INTEGRATING SCIENCE INTO AFTERSCHOOL: A THREE-DIMENSIONAL APPROACH TO ENGAGING UNDERSERVED POPULATIONS IN SCIENCE

FINAL REPORT

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INTRODUCTION

The initiative called Integrating Science Into Afterschool: A Three-Dimensional Approach to Engaging Underserved Populations in Science set out to promote science learning in three out-of-school settings (afterschool programs, home, and community), to promote rich and varied science experiences to underserved Philadelphia communities, and to assess the value of this model for the broader field of out-of-school time and informal learning in science, technology, engineering, and mathematics (STEM). The project was funded through the National Science Foundation's Innovative Technology Experiences for Student and Teachers (ITEST) program, and one of its intended contributions was developing a model to enhance STEM career readiness among elementary school children from communities underrepresented in STEM fields.

The project's framework was articulated in the following way in the initial funding proposal to the National Science Foundation:

> *By offering science program experiences and support structures for those facilitating children's science learning in out-of-school programs for Philadelphia youth and engaging families and the community in extensions of these science experiences, science will eventually become an integral part of numerous communities throughout the Philadelphia area.*

As described in the funding proposal, this initiative had five major goals:

- **Goal 1:** Embed project-based science learning into the program offerings of five afterschool sites serving children grades 3-5, with approximately 50 children at each site**.**
- **Goal 2:** Create a rich and comprehensive professional development program that will be offered to afterschool facilitators at the five sites.
- **Goal 3:** Establish family programs that support engagement with science and accessing scientists and their careers in relevant and meaningful ways, across the contexts of afterschool, home, and community.
- **Goal 4:** Develop home-based science activities that continue children's science learning initiated in the afterschool setting into the home setting with families.
- **Goal 5**: Evaluate the effectiveness of this 3-D approach in engaging children, families, afterschool facilitators, and community-based organizations in science learning and the promotion of STEM professions.

These goals and associated objectives draw on The Franklin Institute science museum's extensive history of implementing evidence-based science curricula and on the Principal Investigator's strength in developing and researching informal science opportunities that emphasize the social nature of science learning and professional development.

The three dimensions of this initiative – afterschool, home, and community – are designed to create strong STEM career pathways for children in underserved communities by:

- Leveraging and supporting informal learning opportunities in out-of-school settings.
- Engaging parents as critical adults in children's science learning.
- Providing children concrete examples of meaningful engagement with science and with scientists with whom they can identify.

In order to accomplish these goals, The Franklin Institute partnered with Philadelphia's Public Health Management Corporation (PHMC), a nonprofit public health institute that aims to build healthier communities through partnerships with government, foundations, businesses, and community-based organizations. PHMC is the city's intermediary for contracting, managing, supporting, and monitoring more than 100 community-based out-of-school time (OST) programs. It also facilitates and coordinates professional development about project-based learning to OST program facilitators.

In this report, we demonstrate that although specific activities of the project (whose name we shorten as STEM 3D) have evolved from the original plan, the overall vision has provided a powerful impetus for change in participating individuals and OST sites and has provided valuable resources to the larger informal STEM ecosystem of Philadelphia.

This report provides findings based on three cohorts of participants, with each cohort experiencing an evolving approach to professional development, project implementation, and technical assistance.

We report and discuss 10 major evaluation findings, divided among three sections.

Section I: Program Implementation

Finding 1: Successful professional development. The initiative offered rich and comprehensive professional development to about 125 OST staff members at about 50 sites.

Finding 2: Success in reaching the target number of sites and children. The project surpassed its goal of embedding project-based learning into the program offerings of five afterschool sites. with about 50 children at each site. The maximum number of children served in-depth over one year was about 315 between June 2015 and May 2016. During this period, adults and children at eight sites were engaged with STEM project-based learning (PBL) units.[1]

Finding 3: High-quality curriculum created. Drawing on knowledge about the needs and affordances of OST developed through interaction with STEM 3D facilitators, Franklin Institute staff developed and refined a six-week project-based curriculum for students in grades 3-5. This learning unit, called Circuit City, incorporates STEM 3D's goal of integrating afterschool, home, and community contexts by building a web of household and neighborhood connections into children's explorations of electricity, circuits, and power sources.

Finding 4: Families and communities engaged. The project successfully supported most participating sites in implementing family and community engagement events tailored to match each one's specific needs and configuration.

[1] For the purpose of this report, program years are considered to run from June through May. Professional development activities began in June 2013 and continued through May 2017. Thus, there were four years of program implementation. Each year is considered to begin with June professional development to prepare for summer-program implementation and to continue with subsequent professional development and school-year implementation.

Section II: Impacts on Facilitators and Students

Finding 5: Positive outcomes for OST staff. Participating facilitators reported deep changes, including increases in their ability to facilitate project-based STEM activities, improvements in their attitudes toward science, and shifts in their understanding of who can pursue a career in STEM.

Finding 6: Positive outcomes for youth. Analyses of student surveys demonstrate statistically significant increases in interest and engagement with STEM.

Section III: Sustainability and Lessons Learned

Finding 7: Increased capacity within the Philadelphia OST STEM ecosystem through partnership between informal science and local government. The partnership between The Franklin Institute and the Philadelphia Health Management Corporation (PHMC) has built sustainable capacity within Philadelphia's out-of-school time ecosystem for implementing project-based science.

Finding 8: Increased awareness of the value of family STEM engagement among participating OST programs. STEM 3D's emphasis on family and community engagement opened up new and exciting opportunities for communication within families and for community-building within OST centers.

Finding 9: An evolving model for age-appropriate STEM inquiry and career-awareness activities. STEM 3D's final iteration of professional development and the Circuit City curriculum provides a usable model for career-awareness activities for upper elementary school children.

Finding 10: Contributions to the field. STEM 3D's professional development framework evolved into a model for a community of practice that melds the expertise of informal science educators with the expertise of community-based OST staff in order to support STEM-rich, student-driven activities. This approach builds respect between professional STEM educators and people who previously felt excluded from STEM, and it allows OST programs to tap into the often-unacknowledged resources that low-income minority communities can offer for supporting youth STEM engagement.

EVALUATION OVERVIEW

From the planning and proposal stages of this project, Creative Research & Evaluation LLC has been an active partner in providing feedback, raising questions, and providing interim findings to the STEM 3D leadership team and participants. The STEM 3D staff consisted of the Principal Investigator (PI) and several other team members who developed and maintained relationships with local OST sites, provided professional development and technical assistance to OST participants, developed curriculum, ordered and managed materials, and maintained relationships with PHMC. The number of museum staff working on the project varied from two (the PI and a project associate) in the beginning of the project to about five during the periods of most intensive activity.

This evaluation has been conducted in close collaboration with project staff and stakeholders, drawing on an approach known as Utilization-Focused Evaluation that is designed to maximize cooperation between the evaluator and evaluation stakeholders. This helps ensure that the evaluation is focused on the stakeholders' actual needs and that evaluation data and findings provide information and insights that are useful and relevant to stakeholders.[2]

Collaboration in this case included evaluator participation in initial meetings with administrators from participating OST sites; consistent cooperation on foci and methods of data collection; and collaboration between project staff and the evaluator in reporting findings to a variety of audiences (e.g., the National Science Foundation, out-of-school time advocacy publications, and virtual or face-to-face meetings of other projects engaged with the goals and activities of the NSF ITEST portfolio).

All evaluation activities were reviewed and approved annually by the Institutional Review Board (IRB) for this project. The project was treated as an evaluation and did not require informed consent from parents. The only data about children was observational or information that was collected by sites during the course of program implementation.[3]

Data sources for this evaluation included observations, interviews, focus groups, program documents, and participant surveys. Figure 1 provides an overview of key data sources.

