Experiencing STEM FirstHand: The Impact of a Novel Approach to Bolstering Scientific Identity, Interest, and Knowledge in Low-Income Middle School Students of Color

Education Innovation and Research Program – Early-Phase Grant
Table of Contents

A. Significance

A1. Project Develops New Strategies and Builds on Existing Strategies

The University City Science Center (UCSC), in collaboration with AnLar LLC and Palmer Wolf, proposes an **Early-Phase Grant** meeting **Absolute Priorities 1** (Demonstrates Rationale) and **3** (Field-Initiated Innovations in STEM) and aligning with **Competitive Preference Priorities 1** (Computer Science) and **3** (Promoting Equity and Adequacy). **The goal of this project is to advance evidence-based STEM/CS educational practices for high-need students of color through immersive, inquiry-based experiences in an out-of-school laboratory setting.** This project aligns well with the Early-Phase funding goal set forth by the U.S. Department of Education to, "fund the development, implementation, and feasibility testing of a program, which prior research suggests has promise, for the purpose of determining whether the program can successfully improve student achievement and attainment for high-need students."

Innovations in STEM have been a cornerstone of the United States' global leadership and economic prosperity, and the importance of STEM advances is more critical now than ever before as the global pace of innovation accelerates. Demand for a STEM workforce continues to outpace the supply of well-trained workers (BLS, 2014; OII, 2016) and the Bureau of Labor Statistics (BLS) estimates that STEM jobs will grow to more than 8 million by 2028 (Fayer et al., 2017), an increase equating to nearly 800,000 new STEM jobs (BLS, 2021). Yet national and international assessments paint a poor picture of students' competencies. Only 35% of U.S. 4th graders reach proficiency in science, and this rate drops to 22% in 12th grade (NAEP, 2019). In 2018, just 9% of U.S. 15-year-olds showcased high scientific literacy – the capacity to effectively analyze information, evaluate evidence, and reason from various sources (NCES, 2020; Schleicher, 2019).

While these overall statistics are disconcerting, those for low-income students of color in the U.S. are dire, and starkly inequitable. Disparities in STEM achievement by income and race/ethnicity emerge in elementary school and widen over time (Reardon, 2011). For example, in the most recent assessment of our nation's scientific literacy, there was a 33-point gap in science achievement between White 4th graders and their Black peers; by 12th grade this gap increased to 35 points (NAEP, 2019). These gaps are created and subsequently widened by systemic, longstanding, and pervasive inequities in STEM education. In a seminal study of 1,200 public and private schools, Oakes (1990) explored systematic differences in the access and quality of educational experiences afforded to elementary and secondary school students. Data suggested that compared to their high-socioeconomic status (SES) and White counterparts, low-SES and minority (Black and Hispanic) students were less likely to have access to (1) advanced and high-quality STEM programs, (2) highly qualified teachers, and (3) educational resources and curricula designed to build problem-solving and inquiry skills. Notably, each of these three points align with **Competitive Preference Priority 3 –** demonstrating that there are policy-level efforts to support initiatives, like the project proposed here, aimed at mitigating these inequities.

STEM learning outside of the formal education space has become a "focal piece of the education opportunities" for secondary school students (NAS, 2015). Organizations like nonprofits, state and federal education agencies/networks, and foundations are investing in out-of-school time (OST) STEM programs based on growing evidence that engaging with STEM/CS content outside of school directly influences classroom competencies and broadens participation in STEM (Saw, 2020). As noted by Saw (2020), "inclusive STEM schools, mentoring, and after-school programs are some promising approaches that can enhance STEM social capital and outcomes of underrepresented students, particularly women, Blacks/Hispanics/Native Americans, youth with low socioeconomic status, and persons with disabilities.”

Despite the plethora of OST STEM opportunities and their potential to mitigate learning disparities, our understanding of effective OST practices and what works best for students, especially underserved students, is in its infancy. In 2015 the National Academies of Sciences commissioned a review of research on OST STEM programs, noting fundamental changes in the STEM learning landscape over the past decade. The report noted that “research and evaluation findings are not yet robust enough to determine which programs work best for whom and under what circumstances” (National Resource Council [NRC], 2015, page 2). Here we propose to refine and evaluate the effectiveness of a novel approach to OST STEM learning through a program which immerses students in STEM activities accompanied with mentorship from STEM professionals with the aim of bolstering students’ STEM identity, interest, and knowledge.

The *Experiencing STEM FirstHand* project seeks to inform effective STEM learning practices through three actional objectives: **Aim 1:** Engage underserved, middle school students in hands-on, discovery-based, mentored STEM programming in a professional laboratory setting; **Aim 2:** Conduct a formative evaluation to collect baseline data and refine program delivery; and **Aim 3:** Conduct a summative evaluation to demonstrate the effectiveness of the program on students’ STEM identities, interest, and knowledge, and to inform effective practices.

A.1.i. The FirstHand Programmatic Approach

The University City Science Center’s (UCSC) FirstHand initiative is a coherent program designed to provide access to and equity in high-quality STEM/CS experiences through free, industry-relevant programming that supports traditional classroom learning by introducing some of Philadelphia’s most underserved students to STEM learning and career pathways through out-of-school STEM experiences. This innovative approach builds STEM social capital by connecting students to the broader STEM ecosystem, something that research shows will likely be key in inspiring them to pursue further opportunities within the STEM classroom-to-career pipeline (Saw, 2020).

The programmatic elements of FirstHand are guided by three significant bodies of research. First, by decades of research on effective learning and instructional practices in science education (NRC, 2007), which has demonstrated that learning in science is an active process, where students investigate and develop knowledge through observations and interactions (Linn and Eylon, 2011; NRC, 2007; Smith, and Neale, 1989). Second, by recommendations on high-quality OST programs (NRC, 2015), which include (1) engaging students intellectually, academically, socially, and emotionally by providing first-hand experiences with phenomena through sustained STEM opportunities, and establishing a supportive learning community; (2) responding to students' interests, experiences, and cultural practices by positioning STEM as socially meaningful and relevant, allowing students to collaborate and lead, and allowing program staff to be learners alongside students; and (3) connecting STEM learning across out-of-school, school, home, and other settings by leveraging community partnerships. **Notably, each of these criteria is highlighted in Competitive Preference Priority 3 and is reflected in FirstHand's programmatic approach.**

Third, in an effort to better understand the landscape of out-of-school STEM programs and make recommendations on their structure, the National Academies of Sciences outlined six evidence-informed action steps needed to support the development of high-quality out-of-school STEM experiences. In the table below, we summarize these action steps and illustrate how FirstHand's programmatic components directly align with them:

Table 1. FirstHand Builds on NAS Recommendations for OST Programs

NAS Recommended Action Steps for High-Quality OST STEM Programs	FirstHand's (FH) Programmatic Alignment with NAS Recommendations
1. **Build a map and bridge the gaps**: Understand the local conditions for creating an ecosystem of high-quality productive out-of-school STEM learning programs	• FH partners directly with Philadelphia school administrators and science teachers to coordinate participation and how to best meet student needs • FH connects students to STEM/CS careers in their own neighborhoods due to hyper-local school and mentor partnerships
2. **Connect young people with opportunities to learn:** Design programs to achieve access, equity, continuity, and coherence	• FH is free with no academic requirement to participate • Coordination through school removes burden from guardians • School-day programming removes barriers to attendance in after-school programs (e.g., sports, sibling care) • Opportunity for alumni students to continue in FH programs as advisers to younger students • Curricular tracks assume no prior knowledge but are informed by STEM/CS careers in students' community
3. **Support innovative evaluation approaches:** Support the use of creative and responsive approaches to evaluating program success at individual, program, and community levels	• The proposed *Experiencing STEM FirstHand* evaluation includes a formative component that will provide data to drive continuous program improvements • The proposed evaluation also features a summative evaluation that will yield a rigorous program evaluation • Evaluation will gather both student and teacher feedback to evaluate program success across engagement levels
4. **Provide professional development**: Increase the professionalization of OST program leaders and staff	• FH staff are full-time employees and competitively paid, leading to staff retention and internal growth • Professional development in culturally-responsive teaching and effective STEM practices is budgeted for each staff person
5. **Build an infrastructure that will last:** Strengthen the STEM learning infrastructure beyond school	• FH students build supportive relationships across STEM learning (educators, peers, families, etc.) • Social capital is bolstered by expanding students' social networks to include STEM professionals in their home city • Continued contact with FH alumni leads to internships
6. **Explore how STEM learning ecosystems work**: Invest in research to improve understanding of STEM learning in OST programs	• To date, FH has invested over $185,000 in program evaluation and formative feedback • Proposed project highlights investment needed to improve research on recommended practices within OST STEM programs

