)?		
	No or Unsure	Yes	Total
No or Unsure	12	6	18
	57.1%	6.5%	15.8%
Yes	9	87	96
	42.9%	93.6%	84.2%
Total	21	93	114
	100%	100%	100%

Similarly, Tomas explained that being in the mentored research program helped expand his perspective about potential careers and helped shape his idea about what doing scientific research involved–as well as contributed to his realization that he liked it. He reflected in his interview that he had always thought that science simply meant working in medicine and didn't view himself as doing medical research. He said, "So, just without the mentoring program, I wouldn't be able to see that research is an option. I always thought it was just medical science and I never thought of doing research as a career."

Discussion

Across three years of quantitative data, and supported by our qualitative data from interviews and case studies, our findings reveal three key supports that OST mentored research contribute to youth pathways into STEM. First, we find consistently that students report experiencing a strong community of practice in STEM. They feel supported, they get feedback on their work, and they feel they are a member of a community. They seem to feel confident that their contributions mattered to the community; they feel valued and important to their research site. These findings are reflective of what research has identified as important elements for young people's participation in complex and demanding fields like STEM (Mulvey et al., 2022; Xu & Lastrapes, 2022).

Second, our quantitative and qualitative data from this analysis also show that in these out of school mentored research programs, students are learning to *do* the practices of science. They report opportunities to design and plan investigations, to collect and analyze data and to present their learnings to others beyond their group. We argue that being able to "do" the work of science—to collect data; analyze data; develop explanations; share findings with a larger audience—may be a critical element to seeing oneself as a scientist. Presenting research findings, for example, as a practice stood out to us: it was not only more frequent at the site than at school, but we think it is an especially important practice for young people. It both helps them 'identify' publicly as someone who does science and learn how to communicate scientific findings with confidence.

Importantly, these are opportunities that are rare for young people, especially high school students from historically marginalized communities, to experience (Darling-Hammond, 2010; Hsu & Venegas, 2018; Milner, 2012; Wai & Worrell, 2020). Again and again, research has underscored that these kinds of advanced, sophisticated opportunities to learn disciplinary practices are not commonly available out of school to youth like our participants– though they may be more regularly available to their more privileged peers (Grissom et al., 2017).

Third, we found that OST mentored research experiences gave students more opportunities to engage in scientific practices than in school. The experiences they gain in their out-of-school research sites are in fact, not available to them to the same degree in schools. In these out-of-school experiences they learned and rehearsed advanced practices that could complement and leverage their in-school learning. These findings support the argument for using an ecosystems view of learning, confirming the critical role of OST settings in offering important learning opportunities to students who may otherwise rarely have them (Allen et al., 2020; Traphagan & Traill, 2014).

Finally, the finding that so many of our study participants are majoring or intend to major in STEM, is encouraging given the nature of their learning experience in community, their sense of being valued, and the advanced learning of STEM practices. It seems possible that participating in mentored research creates a kind of "domino effect," in which each positive experience leads to the next one. We see students' intentions (and ultimate decisions) as an especially promising outcome. While we can't claim a causal link between participation in a community of practice and the opportunities to learn complex science practices, the high number of students planning to major in STEM (or choosing to major) is encouraging. Furthermore, the students themselves describe how their experiences in their OST mentored research programs bolstered their pursuit of specific STEM careers.

Study limitations

Because this is a cross-sectional, descriptive analysis of data from this larger longitudinal study, we cannot make causal claims from the quantitative data about impact on STEM pathways. However, because alumni themselves reported their plans and trajectories, and made connections between their STEM career decisions and their experiences with mentored research, our qualitative data does point to possible causal relationships–as does the high number of participants planning or choosing to major in STEM. In addition, both interviews and surveys have limitations due to the unique dataset (students who have all participated in a mentored research experience and have strong interest in STEM) and the newness of the items we designed. Since the survey was not anonymous–we knew the names of the respondents–and the youth had such deep connections at their research sites, socially desirable responses were possible. We took three steps to minimize the perceived risk to students both in terms of item design and survey timing. We ensured that the survey was not sent by specific sites and asked students to take the survey once their program was completed to ensure they did not worry that it would affect their treatment in the program; we also clarified in consent forms that participation would not impact relationships with mentors in terms of continued support they might seek.