[2] M.Q. Patton. Utilization-Focused Evaluation. 4th Edition. Thousand Oaks, CA: Sage Publications, 2008.

[3] Informed consent from parents proved challenging to plan for due to the site-specific nature and timing of project implementation at each of the participating OST programs.

Figure 1: Key Data Sources by Cohort					
	Interviews and focus groups	**Participant surveys of satisfaction and impact**	**Observations of professional development sessions**	**Observations of PBL implementation**	**Observations of family and community events**
Participating OST staff and families	Cohort I, Cohort II	Cohort I, Cohort II, Cohort III	Cohort I, Cohort II, Cohort III	Cohort I, Cohort II	Cohort I
Youth in participating centers	-	Cohort I, Cohort II	-	Cohort I, Cohort II	Cohort I

Some additional notes:

- Outcomes for adult participants during Cohort I and Cohort II were identified through interviews and observations. By Cohort III, the goals and structure of professional development had evolved sufficiently to use pre-training and post-training surveys to provide baseline information on participant knowledge, comfort with STEM project-based learning, and self-reported impacts on participants.

- Anonymous, non-intrusive audio recording of youth conversations was used during Cohort I PBL implementation. As per IRB requirements, this was approved by site administrators. Parents also signed consent forms, but the consent process did not have to be reviewed and approved by IRB.

- Student survey data was collected by individual program sites and provided to the PEAR (Partnerships in Education and Resilience) Institute for analysis. (https://www.thepearinstitute.org/)

SECTION I: PROGRAM IMPLEMENTATION

Finding 1: Successful professional development. The initiative offered rich and comprehensive professional development to about 125 OST staff members at about 50 sites.

Professional development was offered to three cohorts of OST sites. This took slightly different forms as the model evolved. Cohort I (four sites) received intensive professional development three or four times a year over four years. Cohort II (five sites) received more-focused and shorter sessions over six months. Cohort III (40 sites) received an even more distilled version in a one-day session.

Through this initiative, Franklin Institute staff developed and implemented a professional development framework that successfully integrated pedagogies drawn from inquiry-based science, design thinking, the making and tinkering movement, and project-based learning. This framework evolved over the course of the grant period through collaboration among informal science educators at The Franklin Institute and skilled facilitators and administrators in participating OST sites using a community of practice approach.

Over the course of four years, more than 70 classroom facilitators, coordinators, directors, and other staff members participated in professional development sessions at The Franklin Institute. At least 50 additional OST staff (and a few volunteers) participated in professional development at their sites.[4]

In meeting the goal for providing professional development to facilitators, The Franklin Institute encountered several unanticipated challenges in the OST ecosystem related to organizational instability, staffing patterns, and funding challenges. The original professional development model anticipated providing two years of deep, rich professional development to OST facilitators at five sites.

The Franklin Institute's successful approach to several of these challenges led to positive results, including increased attention to turn-around training at STEM 3D sites and support for a larger number of participants and sites than originally intended. Another positive result of the response to challenges was the unanticipated creation of three cohorts of STEM 3D participants and to the progressive evolution of the STEM 3D professional development model as a framework that was refined for each subsequent cohort of participants.

Cohort I (June 2013-May 2017) consisted of staff from four sites serving a diverse group of underserved communities. The sites were identified for participation by the STEM 3D staff, with assistance from PHMC, because it appeared that the centers could benefit from additional resources, but were stable enough to commit to participating in a two-year professional development program; had an interest in implementing new STEM project-based learning curricula; and had a willingness to engage families in STEM activities. One unanticipated challenge in Cohort I was when a fifth site that was part of the original cohort withdrew from the initiative because the public school that was housing it was closed.

[4] Although it is impossible to assess the quality of turn-around training, observations indicate that by the third year of the program, all facilitators who implemented STEM 3D activities had learned at least some of the pedagogical strategies expected for successful implementation of STEM 3D activities and units.

Staff from the remaining four sites participated in a two-year series of intensive professional development activities that targeted the skills needed for STEM facilitation, exploration of STEM content, curriculum planning, planning for family engagement, and development of STEM career-awareness activities.

After the initial two years, staff from three of these sites continued to participate in professional development that focused on capacity-building, career awareness, and family engagement. One site lacked the staffing and organizational capacity to meet the expectations of STEM 3D and left the initiative in the middle of the third year.

A critical shift occurred in the second year of project implementation. After a year in which participants were excited about the initiative, but did not implement activities as expected, the STEM 3D staff members took a step back to re-conceptualize their approach. One key professional activity in the fall of 2014 was a dialogue about two different interpretations of the term "project-based learning (PBL) unit." Through this dialogue, STEM 3D staff became aware of discrepancies between their own use of the term "PBL" and OST staff participants' use of the term. Participants had valued the STEM 3D approach to PBL and were especially motivated by the ways these PBL units pushed their students to higher levels of engagement and thinking. Yet, when they were implementing non-STEM 3D PBL units, facilitators often found it easier to connect with students' lives and found more options for student voice and choice.

This dialogue about different types of project-based learning began to open up the space for the site-based staff to share important knowledge and expertise about students and about pedagogical approaches. During Year One, staff excitement about STEM activities had been palpable among both site-based and museum-based staff. But in Year Two, there was an important shift in dynamics that continued throughout the rest of the project and with subsequent cohorts. Members of each professional grouping (site-based facilitators and Franklin Institute informal educators) began to display role fluidity, switching from being the expert to being the novice and vice versa.

Another important shift occurred as TFI staff began to grapple with challenges in meeting the original goal of engaging all facilitators of grade 3-5 students from participating sites. The original idea was that all appropriate facilitators would attend professional development activities at The Franklin Institute. Six staff members from three Cohort I centers did attend Institute-based professional development throughout the entire project. Eight additional staff members in Cohort I participated in some, but not all of the Institute sessions.

However, a large number of staff were unable to attend professional development sessions at The Franklin Institute due to the part-time nature of the OST workforce. By the second complete year of the project, one important component of professional development was planning for turn-around training for other staff, as well as creating timelines for STEM 3D staff to interact with larger site-based groups of facilitators unable to attend the originally planned sessions at The Franklin Institute.

During Years Two and Three, two Cohort I sites had provided STEM 3D site-based training to almost all facilitators at their sites. This included facilitators for all age groups, not only the intended grade 3-5 groups. It occurred through turn-around training, team teaching, or other site-based professional development with The Franklin Institute. Based on observations and reports at professional development sessions, about 40 additional Cohort I staff members participated in these types of professional development.

As will be discussed in more depth later in this report, STEM 3D had lasting effects on Cohort I facilitators and their community centers and had statistically significant effects on STEM engagement and attitudes of children in these centers.

Cohort II (January-May 2016) consisted of five additional OST sites supported by a multi-service social agency. In contrast to the four independent centers in Cohort I, the five sites in Cohort II were all part of the same over-arching program, run by the umbrella organization Lutheran Children & Family Services. These sites participated in a shorter, more-focused set of six sessions that crystallized the major themes and skills that had been most important and successful for Cohort I. From the beginning, Cohort II professional development emphasized several key skills for using problem-based learning units to engage underrepresented youth in STEM and increase interest in STEM careers. Among these were the importance of open-ended problem-solving, participant voice and choice, and connections to family and community. This series began with introducing STEM explorations, continued with developing and implementing activities for a projectile PBL unit, and culminated in the implementation of a newly developed Circuit City curriculum unit that integrated the key themes of STEM 3D.