FirstHand has deep, long-standing partnerships with twelve public, private, and charter schools throughout Philadelphia, primarily concentrated within UCSC's West Philadelphia neighborhood (see Narrative File A for schools associated with this project). A small group of middle school students (12-14) from each partner school travel to the UCSC campus weekly for two hours per week via walking or public transit (fare is provided by FirstHand) to participate in a free, 10-week (20 hour) program. Many schools will elect to send the same students to multiple 10-week programs. **This school-time model is widely supported by partner school principals as a way to enhance STEM learning and results in very low program attrition, with nearly 90% of students attending 100% of the sessions in a 10-week program.** By eliminating common barriers such as cost, academic achievement requirements, and transportation, FirstHand fills a gap in the Philadelphia STEM education landscape by providing equitable, accessible, high-quality programming. This model was modified to successfully accommodate virtual learning due to COVID-19 – this virtual implementation is detailed in Narrative File B.

When in-person learning is allowed, students participate in the program in FirstHand's 5,000-square-foot "learning lab," which mirrors a professional lab and shares the building with dozens of STEM/CS companies of all sizes and Drexel University's College of Computing & Informatics. The students are immersed in a STEM ecosystem and share all aspects of the space with professionals – the elevators, hallways, lab supplies, etc. This affords students an opportunity to see what the collaborative, engaging process of science looks and feels like.

FirstHand is unique in that all six middle school curricular tracks are truly industry-informed, with STEM/CS professionals helping to develop activities and later serving as mentors during implementation, creating authentic STEM career exposure while building students' STEM social networks. These curricular tracks range from synthetic biology to electrochemistry, and the FirstHand staff coordinates closely with partner schools to select the track that best supplements students' classroom learning, interests, and knowledge base. Throughout the 10 weeks, students learn scientific knowledge and skills by engaging in a series of scientific practices such as designing and conducting experiments, synthesizing knowledge from different sources, brainstorming, communicating, and collaborating with mentors and peers.

Maintaining industry relevance with the aim of bolstering STEM social capital, all tracks are informed by real-world STEM challenges and are developed in consultation with local industry partners. Exemplifying this focus, **and the program's alignment with Competitive Preference Priority 1**, FirstHand collaborated with computer scientists and bioinformaticists at Children's Hospital of Philadelphia (CHOP) to co-develop a computer science (CS) curriculum titled "*Health Hackers*" in which students learn to code on Scratch, an introductory coding platform, and develop mobile apps on Thunkable, a program similar to Scratch but focused on mobile apps. With support from CHOP professionals, students then apply that knowledge to develop an app or Scratch project that enhances the mental and/or physical health of their peers – mirroring the work done by the CHOP professionals who helped teach the students (Figure 1).

Figure 1. Example CS Curriculum. **(A)** Staff from FirstHand and CHOP help students brainstorm; **(B)** CHOP data scientist introduces Scratch programming through "Viral Chase" game; (**C)** Students test their mobile translator app; **(D)** Student pair presents app they developed to support peers through challenging times to family, community and mentors at the final

A2. Dissemination

Dissemination is essential to our efforts to advance the knowledge base regarding effective OST STEM/CS programs. We recognize that our work is relevant to researchers and educators, and thus we have a multifaceted approach to dissemination. Our team brings a wealth of expertise in the dissemination of science to practitioner, policy, and public audiences. Over the past seven years, we have partnered with schools, educators, community and government organizations, and professional societies to connect research to practice and our in-person dissemination activities (e.g., presentations, workshops) have reached over 3,500 practitioners. The dissemination plan of this project will leverage the team's networks and qualifications, as well as targeted avenues, to ensure that the deliverables reach a broad audience of educators, researchers, community stakeholders, and parents and students in ways that will enable those working to improve equity and access in STEM to use the gathered information and strategies.

Our dissemination plan will employ the following venues: (1) **Social Media –** FirstHand has a large social media following that spans educators, students, community members and researchers, allowing us to quickly share progress, findings and suggestions with a wide range of audiences; (2) **Conferences –** We foresee presentations at conferences for both education researchers (e.g., American Educational Research Association) and educators (e.g., National Science Teaching Association (NSTA); National Association for Research in Science Teaching) to share knowledge gained from the project; (3) **Report Publication/Presentation –** We will regularly share technical reports to stakeholders including the EIR Program, School District of Philadelphia (SDP) leadership (especially within the Science division of the Office of Curriculum and Instruction), and participating families via open-access publications on the partners' websites and town-hall style presentations. We will also leverage UCSC's weekly, community-facing program, Venture Café Philadelphia, to present our findings at least once annually to the community; and (4) **Journal Publications –** Impact study findings will provide data, outcomes, and suggestions for peer-reviewed journal publications in journals that target science researchers and practitioners (e.g., NSTA, Journal of Research in Science Teaching).

B. Quality of the Project Design

B1. Conceptual Framework

The structure of UCSC's FirstHand program, the conceptual framework of this project, and our Theory of Action are informed by the previously described literature on effective science learning. The conceptual framework of this project is clear: Scientific knowledge is gained through doing science and by engaging in practices that expert scientists do such as asking questions, planning investigations, analyzing and interpreting data, and obtaining and communicating information. **FirstHand students regularly practice each of these skills throughout a single, 10-week program.**

Drawing on this collective body of work, FirstHand implements three programmatic elements, or active ingredients, to build students' scientific identities, interest, and knowledge as shown in our Theory of Action (Figure 2 and Narrative File C): **(1)** hands-on, discovery-based STEM/CS experiences for urban, high-need middle school students; **(2)** an immersive, place-based learning environment (UCSC research campus); and **(3)** industry-relevant mentoring by and social networking with STEM professionals. Recognizing the importance of building STEM social capital through social networks (Saw, 2020), the program sources and trains mentors from an array of STEM companies on the UCSC campus to support student learning.

We hypothesize that the program's active ingredients work together to yield improvements in three categories of student outcomes. **(1) Scientific social identity**, defined as their sense that they belong in science, that they are good at science (scientific self-concept), and that they have the skills, determination, and work ethic to succeed in science (scientific self-efficacy); **(2) Interest in participating in other science activities** (e.g., visiting a science museum), and in future science courses as well as interest in working in scientific careers; and **(3) Domain-specific science knowledge** and problem-solving skills.