Implications

This study has implications for those interested in expanding out of school opportunities for STEM-interested youth, especially youth from communities historically marginalized in STEM. Our student population in this study have tremendous potential to contribute to STEM fields to address the multiple challenges facing our society and planet. By showing the kinds of opportunities our youth participants can have in out-of- school mentored research– and the potential relationship between those opportunities and their choice of college major– this research lays out a possible path forward for ways to continue to support and expand such opportunities for youth interested in STEM. This, in turn, contributes to a more diverse STEM community.

This research on OST mentored research and youth pathways also has specific implications for those involved in *designing* out of school programs, helping show how, and in what ways, programs can deepen students' knowledge, practices, and cater to their passions and interests. This research helps illuminate the features that may be important for institutions and organizations to put into place, that can help alleviate inequality.

Finally, this study provides data that help confirm the role of OST learning in STEM pathways as both *different from and complementary to* in-school learning, which has implications for researchers and policy makers. This research shows the kinds of opportunities youth can have in out of school mentored research, that differ from school, and that may be especially important to offer to youth to help them grow and develop a sense of themselves as someone who does science, and in turn, choose to pursue STEM studies. It enables us to continue to recognize the important role out of school experiences play for youth, to study the types of experiences that may be important, as well as ensure that research and policy captures and includes these settings as part of a full understanding.

Conclusion

This analysis drawn from one of few large scale studies to examine youth pathways following out of school settings in STEM, underscores the important contribution of out of school learning. Findings from a set of cross-sectional quantitative data and qualitative data, from this larger study, illuminate the nature of the community in which youth learn STEM practices as well as their decisions to pursue STEM majors in college, showing the important role of out-of-school mentored research for youth learning in STEM. The specific analysis shared in this paper has put our initial anecdotal data into a larger context and revealed some of the reasons behind the choices youth in our programs have made to pursue STEM. It is encouraging that so many participants aim to pursue STEM studies, or are actually doing so, and heartening to hear participants attribute their choices to the experiences they have during mentored research. The study points to the *opportunity yield* these mentored research experiences provide, as a powerful counter to the well-documented opportunity gap, helping pave the way for a more just and equitable ecosystem for youth pursuit of STEM.

The story is not 'over' for these participants, however, which is why we are following them over time and into the final years of college and workplace (Hammerness et al., 2024). The students we interviewed reminded us of their continued challenges in STEM. For instance, when we last spoke to Manuel, while he was in the process of deciding on what STEM major to pursue and reported feeling concerned about "how to get there." He talked about struggling to find mentors on campus that could provide guidance for these decisions, despite feeling that he had been well supported during his mentored research experience in high school. Similarly, Tomas noted that higher education at the large university he was attending represented a "huge culture shock." He noted his intention to mentor incoming students himself because he wants new students to see and interact with a "diverse student body of students further along." Tomas explained the importance of support and mentoring, similar to what he had in his mentored research program, noting: it "hits you differently when someone says 'you can do it' and believes in you."

Our research is ongoing; we have been awarded a second five-year grant to continue to follow the trajectories of our STEM-interested youth–many of whom are now not only in their third and fourth years of undergraduate, and some of whom are already graduated and pursuing work and careers (Hammerness et al., 2024; MacPherson et al., 2024). As the next article reveals (Chaffee et al., this issue), we explore specifically how these youth–who are now young adults–navigate their career decisions and interest in STEM–and the ways that institutional contexts (and the associated sense of belonging or othering) impact our participants.

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Credit authorship contribution statement

Karen Hammerness: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Preeti Gupta:** Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation,

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Data availability

Data will be made available on request.

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