Eight staff members received direct training and about 15 more group leaders and assistant group leaders (averaging three per site) participated in on-site professional development through turn-around training and co-teaching with the group leaders.

Another unexpected challenge occurred when Cohort II was cut short because Lutheran Children & Family Services, the sponsoring agency, announced the year-end closure of its OST programs due to financial problems in the agency. Despite this early end to their participation in the project, these five sites successfully implemented small-scale STEM projects, a projectile PBL unit, and the final Circuit City project. They also successfully engaged parents in STEM 3D activities.

Cohort III (May 2017) provided an opportunity to further refine the STEM 3D professional development model and assess its usefulness in a one-shot, four-hour professional development session. This is the professional development format commonly used by the Philadelphia Health Management Corporation, which is the OST funding conduit for all programs that participated in STEM 3D and the co-organizer of the professional development for this cohort. This session was designed to fit the structure of PHMC trainings, and it has the potential to lay the basis for continued Franklin Institute trainings for PHMC's OST staff.[5]

Cohort III professional development distilled the themes and activities from the Cohort II framework even further. It provided an interactive session that allowed participants to understand the foundations of successful STEM projects, experience examples from Circuit City, and understand and practice methods for facilitating open-ended STEM learning so that they would be comfortable with implementing Circuit City at local sites. In addition, the curriculum draws connections between STEM concepts and practices and the real worlds of home and neighborhood. Within this context, the curriculum encourages youth to identify STEM careers that use the practices and content that they are using as they explore electricity and build their own model electrical grid.

[5] Although data collection for this report ended in May 2017, Franklin Institute staff report that the relationship with PHMC continued into the summer of 2017 and there is currently a process in place for joint exploration of new projects.

At the end of the May 2017 professional development session, all participating staff from these centers reported that they planned to use the project-based learning framework and curriculum during the summer of 2017, with PHMC planning to provide technical assistance to these sites. Subsequent feedback from The Franklin Institute and PHMC staff indicate that PHMC and participating centers were pleased with the amount and quality of project implementation over the summer.

Figure 2: Approximate Number of Participants in STEM 3D Professional Development by Cohort [6]

	Participation in professional development at The Franklin Institute	**Participation in site-based professional development**	**Total Number**
Cohort I[7] **(June 2013-May 2017)**	Consistent participation: 6 Partial participation: 8	35	49[8]
Cohort II (Jan. 2016-May 2016)	8	15	23
Cohort III (May 2016)	53	-	53
Total		50	119

Finding 2: Success in reaching the target number of sites and children. The project surpassed its goal of embedding project-based learning into the program offerings of five afterschool sites. with about 50 children at each site. The maximum number of children served in-depth over one year was about 315 between June 2015 and May 2016. During this period, adults and children at eight sites were engaged with STEM project-based learning (PBL) units.

[6] Numbers are based on site observations and reports by facilitators at Franklin Institute professional development sessions.
[7] Because Cohort I participation lasted four years, there was some variation in who participated over time. This was not true during the shorter periods of Cohorts II and III.
[8] This includes Cohort I participants who were partial as well as consistent.

Figure 3: Approximate Number of Children Engaged in STEM 3D PBL Units		
	Number of Sites Participating	**Approximate Number of Children Reached in Each Site**
Cohort I: June 2013-May 2014	4	65
Cohort I: June 2014-May 2015	4	115
Cohort I: June 2015-May 2016	3	165
Cohort II: Janury 2016-May 2016	5	150
Cohort I: June 2016-May 2017	3	165

As shown in Figure 3, the number of children reached in Cohort I sites increased throughout the project. This was due primarily to the spread of STEM 3D units throughout the three remaining Cohort I centers. During the first year of the program, staff from four centers participated in professional development at The Franklin Institute. Children in the classes of these facilitators (plus a few other staff members who received turn-around training) participated in STEM 3D activities. In the second year, additional staff from two Cohort I sites learned about STEM 3D from Institute visits to their sites or from team-teaching with trained STEM 3D facilitators.

During the third year, all staff at two of the Cohort I centers had received turn-around training in STEM 3D and about 165 children were reached at the three remaining Cohort I centers. (One had left the program due to insufficient capacity.)

During the third year of program implementation, Cohort II also began implementing project-based learning units. All five Cohort II sites were based in public schools and used the cafeteria for OST programming. Rather than having specific activities for specific grades, most of these sites engaged multiple age groups in STEM 3D activities.

Finding 3: High-quality curriculum created. Drawing on knowledge about the needs and affordances of OST developed through interaction with STEM 3D facilitators, Franklin Institute staff developed and refined a six-week project-based curriculum for students in grades 3-5. This learning unit, called Circuit City, incorporates STEM 3D's goal of integrating afterschool, home, and community contexts by building a web of household and neighborhood connections into children's explorations of electricity, circuits, and power sources.

Introducing the curriculum to Cohort III participants, one of the project leaders explained that it:

- Focuses on developing interest, content, and skills relating to electricity and careers in STEM.
- Contains different levels of activities to scaffold learning.
- Culminates in a youth-driven investigation.

As stated in the final written curriculum, the unit's overarching ideas are:

- Design through testing and observation.
- Connecting skills to careers.
- Iterative design.
- Collaborative problem solving.
- Making real world connections.

Originally, the project intended to provide five sites with sample project-based learning units, which would subsequently be enriched by the addition of PBL units created by participating sites to be used for broader dissemination in Philadelphia and elsewhere. The PBL focus was emphasized because this approach was used when STEM 3D's partner, PHMC, entered this partnership.

At that time, all PHMC centers were required to implement PBL units lasting four to six weeks each. The PBL approach enables the development of complex problem-solving skills, depth of understanding over content, comprehension of concepts over memorization of facts, student interest over a fixed curriculum, and a broad interdisciplinary focus.[9]

The PBL framework has much in common with other approaches to inquiry-based teaching and learning, but it shapes this experience with some distinct and specific structural elements. In Philadelphia OST sites, PBL required a single driving question to guide the inquiry of an entire class through teamwork. In addition, PBL units, in general, result in a culminating event consisting of a public display of a product that emerged out of the unit.

By the completion of Cohort I's first two years, it became apparent that although the project's success depended on the sense of ownership of PBL units by OST staff, creation of written curriculum materials fell far outside the scope of work of any of the participating OST facilitators. Instead, the STEM 3D staff at The Franklin Institute focused on developing a PBL unit that could scaffold project-based learning, support STEM practices, and help facilitators embed STEM explorations and discussion of STEM careers in the context of children's households and communities.

Each week of the six-week curriculum identifies three activities, each of which can be implemented in a 30- to 60-minute block. Each activity is broken into three parts: engage, investigate, and reflect. The first week of the curriculum includes an exploration of simple circuits and an open-ended investigation of conductive and non-conductive materials. Suggested reflection activities during the first week include questions about what children learned in their investigations and what they could have done differently in constructing their circuits. Reflection questions also include prompts to encourage children to think about where electricity is found in their homes and to brainstorm careers that require understanding of electricity and circuits.

[9] Buck Institute for Education http://bie.org/object/document/pbl_essential_elements_checklist.

By the end of the curriculum unit, youth complete investigations of parallel and series circuits and work in groups to design, revise, and fabricate their own model city, complete with an electrical grid using parallel and series circuits. Final reflections include probes such as, "What were you thinking about when you created your design?" "What challenges did you encounter?" "How did you change your design?" "What would make this neighborhood appealing to different groups of people?" and "In real life, what skills and jobs would people need to build this city?"