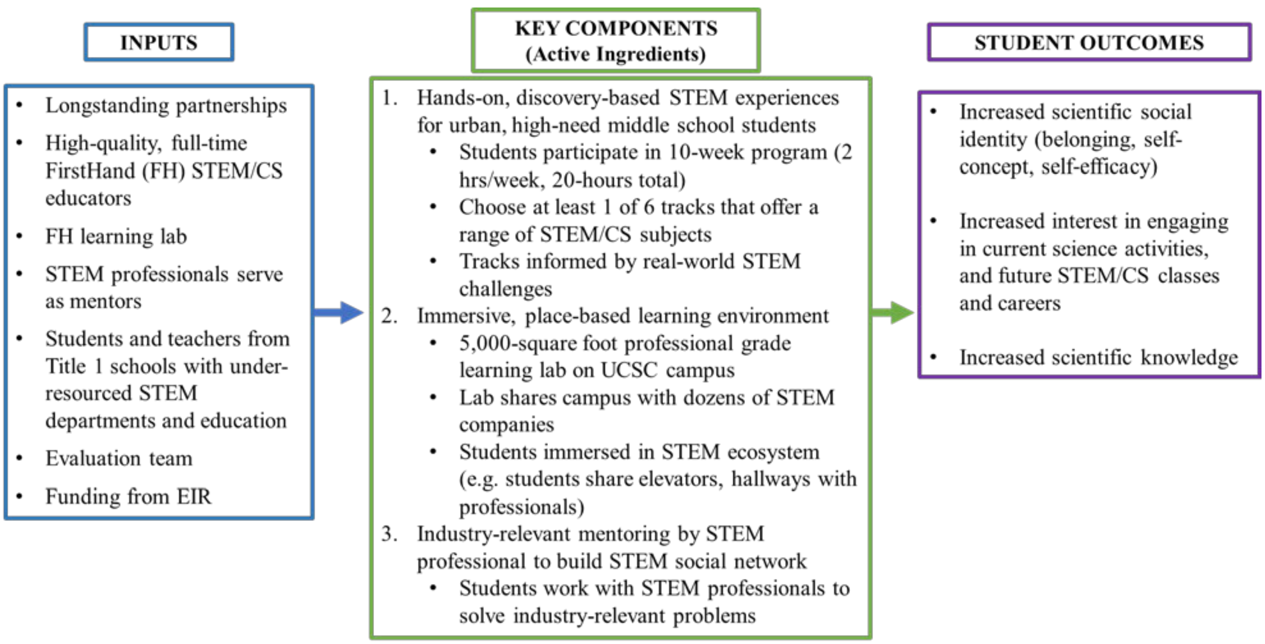


Figure 2. Experiencing STEM FirstHand Theory of Action

B2. Specified & Measurable Goals, Objectives, and Outcomes

UCSC is partnering with researchers from two organizations – AnLar LLC and Palmer Wolf – to conduct an early-phase project that addresses **Absolute Priorities 1 and 3** and aligns with **Competitive Preference Priorities 1 and 3.** The specified and measurable goals, objectives, and outcomes to be achieved by this project are outlined below in Table 2.

Over the course of the 5-year project we take an iterative approach to evaluation in which we conduct formative evaluations and continually refine the design and implementation of

FirstHand. This approach is designed to implement the FirstHand program, collect baseline data on its implementation and outcomes, and then use that data to continually inform the revision and continuous quality improvement of the program. Through these programmatic and evaluation activities, the program seeks to enhance scientific social identity, interest, and knowledge among students who are underrepresented in STEM. Through prior collaborations with AnLar and Palmer Wolf, FirstHand has amassed preliminary evidence of the program's impact on participating students, but to maximize and conclusively demonstrate the program's outcomes, we must accomplish three programmatic and research objectives:

Table 2. Specified & Measurable Goal, Objectives and Outcomes

Goal: *To advance evidence-based STEM educational practices for high-need students through immersive, inquiry-based STEM education experiences in an out-of-school laboratory setting*

Objectives	Outcomes
Objective 1: Engage underserved, middle school students in hands-on, discovery-based, mentored STEM/CS programming that is situated in a place-based environment to mirror authentic industry activities through the implementation of UCSC's FirstHand program with at least 330 students	Data to inform our understanding of target population and factors that promote FirstHand retention: • # of students served over the course of the grant • Retention in the program by both students and teachers (e.g., are there specific student characteristics that predict who will retain in the program and who will drop out of the program) • # of student-mentor relationships established via participation in FirstHand
Objective 2: Conduct a **formative evaluation** to collect baseline data and refine program by tightening alignment between program and literature on effective science instruction.	Collect baseline data to guide the refinement and improvement of the FirstHand Program: • Semi-structured interviews with teachers whose students are participating in the program • FirstHand observations to document programmatic activities and interactions between facilitators and participants • Pilot measures of student science identity, interest, belonging, and knowledge
Objective 3: Conduct a **summative evaluation** to demonstrate the effectiveness of the program on students' (1) scientific identity (self-concept, self-efficacy, and belonging in science); (2) interest in science activities, courses, and careers; and (3) scientific knowledge.	Collect summative data to evaluate the effectiveness of the FirstHand Program on students': • Scientific identify and belonging • Interest in science careers and activities • Science knowledge *Descriptions of measures in Section D3.iv.*

B3. Addressing the Needs of the Target Population

Data on the United States' STEM learning and career outcomes were presented in Section A. In many ways, Philadelphia is a microcosm of the disparities in STEM learning that have been observed nationally. Philadelphia is a haven of STEM innovation with a high concentration of higher education institutions and is a top-ten U.S. life sciences economic cluster (Vey et al., 2017); yet many Philadelphia classrooms lack resources to provide the STEM education necessary to prepare students to join the science and technology workforce. School District of Philadelphia (SDP) students consistently score below proficient on tests of math and science achievement (NAEP, 2009; 2015; 2019), with only 29% of SDP students scoring "Proficient" in Science and 14% in Math on the Pennsylvania System of School Assessment (PSSA) tests (NAEP, 2019). This disconnect between the abundance of STEM professionals and expertise and the STEM educational opportunities available to Philadelphia's youth is the impetus for FirstHand's approach.

These data have led to continued efforts to improve STEM education in the United States (NSTC, 2018), including standards for scientific literacy (e.g., the Next Generation Science Standards (NGSS)), novel recommendations to maximize science teachers' instructional effectiveness (NAS, 2015; Saw, 2020), STEM-focused schools (Eisenhart et al., 2015), and calls to support underrepresented minority students in STEM (Estrada et al., 2016; Leggon, 2006).

Based in this growing body of literature, especially related to the importance of STEM social capital (Saw, 2020), the combination of hands-on STEM/CS learning with high-quality mentorship is FirstHand's strategy to combatting the STEM education and career disparities between underserved students and their more resourced peers. The **target population** for this project is urban, low-income middle school students of color who attend significantly under-resourced schools (See Narrative File A). The self-reported demographic data from past

FirstHand participants is as follows: 83% Black, 6% Hispanic and 6% mixed ethnicity. Additionally, 57% of program attendees identified as female and 9% reported a language other than English as the primary language spoken in their home. This project is appropriate to, and will successfully address, the needs of the target population in the following ways:

- **Grade-appropriate, Equitable Learning**: FirstHand staff works closely with school administrations to select curricular tracks that align with students' interests, existing knowledge and future classroom topics. However, the team assumes no prior STEM/CS knowledge when creating curricula – providing equitable access for all students.
- **Culturally-Responsive Programming.** Black and Hispanic students prioritize giving back to their communities more than their White peers (Garibay, 2015), yet many do not view STEM as a career path through which they can do this (Jidesjö et al., 2009; Potvin & Hasni, 2014). Across all FirstHand curricula, students are tasked with working together to identify, quantify, and solve problems that their communities are experiencing in real time. This shows students that they can give back to their communities through STEM.
- **Curated Mentorship & Activities.** FirstHand's approach to mentorship is unique in that support from STEM professionals is embedded in the design and implementation of all curricula. Drawing upon the importance of STEM-oriented social relationships and support (Saw, 2020), students engage with a STEM mentor at least three times over a 10-week program. Recognizing the importance of learning from someone who can relate to their experiences, FirstHand strives to recruit volunteers and staff with similar backgrounds to the students (Morrow & Styles, 1995; Biggs et al., 2014). To date, 41% of volunteers identify as a race other than White, 28% as non-native English speakers, and 82% as women.

C. Adequacy of Resources and Quality of the Management Plan

C1. Timeline and Milestones

The proposed project will proceed across four main phases. **A Gantt chart of the timeline and main activities in each phase is attached as Narrative File D and described throughout sections C and D.** During Phase 1, we will implement the pilot FirstHand program and conduct a formative evaluation to collect baseline data that will later be used to evaluate whether we have achieved our proposed outcomes. Formative evaluation will include observations of the program to examine implementation fidelity, and interviews with teachers and program participants to identify program strengths and weaknesses. Findings and data-driven suggestions from Phase 1 will be delivered on a regular basis to program staff. The goal of this phase is to guide continuous quality improvement and pilot the measures to be used in the summative evaluation.

During Phase 2, we will refine the program and measures based on the formative evaluation in preparation for the summative evaluation. Phase 3 includes implementation of the refined FirstHand program and continuous summative evaluation, which will occur across four cohorts (I-IV) of students, to improve the program's quality. Students will be recruited for participation in the fall of each year from a selection of eight of FirstHand's existing partner public and charter schools (see Narrative File A). Summative evaluation data will be collected for both the treatment group and the control group during the fall of each year (T3 in Narrative File D). Following the fall of each year, the summative data will be analyzed and presented to FirstHand staff to guide continuous improvements after each cohort. Phase 4 will occur following the summative evaluation of cohort IV and will include final data analysis, synthesis, and dissemination.