This curriculum framework balances disciplinary content, real-world connections, and open-ended exploration. It builds on OST facilitators' experience in relating to their children, the expectation that children will be drawn into hands-on explorations, and the assumption that OST PBL units should be fun and connect directly to youth experience and interests.

The Circuit City curriculum framework also incorporates several elements that have been shown to support children's achievement gains by using a structured approach to project-based learning in an analogous social studies curriculum for elementary school children. These elements are:

- A purpose and audience for children's work beyond just their teacher, classmates, or families.[10]
- A connection between each activity and the project to help maintain children's interest and make connections between and across concepts and contexts.
- Research-supported instructional practices.
- Consistent activity structures within each lesson that included whole-group introduction, small-group or individual activities, and whole-group review and reflection.

As will be discussed below, professional development and implementation of the Circuit City curriculum and other PBL units served as an effective framework for broadening and deepening the understanding of STEM and the practice of STEM facilitation approaches among Cohort II facilitators over six months. Furthermore, the four-hour professional development session for Cohort III gave facilitators and site directors confidence and enthusiasm about their ability to implement this Circuit City curriculum as well.

Finding 4: Families and communities engaged. The project successfully supported most participating sites in implementing family and community engagement events tailored to match each one's specific needs and configuration.

Eight out of nine sites that participated in extended STEM 3D professional development also implemented family and/or community engagement events that were individualized to match the needs and configuration of each site. Similar to STEM 3D's evolving approach to PBL units, the approach to family and community engagement evolved as the staff at The Franklin Institute learned about the capacities, needs, and goals of a range of OST sites. In particular, activities

[10] https://www.edutopia.org/article/projects-have-been-put-test-anne-lise-halvorsen-nell-duke. Downloaded September 6, 2017. In the case of the social studies curriculum, the larger audiences are stakeholders and community members concerned with the policy issues being explored by 2nd grade children. In the case of Circuit City, the larger audience is envisioned as the users of electricity who are affected by the structure and power source of a city's electrical grid. As the project continues to be built out, these audiences can become more and more specific as sites take this project in their own direction.

designed to engage families and communities with STEM required a center-wide commitment and targeted technical assistance relating to logistics, content, and planning.

The original strategy for community engagement was that families, friends, and local STEM professionals would attend bi-annual events where children presented the final products of their project-based STEM units. Participating OST staff expressed growing confidence and excitement about themselves as STEM learners and STEM facilitators. However, few of the participating OST sites had the resources or the experience to plan and implement local community events that would bring together families and STEM professionals.

Similarly, the intended strategy of creating STEM activities for children and families to do at home was challenging because there was no precedent for this in the OST world. Although regular classroom teachers regularly send activities from school to home in the form of homework, this practice does not exist in the OST centers participating in this project, so attempts at doing so were not successful.

Tools and strategies for family and community engagement evolved through the course of the project as OST staff and The Franklin Institute staff alike learned what family and community connections might look like in OST settings. By the end of the funding period, the participating sites provided multiple and varied models for how to support family and community STEM connections.

Cohort I sites with strong family engagement

Two out of four Cohort I sites organized family showcases as part of the culminating activities for a PBL unit. These sites also organized family science events in ways that matched the schedule and culture of their families and centers.

- One Cohort 1 site began a tradition of an annual family science event for the whole center. One year, this event was held in the evening for families from children in all grades, and the next year, each teacher organized a science activity in his or her classroom during pick-up time. In coming years, the director anticipates that family science activities may be the core of the center's big annual family activity. The staff at this center, which serves a largely non-English-speaking immigrant community, believe that family involvement is very important and find that adults will attend activities that they know are important to their children. Parents also report that it is challenging for them and their children to attend activities off-site or outside of regular hours. For this reason, the center has adopted a flexible model where family STEM activities are offered during times when parents can participate.

- Another Cohort I center participated in STEM 3D and also was a member of a community science network, a neighborhood collaborative of community-serving organizations convened by The Franklin Institute to provide opportunities for neighborhood residents to engage in science in their communities. This center has successfully organized family stargazing parties and science block parties. In addition to organizing regular STEM 3D project showcases for family members, this center also brings groups of children to share their STEM 3D projects with the public at a local library as part of the annual Philadelphia Science Festival.

Cohort I sites with challenges to family engagement

- A third Cohort I site had two STEM 3D facilitators (a brother and sister) who were neighborhood residents and had attended the school and program where they now worked. Ironically, the administration of the school where this program was located was not interested in facilitating family engagement with out-of-school programming. These two siblings were college graduates who were excited about STEM and had many friends who were pursuing STEM careers. To meet TFI's goal of engaging community members and introducing STEM careers to elementary school children, these facilitators invited a friend from the neighborhood who talked to STEM 3D classes about his career and demonstrated the 3D printer that was part of his work.

- One site in Cohort I had no family or community engagement. This was the Cohort I site that left the STEM 3D program because of lack of organizational capacity. This site faced challenges in organizing family and community engagement activities. Hosting family activities was also challenging because this site used classroom space in schools where the school administration was not invested in supporting family engagement with out-of-school programming. Overall, these factors made holding a family event too challenging.

Family showcases at Cohort II sites

- Five out of five Cohort II sites organized showcases for families as the culminating event of their Circuit City project. Four of the five sites also provided opportunities for families to attend the Philadelphia Science Festival, where children demonstrated the projects they had created through STEM 3D.

Home and community connections in Cohort III

- Although the third cohort of professional development participants did not have an opportunity to plan family or community events during the period of this grant, 92 percent of the 53 participants agreed that the professional development session had increased their understanding of how to help youth identify uses of electricity in their homes and communities.

Finding 5: Positive outcomes for OST staff. Participating facilitators reported deep changes, including increases in their ability to facilitate project-based STEM activities, improvements in their attitudes toward science, and shifts in their understanding of who can pursue a career in STEM.

One hundred percent of the participants interviewed who implemented STEM 3D PBL units indicated that their facilitation of activities has changed in the following ways[11]:

- Greater use of open-ended problem solving and collaborative learning approaches in STEM.
- More youth-driven approaches.
- More depth and breadth of STEM content.

Cohort I and Cohort II

Facilitators and program coordinators in Cohort I and Cohort II report radical changes in their understanding of science processes as something that is accessible to them and youth in their centers. They come to see science as something that involves fun, curiosity, persistence, risk-taking, teamwork, and testing and retesting – rather than as an otherworldly discipline only available to a small, elite group. They also report that the youth in their centers gain confidence from participating in the creative problem-solving projects that are part of STEM 3D. In addition, interviews suggest that staff in Philadelphia OST sites have a hidden wealth of STEM experiences, such as knowledge about circuits from fixing their own wiring, that are unacknowledged and undervalued.

After a fall 2014 workshop, Cohort I professional development participants commented on some of the most valuable things they had learned:

- STEM 3D isn't just about science projects. It's about scientific thinking / curiosity / experimentation and this can be developed in all classes, not just the STEM 3D classes.
- My goal is allowing the project to be more about the process and not about the end result. As I leave today's training, I will try to think of everyday subjects that can incorporate science.
- The big picture of "introduce, explore and design" was extremely helpful and was one of my biggest take-aways. I felt I gained a stronger grasp of the process instead of being overly concerned with the details and not seeing the bigger picture.
- It was great to think about extending the learning and building on prior knowledge.
- I feel that this set of workshops helped to make me feel more comfortable with the idea of the exploration and inquiry method of doing PBL or projects.
- During this training period, I felt that we discussed how to make projects relevant to the youth and I find this to be very helpful. … Having prior knowledge of content learned during the previous projects is also very helpful.

At the end of the project, participants from the same sites reflected on some of the biggest impacts that STEM 3D had on them.

[11] Final interviews about PBL implementation were conducted with 9 Cohort I staff and 5 Cohort II staff.

- The project gave birth to new ideas. It sparked a little more creativity and new ideas that influence the PBLs I'm doing. I want to keep working on using questioning to help the kids learn – ask the right questions so that the kids' investigations will have to move forward.
- The STEM 3D approach taught me how to get from point A to point B or wherever you are going. In the beginning, I was clueless. In the beginning, I thought that the final project was just something to do. It was something cute for the parents. But it didn't have a purpose. But it became a lot more important as we developed it. Now we are trying build a village and light it up.
- As a facilitator. I am very naturally a type A personality, so in working with kids, I'm very quick to be like, "Oh, just give it to me. I'll do it myself." But since starting the STEM 3D, I've been able to think as a facilitator and not as a teacher and to kind of let them have their freedom. That has been my biggest growth since this started. … I think the biggest things I got out of the trainings would be just understanding exactly what the kids are dealing with as they're building something because we experienced it first. I always tell them, "You know what, I understand your frustration. I did this too. I had this exact same problem. Here are the things I've explored." I'm not here to tell them what to do.
- I just got certified to be a professional development instructor. The training that I put together is all related to what I learned from The Franklin Institute. And for me, I will be offering trainings to other teachers to do things that I learned in STEM 3D. I will be doing it in my classroom and other teachers will be there. It's pretty much going to be people within the city. Not just for my center.

Facilitators from Cohort II also described changes in their self-confidence, in their facilitation skills, and in their attitudes toward science and STEM. For these facilitators, the professional development process was more compact, the model was more streamlined, and the expectations even clearer for what facilitation should look like in STEM 3D.

One told the story of her leap forward in confidence about taking chances and exploring open-ended STEM problems:

> [One of the big things was] just boosting my confidence in science, and not being afraid to go into the unknown. You know [you think] science is like you have to be this whiz kid, this brainiac. No, it's just everyday stuff that you can put together to create something, and you can be successful with whatever you have placed in front of you. So it opened up my eyes. … So say, for instance, something breaks in my home? I don't give it a second thought, I let my husband handle it, deal with it. So say, for instance, an outlet is broken – I would have never thought to go over and try to maneuver it myself. But now, having the STEM 3D, I'm like, "Oh, let me see. Turn the circuit breaker off."
>
> There were some times when students couldn't do it on their own – I was one of those students when we started STEM 3D. One of those students where we did have to sit down side by side with the student and say, "OK, now put this together here. Now put this together there." There were some students that weren't really there with that self-confidence that they needed. I was there when I first started. I was like, "Tara, what am I supposed to do with this?" And once I got the hang of it and

> began to do it more, I became comfortable, and my confidence built. I was like, "Oh, just connect this and do this, and voila." So that was that.

A second also told the story of how the Institute's science educator modeled open-ended problem solving and design.

> So, when Miss Tara first came out and told us, "OK, we're doing something with STEM 3D. We're doing something where you're the instructor. You're going to be the one implementing to the children." And I was like, well, what? I don't know anything about doing *anything* STEM, or trying to be the facilitator of *anything*. So I was like, yeah, this is probably not going to work. I don't know how I'm going to try to teach *them* anything when I barely know anything about anything STEM 3D.
>
> When I explained to Miss Tara what I wasn't confident about, she just made the transition to doing … easier than I thought it would be. She was a facilitator with us, so it wasn't like, "These are the steps, A, B, C. This has to be in the order it is." So she made me feel confident about not having to go, "Step one, this is what we have to do. Step two, this is what we have to do. Step three."
>
> She made me understand that I should give my kids creative ability to do it how *they* think it should be done, because that's when they're learning the most and that's when they're in their element the most, being creative, thinking of new ways to do something. And she let me know that everything doesn't always have to be the same. It doesn't always have to go a certain way. Like, she may do it this way, and then he may do it a different way. Just as long as they're getting the end result that they should be getting, or grasping what they should be grasping, however way they do it doesn't matter, because everyone does everything differently.

Observations of Cohort I and Cohort II largely matched facilitators' self-descriptions of how the project changed their practice. For Cohort I, it was possible to see change over several years. Observations during the first summer and school year of the project indicated that even though youth were actively engaged in open-ended STEM activities during site visits, facilitators were hesitant to let children play with materials and had a hard time helping children form conceptual connections between discrete activities. Facilitators themselves sometimes noted that activities they thought would be engaging held little interest for youth and thus ended much more quickly than intended. Resource binders provided by TFI staff included many additional extension activities, but few if any facilitators used these additional ideas during the first year of STEM 3D implementation.

By the second year of the project, observations of a design challenge (creation of a tinkerbot) indicated that adults and youth were indeed engaging in challenging, creative activities. At three of the four Cohort I sites,[12] facilitators structured introductory, exploratory, and culminating activities as planned. The introductions and the explorations provided opportunities for youth to read about robots and robotics, experiment with circuits and motors, and examine simple machines. Across sites, students were also asked to design a robot that could move and were instructed to draw a picture of it before they began physically constructing it, using small motors, wires, batteries, light bulbs, Styrofoam cups, construction paper, and other common items. Notable construction design examples include a giraffe that walked, a snowman with a swiveling head, a girl with a turning head full of wiry, colorful pipe-cleaner hair, and a dog made from a vibrating toothbrush.

[12] The site that did not complete the tinkerbot PBL ended up leaving the project the next year.

In each site, students came up with diverse and creative tinkerbots, often struggling with design problems and asking for assistance from adults. In many cases, adults were observed to ask open-ended questions as they had been prompted to by the STEM 3D staff, such as "Why do you want to do that?" "What do you think will happen if …?" In other cases, adults and children solved difficult problems together, such as why a ball attached to a motor would not rotate.

Observations of Cohort II exploration of circuits showed similar open-ended explorations and question-asking. Not surprisingly, children and adults in both cohorts also struggled with some management, pedagogical, and content issues. During observations, some students were stuck and unable to get any adult assistance. Others had solved their problems, didn't know how to move their projects any further, and often peer-to-peer coaching was not visible to the observer. In addition, students sometimes seemed to be lacking content knowledge – for example, when they tried to create circuits without understanding their basic principles or incorporated switches as an aesthetic design feature without understanding their function. Conversations with some adults also indicated some content weaknesses – for example, not understanding the difference between parallel and series circuits or not understanding how to incorporate LED lights into an electric circuit. Although understanding underlying content can help a facilitator to deepen a project-based learning unit, the challenges observed did not get in the way of children and adults in all sites being enthusiastic and persistent.

Cohort I facilitators, who knew they would be continuing with the project, were often reflective about how they could do their projects even better in the future. One site coordinator mentioned that she would like her students to do more frequent reflections on their projects, not waiting until the end. Another facilitator grappled with whether students should be required to plan out their designs before they had an opportunity to experiment with the materials, and a third raised questions about how best to frame the culminating project, commenting, "Some students didn't understand what we wanted them to do. They didn't get the idea of making a robot that could move." These reflections about gaps and challenges in project implementation indicate that facilitators are themselves thinking deeply about the flow and purpose of a STEM PBL unit, indicating major growth from the starting point of the project or from their experiences the year before.

Cohort III

A number of indicators suggest that the Cohort III training session offered in the spring of 2017, along with the Circuit City curriculum, is a successful model that can meaningfully be scaled up to reach any sites where staff are able to attend an off-site four-hour session. These indicators include participant satisfaction with the professional development, participant belief that they can implement the curriculum, and PHMC reports that the curriculum was successfully implemented.