The team will work collaboratively to iteratively implement, assess, and refine the program. Communication and joint decision-making are critical to the success of this project. At the beginning of the grant, the project team will meet to discuss the overall project plan and set meeting schedules. Throughout the grant, we will hold leadership meetings and smaller Program Development team meetings and Evaluation team meetings. The monthly leadership meetings will be attended by PIs to ensure that the project runs smoothly and in accordance with the proposed project timeline, to monitor progress towards goals, deliver recommendations on program delivery gleaned from formative evaluation, and confirm that project personnel are operating in accordance with the rules, regulations, and requirements. Program Development team meetings and Evaluation team meetings will occur weekly. During Phase 1, the goals of these meetings will be to review program materials, ensure alignment to program goals and measures and discuss formative evaluation protocols. During Phase 2, the goals of these meetings will be to discuss how the formative results inform program and measure refinements. During Phase 3, the goals of these meetings will be to discuss data collection, analytic results, and implications for program refinement. Also during Phase 3, the Evaluation team will meet weekly to plan and review protocols for data collection and storage, discuss challenges with data collection, and formulate plans for data entry and analysis.

Throughout the grant, partners will jointly agree to changes to the research plan, as and when appropriate. We will employ an iterative, internal quality review process, in which all products are reviewed by all team members for scientific integrity and usability.

C2. Qualifications of Key Project Personnel

This project will apply a team-based approach to the management, implementation, and evaluation of the proposed project. To maintain objectivity in all research efforts, we have separated the key personnel into two groups: Program Development & Implementation, and

Evaluation. The interdisciplinary team for this project includes leaders in OST STEM programming, science learning research, and program evaluation. **Aligning with Competitive Preference Priority 3, UCSC is committed to employing and retaining fully certified and/or highly experienced educators to ensure that participating students are receiving the best possible programming.** See Appendix B and Budget Narrative for detailed resumes and outlines of the team members' qualifications and roles in this project.

Program Development & Implementation Team: UCSC's FirstHand program staff will lead program design and refinement, coordination, and implementation.

- [redacted] (Director of STEM Education, UCSC) will serve as project director and will devote an average of 12% effort (1.4 person months) to this project. [redacted] will oversee all program staff, and manage the budget, program development, and reporting.
- [redacted] (Program Coordinator, UCSC) will devote an average of 75% effort (9.0 person months) to this project and will coordinate with the Evaluation Team, program refinement in response to formative evaluations, and assist in reporting and dissemination.
- [redacted] (Program Manager, UCSC) will devote an average of 40% effort (4.8 person months) to this project and will serve as the primary liaison to participating schools. [redacted] will also manage implementation of the 10-week STEM programs.
- [redacted] (Program Facilitator, UCSC) will devote an average of 60% effort (7.2 person months) and will serve as the primary facilitator for this project.

Evaluation Team:

- [redacted] (Senior Research Scientist, AnLar LLC) will devote 25% annual effort (3.0 person months) for this project as a co-PI. She will lead and implement the evaluation design (both formative and summative) and will oversee the AnLar budget for this project and submit budget expenditure reports to UCSC for reporting purposes.

- [redacted] (Chief Research Officer, Palmer Wolf Corporation) will devote 20% effort (2.4 person months) to this project as a co-PI. He will be responsible for developing and implementing the project's analytical framework and ensuring that measures and metrics are aligned with the project's goals, and will oversee the Palmer Wolf budget for this project and submit budget expenditure reports to UCSC for reporting.
- [redacted] (Research Director, AnLar LLC) will devote 5% effort (.6 person months) in Year 1 and 10% effort (1.2 person months) to this project in Year 2-5 as a co-PI. She will be responsible for the development, implementation, refinement, and dissemination of the FirstHand Implementation Fidelity measure. In addition, she will provide high-level guidance and oversight on the evaluation design to ensure that measures are aligned with programmatic goals and objectives.

C3. Cost Rationale

All budgeted costs are reasonable in relation to the objectives, design, and potential significance of the proposed project - see Budget Narrative Attachment for more details. Our team consists of subject matter experts who can anticipate challenges and develop strategies for addressing them (e.g., data collection postponed due to unforeseen circumstances). We anticipate and have budgeted for such challenges and developed protocols to minimize their occurrence. Research & Evaluation costs are informed by the team's combined tenures in the field and in working on large, federally-funded projects such as this. Program Development costs are based on the FirstHand program's annual operating budget for middle school programming and forecasted over the 5-year funding opportunity.

C4. Feedback and Continuous Improvement

In Section C1 above, we introduced the procedures that will be followed to ensure feedback and continuous improvement throughout the proposed project. In brief, the project team will implement and continually refine FirstHand's STEM program (objective 1) while conducting an evaluation that features a formative (objective 2) and summative (objective 3) evaluation. The formative evaluation will begin in spring 2022 and employ qualitative measures (observations of program sessions and semi-structured interviews with classroom teachers) and analyses of data collected using those measures will be shared with the program team. This will allow the program to be refined prior to the start of the 2022-23 academic year. The summative evaluation will begin in fall 2022 with the first study cohort. As each of the first three cohorts participates in the study (fall 2022, 2023, and 2024), data on implementation fidelity and students' scientific identity, interest, and knowledge will be collected. These data will be analyzed in the winter of each academic year, and then recommendations with be shared with FirstHand educators prior to the program beginning in the following spring.

D. Quality of the Project Evaluation

D1. Evaluation Overview and Meeting What Works Clearinghouse Standards

The evaluation of the project will include two phases: an initial, formative evaluation (objective 2) and a subsequent summative evaluation (objective 3). The formative evaluation will take place concurrently with a 10-week program in spring 2022 and will provide data for the first round of feedback for continuous improvement while also affording the opportunity to develop, refine, and pilot our measures. The summative evaluation will begin in fall 2022 and continue through the length of the grant to yield evidence about the project's effectiveness that **will meet the What Works Clearinghouse standards** as is required by the selection criteria D1 and is described throughout this section.

D2. Performance Feedback and Periodic Assessment

D2.i. Formative Evaluation (March – June 2022)

The first goal of the formative evaluation is to provide data for the initial round of project refinement. **We will collect two forms of data over the spring 2022 implementation:**

1. The Evaluation team will **conduct semi-structured interviews with classroom teachers** whose students are participating in the program to explore teachers' expectations for the program, the extent to which those expectations were met, what they thought "worked" in the program for their students (and what did not), and how the impact of the program on their students' scientific identity, interests, and knowledge could be increased.
2. The Evaluation team will also **conduct observations of approximately 30% of FirstHand's program sessions**, employing a systematic approach to session selection that will ensure a representative cross-section of sessions are observed over time and across student groups. A low-inference running record that details program activities, educator-student interactions, and student-student interactions will be created. Should virtual programming be required in response to COVID-19 safety protocols, FirstHand sessions and observations will be held through a virtual platform (see Narrative File B). Records will be subject to a deductive content analysis (Elo & Kyngas, 2008) to better understand the context of FirstHand's programming and to the extent to which instruction, as implemented, aligned to the Theory of Action (Figure 2).

The second goal for the formative evaluation will be to develop, refine, and pilot the measures that will be used in the summative evaluation. The low-inference running records yielded by the observations described above will be used to codify a set of essential programmatic elements that must be present in any program session to be deemed to have been implemented with fidelity to the program's design. **These elements will form the core of the FirstHand Implementation Fidelity Measure that will be used throughout the summative evaluation** (see section D3.i).

The measures of student outcomes that will be used in the summative evaluation are described in detail below. All measures have demonstrated good psychometric properties in previous research with students of similar demographics. Nevertheless, all measures will be administered to students participating in FirstHand's program in the spring of 2022 prior to and following participation. Our analyses of the data collected using these measures will examine internal consistency, test-retest reliability, convergent validity, and sensitivity of these measures to inter-individual differences and intra-individual change over time.

D2.ii Interim Analyses

Interim data analysis will occur following data collection in the fall of the 2022-23, 2023-24, and 2024-25 academic years. The results of these analyses will be shared with FirstHand educators prior to the spring implementation of the program, allowing these educators to continuously improve and test these improvements with smaller groups of students who have already completed their participation in the study (i.e., the students assigned to the control group of Cohorts I, II, and III) prior to implementing them at scale the following fall. The results shared with educators following each round of interim analysis will include:

- The proportion of essential program elements for each session that was observed according to data collected using the implementation fidelity measure, with a focus on documenting those elements that were most often omitted, if any.
- Baseline levels of scientific identity, interest, and knowledge, to inform how instruction might be tailored to best suit students' initial levels in the areas when the program begins.
- Students' self-reported levels of satisfaction, engagement, and learning (including favorite and least favorite program components), as assessed by items on the post-program survey.
- Intra-individual levels of student change in scientific identity, interest, and knowledge, among students in the treatment group.