Fifty-three participants in Cohort III completed surveys that indicated the STEM 3D professional development program increased their confidence in all areas addressed by the session. These areas included: facilitating open-ended questions, integrating science process skills, asking questions in all stages of a STEM activity, testing and retesting, building reflection into STEM projects, keeping youth engaged in STEM projects, helping youth make choices in STEM activities, conveying STEM content, and introducing ideas about STEM careers. Participants reported very high levels of satisfaction, learning gains, and expectations for implementation. In open-ended questions, they reported that the meaningful parts of the training were: engaging in activities, learning about circuits, teamwork, opportunities to reflect, and opportunities to learn facilitation methods. To a large extent, participants expect that they will be able to implement activities, implement the culminating project, share what they learned with others, and to a slightly lesser degree, be able to use the written Circuit City curriculum for planning purposes.

Figure 4: Cohort III responses to the post-workshop survey question: "As a result of this workshop, I have increased my understanding of how to..."(May 2017, reported by number of responses)

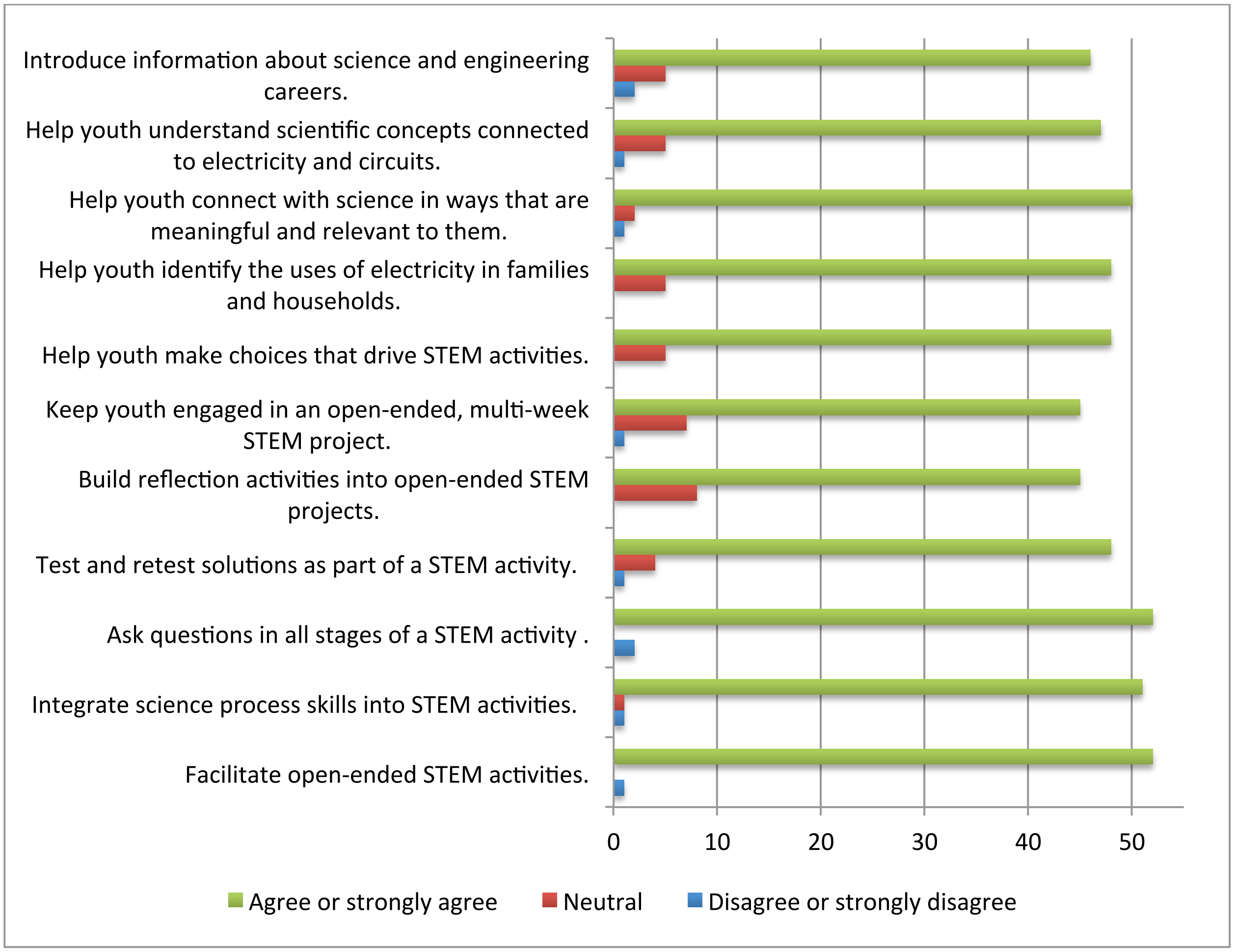
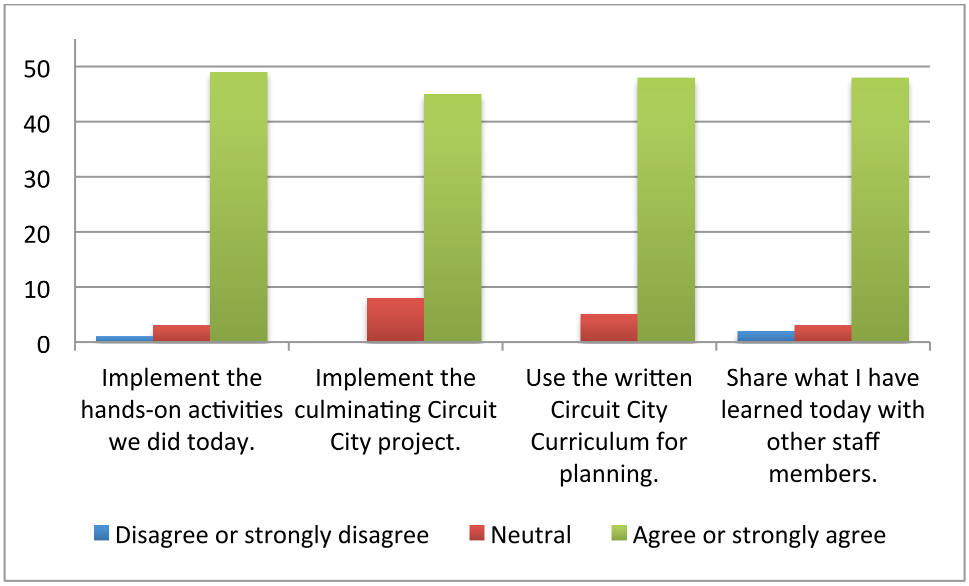


Figure 5: Cohort III responses to the post-workshop survey question: "In my OST site, I will be able to…" (May 2017, reported by number of responses)



Finding 6: Positive outcomes for youth. Analyses of student surveys demonstrate statistically significant increases in interest and engagement with STEM..[13]

Children who participate in the classes of STEM 3D facilitators report feeling significantly more interested in science at the end of the program than they had before the program.[14]

- The PEAR Retrospective Common Instrument was administered to 66 youth in the three Cohort I programs during the summer of 2015. A rigorous statistical analysis by PEAR researchers indicates that at each of the three STEM 3D sites, students reported feeling significantly more interested in science at the end of the program than they had been before starting.
- The same survey was administered to 38 youth in four Cohort II programs in spring of 2016. Altogether, youth in these four programs showed a statistically significant increase in their interest in science at the end of the program. In this administration, the numbers were too small to analyze on a program-by-program basis.