The focus of this last set of interim analyses will be on the magnitude of change, operationalized in terms of effect size, in both an absolute sense (i.e., does it constitute a meaningful change, as per current guidelines for educational research) (e.g., Kraft, 2020) and a relative sense (e.g., are changes smaller or larger for measures of identity, relative to interest), as well as exploring whether rates of change differ across sub-groups of students (e.g., girls versus boys).

D3. Project's Contribution to Knowledge and Understanding

D3.i. Summative Evaluation (September 2022 – December 2026)

Beginning in the fall of 2022, we will conduct a summative, experimental evaluation of the project designed to yield evidence about its effectiveness that will meet the **What Works Clearinghouse standards in response to the required selection criteria D1**. This evaluation will include four cohorts of students (one for each academic year) from whom data on our outcome measures will be collected before and after participation in the program. Students in each cohort will be assigned at random to participate in a 10-week program in the fall of each academic year or to delay participation until the spring. We will also collect observational data to ensure that the project is implemented with fidelity to its design. Results from annual preliminary data analysis will be shared with the program team to facilitate continuous quality improvement and final data analysis will occur after data collection concludes.

D3.ii. Sample

The sample for the summative evaluation will comprise all students attending FirstHand's program for middle schoolers (grades 6-8) in the 2022-23, 2023-24, 2024-25 and 2025-26 academic years. The students participating in each of these years will constitute a study cohort, and thus there will be four cohorts: I (2022-23), II (2023-24), III (2024-25), and IV (2025-26). Based on prior enrollment and rates of participation in research, we anticipate that 84 students from 3 schools will participate in each year of the study, yielding a total sample of 336 students. FirstHand has longstanding relationships with all target partner schools that will ease recruitment, and the student populations at these schools comprise a sample that is representative of the broader population of students attending public schools in Philadelphia and large urban districts across the United States. See Narrative File A for details on target schools.

FirstHand's previous partnerships with these schools suggests that there will be minimal attrition from the study. Students participate in the program (and will participate in the summative evaluation) as part of their regular classroom attendance. Therefore, students only stop participating in the program if they switch schools or stop attending school. Moreover, given that student measures will be administered during program time, the only way that a student would not complete these measures is if they stopped attending or refused to complete them. Based on rates of attendance for the middle school program in previous years, we anticipate an attrition rate from the program of less than 10% due to changes in school attendance, with an additional attrition rate of 1% for students who refuse to complete their measures.

D3.iii. Methods

Prior to each academic year of the summative evaluation, FirstHand will contact partner schools to obtain a list of classrooms that will participate in the program. Parental permission packets will be distributed to all participating classrooms, and teachers will facilitate distribution and collection of the packets. Once the student roster is assembled, students will be assigned to the treatment or control group after being stratified by school, classroom, and gender.

Students assigned to the treatment group will participate in FirstHand in the fall of the academic year in which they participate in the study. Outcome measures of scientific identity, interest, and knowledge will be administered during the first and final program sessions. Students assigned to the control group will wait until the spring of that same academic year to participate. However, they will complete the outcome measures in the fall, and according to the same schedule as their treatment-group peers. The arrangement will minimize the loss of classrooms (i.e., clusters) prior to data collection, as well as attrition at the student level. Moreover, data will not be collected from students who join the program after the first session, thereby eliminating the possibility of bias due to students entering the classroom.

During the fall session, 30% of FirstHand program sessions for each classroom of treatment-group students will be observed and rated using the FirstHand Implementation Fidelity measure. Observation of 90% of essential program elements will serve as the **threshold for acceptable program implementation (as is required by selection criteria C2.)**.

D3.iv. Instruments/Measures

The following measures will be used to provide performance feedback and permit periodic assessment of progress toward achieving outcomes as is required by criteria D2. Scientific Social Identity will be assessed using three measures: **(1)** a measure of scientific self-concept, based on Marsh's measure of academic self-concept from the Self-Description Questionnaire (Marsh, 1988); **(2)** a measure of scientific self-efficacy, which was created following Bandura's guidelines (Bandura, 2006). These measures were developed by two of the proposed project's Principal Investigators [redacted] for use in their study of how teacher behaviors may influence scientific identity and interests among elementary school students, funded by the Institute of Education Sciences (R305A170411). In pilot testing with a sample of N=204 elementary-school students, both measures exhibited good internal consistency (a = [.81-.86]) and convergent validity. The measure of scientific self-concept was subsequently used in a preliminary study of FirstHand's middle school students (N=192) and again demonstrated good psychometric properties (a = .87); and **(3)** A measure of belonging in science which is adapted from Trujillo & Tanner (2014), who measured scientific belonging in university physics students. This questionnaire probes the degree to which students agree with belonging statements such as “When I am in a (math/science) setting, I feel a connection with the (math/science) community.” “When I am in a math/science setting, I feel comfortable.” “I feel like I belong in (science).”

Scientific Interest will be assessed using two measures. **(1)** A measure of students’ interest in currently engaging in science-related activities outside of school (e.g., participating in a science club or visiting a science museum). This 11-item measure is rated on a five-point scale from not at all interested to very interested. This measure was developed by [redacted] and, like the measures of scientific identity, exhibited good internal consistency (a = [.73-.80]) and convergent validity in pilot testing. **(2)** A measure of interest in future science careers (Friday Institute, 2012; Unfried, Faber, Stanhope, & Wiebe, 2015). This 15-item measure describes scientific fields and asks students how interested they would be in working in this field when they are older, rated on a five-point scale from not at all interested to very interested. In a survey of over 17,000 middle and high school students, this measure demonstrated high internal consistency (a = [.89-.92]; Unfried et al., 2015).

Scientific Knowledge will be assessed using two types of assessments to ensure measures are sensitive to the intervention while at the same time have practical significance for educational stakeholders. Our primary measure of scientific knowledge is the Woodcock-Johnson Academic Knowledge Subtest focused on Science. This is a reliable and valid measure that probes aspects of general information and acquired content or curricular knowledge in various areas of the biological and physical sciences. Additionally, our educational partners are interested in whether participation in FirstHand leads to improvements on measures of scientific knowledge that are curriculum-aligned. Thus, we will explore performance on assessments aligned with the Next Generation Science Standards (NGSS), a set of standards outlining what students should know and be able to do in science (NGSS Lead States, 2013). Each NGSS is organized around a performance expectation (PE) for what students should be able to do by the end of instruction (e.g., "Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials"). To gauge students' curriculum-specific scientific knowledge, we will use grade-level specific Next Generation Science Assessments (NGSA) developed by NGSA Collaborative. This group is a multi-institutional collaborative (consisting of researchers from Michigan State University, WestEd, the University of Illinois at Chicago, and the Concord Consortium) that is applying the evidence-centered design approach to create classroom-ready assessments for teachers to use formatively to gain insights into their students' progress on achieving the NGSS performance expectations (PE). Assessments gauge knowledge and skill for individual PE. For example, a 6th-8th grade PE is to "Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred." Our research team will identify the NGSAs which are specifically aligned to FirstHand's program content, and then examine improvement on said measures as a function of participation in FirstHand.

D3.v. Final Analyses

The final analyses will occur after all data have been collected in the fall of 2026 with the full sample of students (cohorts I-IV) and will comprise two phases. In the <u>first phase of the final analyses</u> we will conduct preliminary analyses to:

- Partition the variance in our post-program outcome measures into proportions attributable to students, classrooms, and schools through a series of random effects ANOVAs. These analyses will indicate which random effects must be accounted for in our final models.
- Establish if students in the treatment and control groups exhibited equivalency on outcome measures collected in pre-program assessment within guidelines established by the What

Works Clearinghouse Standards Handbook (version 4.1). We will control for pre-program levels of all measures in final models (see below), but this preliminary analysis will confirm that any inequivalency in baseline measures can be adjusted for via statistical means.

- Identify patterns of missing data on post-program outcome measures and determine whether missingness is systematically related to any other variables following procedures outlined by Jelicic, Phelps, & Lerner (2009). If data are missing on any outcome measure as a function of the values of another variable, that variable will be included in our final models as a covariate.
- Identify any significant associations between levels of our post-program outcome measures and variables other than pre-program outcome measures or condition (e.g., gender, race). Variables that display such associations will be included in our final models as covariates.

In the second phase of the final analyses we will specify and test our final models. To test the effect of the program we will estimate a series of multilevel linear models predicting post-program scores on each outcome measure as a function of group assignment while controlling for pre-program scores and relevant covariates as revealed by our preliminary analyses (Raudenbush & Bryk, 2002). Assuming our random effects ANOVAs recommended a three-level model for a given outcome measure and no covariates, for the i^{th} student in the j^{th} classroom at the k^{th} school, post-program scores on that measure would be estimated as:

$$\textbf{post-program score}_{ijk} = \textbf{pre-program score}_{ijk} + \textbf{condition}_{jk} + \textbf{error}_{ijk}$$

where condition is a dichotomous variable with two levels (0 = control, 1 = treatment). All models will be estimated using the PROC MIXED command in SAS.

A significant, positive coefficient for condition for a model estimating post-program scores on a given outcome would indicate that students exhibited larger rates of intra-individual (residual) change, on average, than their control-group peers, and that this difference was statistically significant. By dividing the difference in model implied estimates for the treatment and control groups by the pooled standard deviation for pre-program scores on the outcome measure in question, we can calculate the effect size for the program on that measure in terms of Cohen's d. Given that these effect sizes were yielded by an experimental design that controlled for baseline levels on each outcome, it will constitute evidence of the program's effects on that domain that satisfied the What Works Clearinghouse standards without reservations.

Conclusion

Experiencing STEM FirstHand will advance evidence-based STEM educational practices by studying the impact of immersive, inquiry-based STEM education experiences in an out-of-school laboratory setting on low-income minority students' science identity, interest, and knowledge. By connecting high-need students to the STEM ecosystem within their own community, Philadelphia in this case, this project mitigates barriers that have historically prevented students of color from pursuing STEM opportunities and careers. Once validated and disseminated, the findings from this project could be implemented in STEM ecosystems across the nation as an innovative solution to encouraging students historically underrepresented in STEM to advance in the classroom-to-career STEM pipeline. Thus, this work has great potential to lead to important advances for STEM/CS educational practices

Optional Project Narrative Files - Reference Table

File Name	Descriptive Title
Narrative File A_Target Schools	*Target Schools, Student Demographics and Map*
Narrative File B_Virtual Learning Overview	*FirstHand COVID-19 Virtual Learning Overview and 2020 Impact Report*
Narrative File C_Theory of Action	*Figure 2. Experiencing STEM FirstHand Theory of Action*
Narrative File D_Timeline	*Timeline and Milestones of Project Activities*

Bibliography

Bandura, A. (2006). Guide for constructing self-efficacy scales. *In F. Pajares & T. Urdan (Eds.), Self-Efficacy Beliefs of Adolescents (pp. 307-337)*, Greenwich, CT: Information Age Publishing.

Biggs, S., Musewe, L.O., & Harvey, J.P. (2014). Mentoring and Academic Performance of Black and Under-Resourced Urban Middle Grade Students. *The Negro educational review, 65*, 64-86.

Bureau of Labor Statistics (2014). John I. Jones, "An overview of employment and wages in science, technology, engineering, and math (STEM) groups," *Beyond the Numbers: Employment & Unemployment, vol. 3, no. 8* (U.S. Bureau of Labor Statistics, April 2014), http://www.bls.gov/opub/btn/volume-3/an-overview-of-employment.htm

Elo, S. and Kyngäs, H. (2008). The qualitative content analysis process. Journal of Advanced Nursing, 62: 107-115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Eisenhart, M., Weis, L., Allen, C. D., Cipollone, K., Stich, A., & Dominguez, R. (2015). High school opportunities for STEM: Comparing inclusive STEM-focused and comprehensive high schools in two US cities. *Journal of Research in Science Teaching, 52(6), 763-789.*

Estrada, M., Burnett, M., Campbell, A. G., Campbell, P. B., Denetclaw, W. F., Gutiérrez, C. G., ... & Okpodu, C. M. (2016). Improving underrepresented minority student persistence in STEM. *CBE—Life Sciences Education, 15(3), es5.*

Fayer, S., Lacey, A., & Watson, A. (2017). STEM occupations: Past, present, and future. *Spotlight on Statistics, 1-35*.

Friday Institute for Educational Innovation (2012). Teacher Efficacy and Beliefs Toward STEM Survey. Raleigh, NC: Author.

Garibay, J.C. (2015). STEM students' social agency and views on working for social change: Are STEM disciplines developing socially and civically responsible students? J Res Sci Teach, 52: 610-632. https://doi.org/10.1002/tea.21203

Jelicic, H., Phelps, E., & Lerner, R. M. (2009). Use of missing data methods in longitudinal studies: The persistence of bad practices in developmental psychology. *Developmental Psychology, 45, 1195–1199*. doi:10.1037/a0015665

Jidesjö, A., Oscarsson, M., Karlsson, K.-G., & Strömdahl, H. (2009). Science for all or science for some: What Swedish students want to learn about in secondary science and technology and their opinions on science lessons. Nordina, 5 (2), 213-229. https://doi.org/10.5617/nordina.352

Kraft, M.A. (2020). Interpreting effect sizes of education interventions. *Educational Researcher*, *49*, 241-253. doi:10.3102/0013189X20912798

Leggon, C. B. (2006). Women in science: Racial and ethnic differences and the differences they make. *The Journal of Technology Transfer*, *31(3), 325-333.*

Linn, M. C., & Eylon, B. S. (2011). Science learning and instruction: Taking advantage of technology to promote knowledge integration. *Routledge*.

Marsh, H. W. (1988). The Self Description Questionnaire (SDQ): A theoretical and empirical basis for the measurement of multiple dimensions of preadolescent self-concept. San Antonio, TX: The Psychological Corporation.

Morrow, K.V., & Styles, M. (1995). Building Relationships With Youth in Program Settings: A Study of Big Brothers/Big Sisters.

National Academies of Sciences, Engineering, and Medicine 2015. Science Teachers' Learning: Enhancing Opportunities, Creating Supportive Contexts. *Washington, DC: The National Academies Press*. https://doi.org/10.17226/21836.

National Center for Education Statistics. (2019). Nation’s report card. National Assessment of Educational Progress.

National Center for Education Statistics. (2020). The Condition of Education 2020.

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

National Research Council. (2015). Identifying and Supporting Productive STEM Programs in Out-of-School Settings. Washington, DC: The National Academies Press. https://doi.org/10.17226/21740.

National Science and Technology Committee (NSTC). (2018). Charting a Course for Success: America’s Strategy for STEM Education https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf

Oakes, J. (1990). Chapter 3: Opportunities, achievement, and choice: women and minority students in science and mathematics. *Review of research in education, 16(1), 153-222*.

Office of Innovation and Improvement (OII). (2016). *STEM 2026: A Vision for Innovation in STEM Education.*

Potvin, Patrice & Hasni, Abdelkrim. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: A systematic review of 12 years of educational research. Studies in Science Education. 10.1080/03057267.2014.881626.

Raudenbush, S. W., & Bryk, A. S. (2002). Hierarchical Linear Models. Thousand Oaks, CA: Sage Publications.

Reardon, S. F. (2011). The widening academic achievement gap between the rich and the poor: New evidence and possible explanations. *Whither opportunity, 1(1), 91-116*.

Saw, G. K. (2020). Leveraging Social Capital to Broaden Participation in STEM. *Policy Insights from the Behavioral and Brain Sciences*, *7*(1), 35–43. https://doi.org/10.1177/2372732219895997

Schleicher, A. (2019). *PISA 2018: Insights and Interpretations*. OECD Publishing.

Smith, D. C., & Neale, D. C. (1989). The construction of subject matter knowledge in primary science teaching. *Teaching and teacher Education, 5(1), 1-20.*

Trujillo, G., & Tanner, K. D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE—Life Sciences Education*, *13*(1), 6-15.