Qualitative data, including evaluator observations and facilitator interview data, are consistent with the self-report of students about their increased engagement and interest in STEM and science.

One of the Cohort II facilitators explained at length what her students got out of the program.

> Before, my kids didn't really like to ask questions. And I also think that they got out of it that I'm not going to know everything. So don't always look at me, because I don't know everything. So I think that it welcomed them more to learn, because they looked at Miss KA, and I would be like, "I don't know, either. So let's find out together." …
>
> So I think it gave them the confidence to keep going, just because I would ask them a question. I would be like, "Oh, well, I don't know how to do this, so can you show me how to do this?" Or, "If we take this apart, how would this work better?" So I feel like they walked away with knowing that asking questions is OK. It's not wrong to ask the questions.
>
> And I think they also walked away with learning how to be better critical thinkers, and not just stopping. And learning how to ask a better, not just … a yes or no question. So I think they got better with asking open-ended questions and learning how to answer open-ended questions. And putting another question over that open-ended question.
>
> And I think they learned to keep pushing themselves scientifically. … At the beginning, if they saw a project didn't work or their project failed, they'd be like, "Oh, I don't care. I don't want to do it anymore." And as the weeks went on, and the projects got better, and the projects got more intense, even if they seen that they failed this project, it was like, "OK, well, I failed this way, but I'm going to start over and see what I can do better." Or "I'm going

[13] Additional information about this survey is included in the Appendix.
[14] Retrospective surveys were collected from 104 students between June 2015 and May 2016. This represents about 33 percent of all students who participated in STEM 3D activities during this year. Lead facilitators collected surveys from students in 4th grade and above who participated in STEM 3D and who were in attendance the day the surveys were distributed. Completed data analyses were shared with CR&E.

> to take this weight off of my scribble bot and put this one on." Or "I don't want this motor, because I see that this motor has a little screw on it, so I need to take the screw off of the motor to make it go." Or "This isn't the type of container I need for my scribble bot to go in a circle the way I want it to go in a circle."
>
> … So I think that was one of the best things that they got out of it: They learned how to not quit. Or they realized that quitting wasn't the answer, and you weren't going to get your answer. Because if you quit, you still don't know how this or that worked. So I was really proud of them. … As stuff went on, it was days where we were still doing STEM 3D at 5:50 and they didn't want to leave, because they wanted to figure out how the scribble bot was going to work. … So I was really proud of them in that aspect, and I think they learned a lot from STEM 3D.

Another explained that the program helped students see STEM all around them.

> So I think it really opened up their eyes to just where science is at, and where you find it on a daily basis. How much they're in it, and not realizing that they're in STEM every day. You go home, you flip your light switch on. The circuits are connected. Even when you think about your piping: Your pipes are connected to your hot water tank, which connected to this, which causes different things to maneuver. If you have central air in your home, you have to have all these circuits connecting to make this work.
>
> So I think for them, just being able to see, instead of saying, "I don't know anything about STEM 3D," you really do. You know. If you've been to the museum, you've experienced it. If you go outside and you see the streetlight's off, and then all of a sudden, the streetlights are on, that's a part of STEM. Someone has to make those things connect in order for them to actually work. So it's not so much [that] it's someone sitting in a laboratory with a white coat on, dissecting or putting chemicals together. It's so much more than that, because every day there's a train that runs. Someone has to conduct the train that runs on tracks. When the trains are coming, they have to switch the gears.
>
> So all of that is part of – I think once we really begin to open up and ask some questions: Where did you see that? How does it affect your life? They were like, "Oh, wow, right, really, yes." Even down to pushing a button on your car for your window to roll down. Or pushing your alarm on your keypad to open up your car door. That's all a part of our everyday science, and STEM.

Other facilitators from Cohort I focused on issues such as persistence, cooperation, and motivation to do STEM activities.

- It has really helped in the classroom. They are not as quick to give up. They have learned through these projects how to persevere and get over problems. It is not just STEM 3D. When they are doing their homework, they used to ask me, teacher, can you help me? Now they try more on their own. Instead of asking me the question, they ask each other. Or they go on the computer to find it.

- Even watching them during an activity – say they couldn't figure out how to do a circuit board. It's interesting to see how they speak among themselves. We can watch them talk it out and work it out. When they do get it, they are more excited because they got it on their own.

- One good thing is that some of the kids are in the STEM 3D program for a while. By the time they get to 5th grade, they are in the routine and they know what they are doing. I see some of the kids that I had last year, and they are really, really into it. If they see me bring out a box that they know has the materials for, say, circuits or water testing, they'll say "Can I stay and show the kids how to do that?" You can see that it still holds their interest. And sometimes I let them stay and help with the younger kids.

- They learned to get along with each other. They had to work together. They also learned sometimes you fail and there's nothing you can do about it. You pick yourself up and you try all over again. … I am not saying they got along perfectly. I told them, "All right. You guys gonna argue? If you spend an hour arguing over what you got to do, you won't finish. The other group will have an hour to work on their project, and you haven't even started yet." … The beginning was tough. Then they got used to it. After they formed the groups, they wanted to stay together.

- The fact that that the program can continue and build, that is really exciting. I see our older kids and they may have done the first circuit PBL last year and now they are doing the second one and thinking about robots and thinking about all the different things that they can create to build upon the knowledge. That's what it's all about, building on prior knowledge. I'm really excited about that.

SECTION III: SUSTAINABILITY AND LESSONS LEARNED

Finding 7: Increased capacity within the Philadelphia OST STEM ecosystem through partnership between informal science and local government. The partnership between The Franklin Institute and the Philadelphia Health Management Corporation (PHMC) has built sustainable capacity within Philadelphia's out-of-school time ecosystem for implementing project-based science.

Capacity was built at the individual centers of Cohort I, as well as within the entire PHMC system for Cohort II. The ability of The Franklin Institute to provide resources, knowledge, and the flexibility to recognize local organizational needs and local cultures has been important not only for individual sites, but also in the larger professional development offered to PHMC sites as a whole.

Capacity at the center level

A long-lasting partnership with the centers that made up Cohort I led to sustainable capacity at two Cohort I centers. Three of the four Centers from Cohort I participated for the entire four years (2013-2017). Of these three centers, two made strong administrative commitments to the project. In addition to involving OST facilitators, each of these centers had another staff person who was able to support classroom implementation and family engagement through activities such as curriculum planning, turn-around training to other staff, coaching, and outreach for family events.[15] Both of these sites will sustain and/or expand the project-based learning approach to science with plans in place to continue using existing units, create new units, develop more staff, continue family STEM events, and broaden their connections with STEM professionals.

As one coordinator of an afterschool program where STEM 3D made a lasting impact stated:

> It's been amazing. I just can't get over how lucky we are to be a part of this. It's totally changed – enhanced – our program. It's given our teachers things that would have been much harder to get. There's been resources there for us. And actual training that happens three times a year. Then they can turn-key the training. And we've allowed time for that. And that's really invaluable. And it's been going on for 3.5 years. We thought it would be a yearlong program. That has been really great, having access to that. I have really qualified teachers. With a little professional development, they've been able to go all the way, so it is really incorporated into the program. One year, the participating teachers had STEM PBLs the whole year. Kids wanted to do that. It was so much fun. That was really a testimony to what we have been able to create.
>
> We're also trying to extend it to the other groups and keep going after the grant is over. And I am allowing them the time to plan and make sure they have the resources they need. I bought a bunch of books and want to order more, so that STEM becomes a regular part of our program, and it's not just for a short period of time of the grant.
>
> It's the philosophy and it's about teaching other afterschool programs how to do this, which is a great thing. That's what they sort of did. They gave to three or four sites in the city. How

[15] The third site that participated throughout the four years of project implementation had classroom facilitators who were equally committed and equally skilled at scaling up activities throughout the center, but there was no active engagement from institutional leadership at this site.