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). *The Development and Validation of a Measure of Student Attitudes Toward Science, Technology, Engineering, and Math (S-STEM).* Journal of Psychoeducational Assessment, 33(7), 622–639. https://doi.org/10.1177/0734282915571160

Vey, J. S., Scott, A., Hachadorian, J., & Katz, B. (2017). C*onnect to compete: Philadelphia's University City-Center City innovation district.* The Brookings Institute. https://www.brookings.edu/research/connect-to-compete-philadelphia/

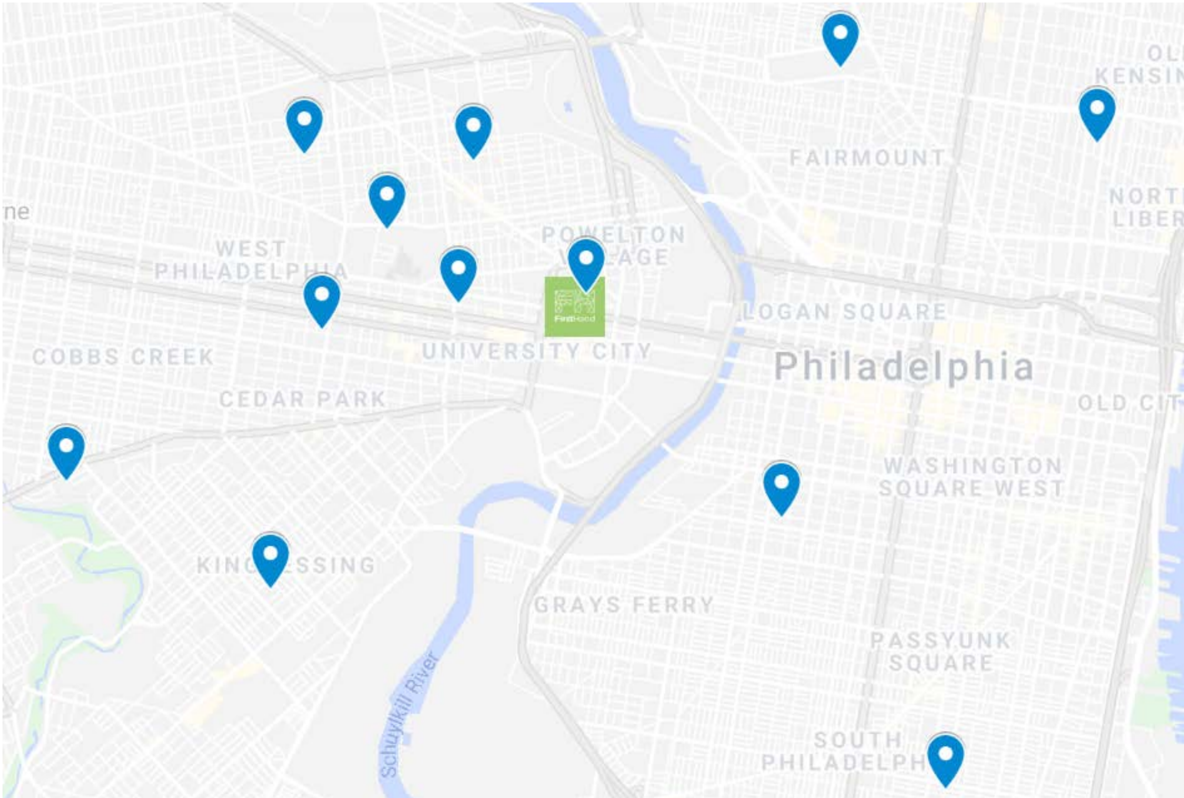
Zilberman, A. & Ice, L. (2021). *Why computer occupations are behind strong STEM employment growth in the 2019–29 decade.* Beyond the Numbers: Employment & Unemployment, 10(1) (U.S. Bureau of Labor Statistics). https://www.bls.gov/opub/btn/volume-10/why-computer-occupations-are-behind-strong-stem-employment-growth.htm

Target Schools and Student Demographics

Partner School	Demographics		
	Underrepresented Groups	**Students/ Grade**	**Reduced Lunch***
Alain Locke	84.1% African American; 4.4% Hispanic; 4.6% Asian; 4.8% Multi	50	100%
Belmont Charter	93.3% African American; 2.5% Hispanic; 3% Multi	63	N/A
Chester A. Arthur	54.8% African American; 4.8% Hispanic; 5.2% Asian; 9.2% Multi	22	87.7%
James Rhoads	96.3% African American; 1.6% Hispanic; 1.8% Multi	40	100%
John F. McCloskey	93.3% African American; 2.62% Hispanic; 2.62% Multi	45	100%
KIPP West Charter	98% African American; 2% Hispanic	90	100%
S. Weir Mitchell	93.8% African American; 1.3% Hispanic; 2.81% Multi	44	100%
Science Leadership Academy Middle School	63.0% African American; 7.0% Hispanic; 4.8% Asian; 12.2% Multi	88	80%

**CEP (community eligibility provision) is a federal non-pricing meal service option for schools and school districts*

Map of FirstHand's Partner Schools



**FirstHand is indicated in green. Note that we propose to partner with eight of the 12 partner schools mapped here.*

FirstHand COVID-19 Virtual Learning Overview

FirstHand shifted to virtual learning in March 2020 due to COVID-19. Since all partner school classes were virtual, FirstHand was easily incorporated into school schedules and became a direct supplement to classroom learning, often serving as the "science class" for one day per week. Detailed below is a brief timeline of the program's virtual pivot with linked blog posts followed by the program's 2020 impact report, highlighting FirstHand's middle school program capabilities within the virtual learning space:

Spring/Summer 2020:

- Piloted first virtual program with delivery of applied chemistry activity kits to 14 students as continuation of in-person programming. These kits, designed and packed by FirstHand staff, included everything such as lab procedures, experiment supplies, scissors, and safety goggles and were sent to the students for free.
- Pilot was successful and led to development of two, three-day (three hours total) summer curricula titled "Move into Physics" and "STEM in the Real World". Packed and delivered 41 STEM activity kits.

Fall 2020:

- Developed two, four-week (four hours each) curricula focused on Chemistry and Material Science and coordinated with STEM teachers at partner schools to facilitate activities during students' classroom learning time which allowed seamless integration into STEM classrooms. Delivered 88 Chemistry and 87 Material Science kits.
- **Engaging Industry Mentors:** Coordinated virtual lab tours every other week (titled "Lunchtime Labs") with FirstHand mentors – bringing the STEM industry of Philadelphia into viewers' homes. These sessions were open to the public but targeted Philadelphia students.

Spring 2021:

- Developed eight-week (eight hours total) curriculum titled Designing with Science focused on creative applications of STEM. A total of 90 Designing with Science, 67 Chemistry, and 16 Material Science kits were delivered.
- Lunchtime Labs continued with increasing attendance (over 20 STEM mentors and 250 attendees to date).

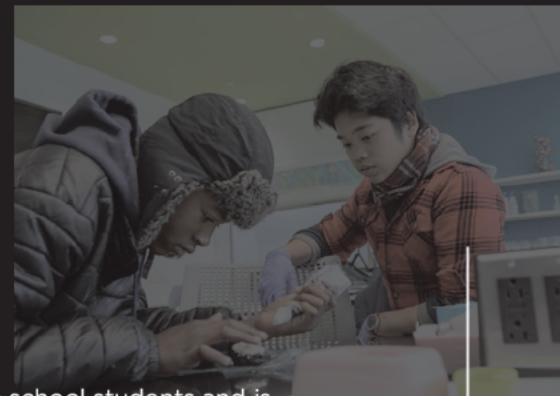
Summer 2021

- Refined and implemented virtual STEM in the Real World. Based on learnings from a full year of virtual programming, the curriculum was modified to be longer (4 days, 6 hours total) and include more relevant experiments. 58 middle school students participated.
- Inspired by the concept of STEM social capital (Saw, 2020), FirstHand piloted a 5-day (7.5 hour) curriculum titled Hi-5 for FirstHand alumni who participated in 2020/21 virtual programming. Each activity was developed and supported by STEM professionals who work at companies on the UCSC campus. Three high-school aged FirstHand alumni served as near-peer mentors for the program by shadowing each of the 5 highlighted companies, helping to develop student activities, and supporting facilitation of the sessions. They received a stipend for their contributions. 11 middle school students participated.

UNIVERSITY CITY SCIENCE CENTER

FirstHand

2020 IMPACT



FirstHand offers free year-round, supplemental STEM learning for middle and high school students and is designed to provide skills-based career exposure. Our FirstHand Lab connects students from surrounding neighborhoods to the entrepreneurial and innovation ecosystem in Philadelphia. Our industry-informed curricula provides real-world, hands-on experience in an effort to open doors for the minds of tomorrow.

JANUARY - MARCH
In-person programming

THE WORLD CHANGED

APRIL - JUNE
FirstHand piloted virtual program with partner school and developed virtual summer curriculum with free STEM kits for participants.

JULY - AUGUST
Two new programs developed with free STEM kits.

SEPTEMBER - DECEMBER
Chemistry + material science programs developed. Students received custom STEM kits to join weekly sessions and run experiments with FirstHand facilitators.

IN-PERSON | VIRTUAL

"I feel important in this lab coat"
-[redacted], 8TH GRADER LOCKE ELEMENTARY

FirstHand students

"I always wanted to do experiments at home and now I can!"
-[redacted] 7TH GRADER MCCLOSKEY ELEMENTARY

	PROGRAMS		YOUTH ENGAGEMENT		MENTOR PARTICIPATION	
12 schools	15 in-person	21 virtual	170 in-person	138 virtual	39 in-person	18 virtual

NEW CURRICULUM

MIDDLE SCHOOL

VIRTUAL PILOT
When COVID hit, FirstHand partnered with Mitchell Elementary, a Philadelphia public school, to explore how to best support this new learning environment by facilitating hands-on STEM demos during virtual science "office hours," to directly complement science learning objectives.

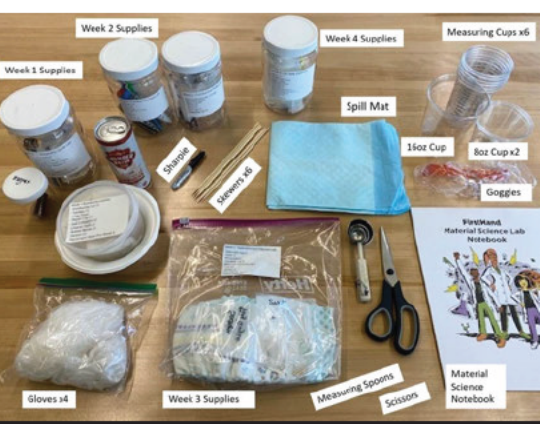
STEM IN THE REAL WORLD
"When would I ever use this in real life?!" - a question often asked by students. FirstHand explored real-life applications of science. Students made their own thermometer, hand sanitizer, and speaker with easy-to-find materials.

MOVE INTO PHYSICS
Students applied basic principles of physics to make things that fly, spin, and bounce with household materials and their own creativity.

CHEMISTRY
Students experienced chemical reactions right in their own home. This program taught them about exothermic reactions, gave students a chance to change liquids into solids, and study the pH of liquids they use every day.

MATERIALS SCIENCE
Students created and studied new materials like magnetic slime, conductive paint, and milk-based glue then connected the materials to everyday life.

To learn about FirstHand's in-person curriculum visit sciencecenter.org.



HIGH SCHOOL

BIODESIGN CHALLENGE
A collaboration with Berlin-based AULA Future and Paul Robeson High School, students developed two projects for the Biodesign Challenge, an international competition that encourages the exploration of biotech's entanglements within society. Students will present their projects at the June 2021 Biodesign Summit.

FIRSTHAND VENTURES
FirstHand Ventures engaged FirstHand alumni by providing funding and support to develop their own business plan. Students created their own marketing materials and budgeted for supplies. Projects included a clothing line, educational podcasts for young learners, and home dècor crafts!

FIRSTHAND INTERNSHIP
FirstHand piloted a paid internship program with creative agency, Cohere, and Paul Robeson High School as a system of training for a new generation of practitioners in the fields of creative storytelling, design and impact.

STEM MENTORS

LUNCHTIME LABS
When students couldn't visit the FirstHand lab in person, we brought the labs to them! Lunchtime Labs offered a virtual look inside professional labs and introduced learners of all ages locally and beyond to STEM careers - expanding access to FirstHand.

SCHOOL PARTNERS

Alain Locke	James Rhoads
Belmont Charter	John F. McCloskey
Chester A. Arthur	Paul Robeson High School
The City School	S. Weir Mitchell
Girard College	Science Leadership Academy Middle School
KIPP West Philadelphia	The Workshop School

"FirstHand benefits the students at my school by exposing them to the opportunities in science and the world beyond their immediate surroundings. I think exposure is everything. In order for them to want more, they have to see more."

- [redacted] **ALAIN LOCKE 8TH GRADE SCIENCE TEACHER**

University City Science Center
3675 Market Street, Suite 400
Philadelphia, PA 19104

sciencecenter.org

Figure 2. Experiencing STEM FirstHand Theory of Action

INPUTS

- Longstanding partnerships
- High-quality, full-time FirstHand (FH) STEM/CS educators
- FH learning lab
- STEM professionals serve as mentors
- Students and teachers from Title 1 schools with under-resourced STEM departments and education
- Evaluation team
- Funding from EIR

KEY COMPONENTS (Active Ingredients)

1. Hands-on, discovery-based STEM experiences for urban, high-need middle school students
    - Students participate in 10-week program (2 hrs/week, 20-hours total)
    - Choose at least 1 of 6 tracks that offer a range of STEM/CS subjects
    - Tracks informed by real-world STEM challenges
2. Immersive, place-based learning environment
    - 5,000-square foot professional grade learning lab on UCSC campus
    - Lab shares campus with dozens of STEM companies
    - Students immersed in STEM ecosystem (e.g. students share elevators, hallways with professionals)
3. Industry-relevant mentoring by STEM professional to build STEM social network
    - Students work with STEM professionals to solve industry-relevant problems

STUDENT OUTCOMES

- Increased scientific social identity (belonging, self-concept, self-efficacy)
- Increased interest in engaging in current science activities, and future STEM/CS classes and careers
- Increased scientific knowledge

Timeline and Milestones of Project Activities															
PHASE	**2022**			**2023**			**2024**			**2025**			**2026**		
Activities	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Phase 1: Implement Program Pilot and Conduct Formative Evaluation															
File Institutional Review Board application for summative evaluation															
File Research Review Committee application for summative evaluation															
Program implementation and observations: Pilot cohort															
Formative evaluation data collection (observations & teacher interviews)															
Pilot of outcome measures to be used in summative evaluation															
Share results of formative evaluation with program staff and leadership															
Phase 2: Initial Program and Measure Refinment															
Program refinement based on formative evaluation results															
Refinement of fidelity implementation measure															
Refinment measures of scientific identify, interest, and knowledge															
Phase 3: Program Implementation and Continuous Summative Evaluation and Program Refinment Across 4 Cohorts															
Cohort I															
Recruit schools and classroom for evaluation study cohort I															
Recruit students for evaluation study cohort I															
Program implementation: Evaluation study cohort I, Tx group															
Summative evaluation data collection cohort I (Tx & Control Groups)															
Preliminary data analysis for summative evaluation study cohort I															
Share results of preliminary data analysis for evaluation study cohort I															
Program refinement based on preliminary results for cohort I															
Cohort II															
Recruit schools and classroom for evaluation study cohort II															
Recruit students for evaluation study cohort II															
Program implementation: Evaluation study cohort II, Tx group															
Summative evaluation data collection cohort II (Tx & Control Groups)															
Preliminary data analysis for summative evaluation study cohort II															
Share results of preliminary data analysis for evaluation study cohort II															
Program refinement based on preliminary results for cohort II															
Cohort III															
Recruit schools and classroom for evaluation study cohort III															
Recruit students for evaluation study cohort III															
Program implementation: Evaluation study cohort III, Tx group															
Summative evaluation data collection cohort III (Tx & Control Groups)															
Preliminary data analysis for summative evaluation study cohort III															
Share results of preliminary data analysis for evaluation study cohort III															

	2022			2023			2024			2025			2026		
Cohort III (Cont.)	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Program refinement based on preliminary results for cohort III															
Cohort IV															
Recruit schools and classroom for evaluation study cohort IV															
Recruit students for evaluation study cohort IV															
Program implementation: Evaluation study cohort IV, Tx group															
Summative evaluation data collection cohort IV (Tx & Control Groups)															
Preliminary data analysis for summative evaluation study cohort IV															
Share results of preliminary data analysis for evaluation study cohort IV															
Program refinement based on preliminary results for cohort IV															
Phase 4: Final Data Analysis & Dissemination															
Final data analysis															
Dissemination of final findings															