> do we share it with everybody else? Ultimately, that's kind of what you want to do, if you are thinking about the whole community, and not just your community or your school.

Capacity at the agency level

Although the agency that brought Cohort II participants to STEM 3D no longer manages afterschool programs, many of the facilitators are still engaged with OST in the Philadelphia region. In addition, the director of the OST sites for the program participating in Cohort II of STEM 3D, who was trained and knowledgeable about the STEM 3D approach, now oversees OST programming at another large social service agency in Philadelphia, CORA, that is part of PHMC's funding portfolio.

Capacity at the system level

In addition, PHMC as a whole is now actively engaged with The Franklin Institute. About 40 centers participated in the Cohort III training and received technical assistance during the summer of 2017 to implement the Circuit City curriculum. The professional development director for OST at PHMC is adamant about the need for additional STEM resources for PHMC centers, and the whole PHMC OST administrative arm looks forward to future collaboration with The Franklin Institute. While the Institute and PHMC began this project as partners, it took many years of commitment and relationship-building to identify the way for each partner to recognize the other's unique and complementary strengths.

Informal science as a partner to OST

It is notable that The Franklin Institute was able to maintain a consistent and developing program in the face of multiple challenges and instabilities in the world of public education and out-of-school time. The Franklin Institute, as an informal science institution, was able to bring content and pedagogical expertise.[16] Equally as important, it was able to bring flexibility and commitment to changing circumstances and to the individual needs of different centers.

Challenges mentioned earlier in this report included:

- Closures of public schools where programs were located.
- Closures of out-of-school time programs by social service agencies.
- Lack of capacity in social service agencies supporting OST.
- Lack of administrative support for innovation in OST programs.
- Inability of OST staff to attend planned trainings.

It is unlikely that these issues in funding, staff, and support for OST programming will resolve in the near future. Thus, it may be that informal science institutions like The Franklin Institute bring a special ability to be nimble and responsive with their programming at the same time that they bring well-developed pedagogical and material resources.

[16] In spite of turnover among project staff, OST sites reported consistently positive relationships, valuable professional development, and high-quality resources.

Finding 8: Increased awareness of the value of family STEM engagement among participating OST programs. STEM 3D's emphasis on family and community engagement opened up new and exciting opportunities for communication within families and for community-building within OST centers.

Parent involvement was initially a challenge for most sites. At early meetings, facilitators and coordinators often talked about the obstacles to family involvement: parents had to work, they had to get home to feed the children, they had other things on their minds. However, as adults and other children picked up on the excitement of STEM 3D, they also were attracted to it. Moreover, the process of involving families also increased the sense of community among staff within the center.

Many facilitators mentioned that seeing the children do the projects gave parents a different view of their children and that they could see them as creative, capable problem-solvers. They also mentioned that parents got engaged and jumped in when they saw their children working on open-ended projects.

One facilitator who had initially been very skeptical about parent involvement commented on how much STEM 3D was able to draw in parents:

> [The parents] knew that we were doing a unit on robots. And some of the parents had come in and, like, if they come to pick up their kid early and the kid starts crying, because "I haven't made my robot do it yet. My robot hasn't turned on yet!" So [the parents] would sit and work with [them] on that.

According to a facilitator where there was a center-wide Science Night:

> The Science Night has been really beneficial. It's like an extension of the children's day. While the parents are here, they enjoy seeing what their children are learning and doing. They are surprised. They expect them to be sitting down and doing homework or else playing. They get excited by seeing children doing something like making circuits, building robots, making slime – outside of what they expected. It's hard for our parents to get to activities outside the [center], but this works for them.

The coordinator of the same center described how motivating the Science Night was for teachers, as well as for parents and children.

> Maybe at the beginning, I felt like family engagement with science was forced by the project. But it's part of our goal as a program. I remember feeling a little overwhelmed about Science Night. And once we did it, it felt easier and it was fine. It was great. The teachers were on board. We had a lot of teachers really excited – more than just the ones that were involved in the training at The Franklin Institute.
>
> Before we did the Science Night, I gave our STEM 3D teachers a little bit of time to plan stuff. They had to turn the other 12 teachers around to sort of buy into the Science Night from 6 to 7:30. It's an evening you might want to go home. They all bought it. Not everyone could make it. The majority of them made it. And we had an hour meeting. They presented activities and ideas and thoughts about what to do.

> And they all bought in. It was just great. That was the STEM 3D teachers' presentation, and they took what Tara had been guiding us on and it was great.

Observation notes from another center provide a glimpse of how science exploration through STEM 3D has begun to knit together adults and children, parents and teachers.

> The coordinator and facilitators are setting up activities and getting snacks ready for the monthly open house. It is keyed into Lights on Afterschool. Nine kids (five boys, four girls) are sitting at a computer playing. The coordinator and facilitator remind them they'll be doing an experiment with the water filter.
>
> About 5:15, one mother comes in. She tells me her son loves the science experiments. He talks about them when he comes home. While we are waiting for the activities to start, another woman comes in. She says her son likes science also.
>
> At about 5:30, things get started. The coordinator explains the goal and the materials. Kids are fascinated and engaged throughout. The goal is to make a filter and produce clean water. Parents (all mothers) are also interested. They watch their children, make suggestions, and get excited about what is happening. Children ask questions, try things out, and redo them.
>
> There is also an older woman whose grandson is in another class. She has come in "because they have the best experiments here." There is plenty of other evidence that kids really like the experiments and the program. After the activity starts, one of the staff people tells me about another boy. She says, "He went home sick today but he wanted to come back for the science activity."
>
> At about 5:45, one mother says to her child, "Can this be continued tomorrow?" He says that he doesn't want to stop. She says she's tired and has to go the store. She and I chat. She says, "It's always like this, it's good." I say to her, "I guess he likes science." She laughs and says, "His brother is the science guy, but I guess he does." Another mother watches her daughter and another girl. She says that her daughter really likes doing science experiments and adds, "I like science, too." Her daughter says she is a scientist and makes up her own little experiments all the time at home.

Engaging adult family members in STEM exploration at OST centers not only supports children's learning, but it also challenges basic societal assumptions about who has the right and the capability to do science. As this vignette demonstrates, family members in low-income communities (in this case, all of them African American women) *can* make the time and *do* engage with their children in open-ended investigations that are beginning to engage both children and adults in the authentic practices needed in the world of STEM.

Furthermore, as this example suggests, families in low-income communities often have access to socially unrecognized resources for science learning and teaching. As this mother says, she and her daughter both like science, and her daughter role-plays being a scientist at home, creating her own experiments.

Informal conversations and interviews between the evaluator and adults in every center provided examples of community-based STEM activities. In particular, as STEM 3D participants explored circuits, it became apparent that in poor and working-class communities (perhaps more than in middle- or upper-class communities), people fix their own wiring. Thus, almost every site had an adult who mentioned a family member who understands circuits and knows how to problem-solve if something goes wrong.

In addition, engagement with STEM activities, STEM skills, and STEM practices goes well beyond practical problems in the communities where these centers are located. For example, one father mentioned that he buys robotic kits and has a large collection of homemade robots. A facilitator who grew up in an African American working-class neighborhood reflected that his first exposure to working with technology came with watching his uncle create a sound system to play his records.

The crucial dimension in engaging families and community members in STEM is likely not to be the absence of family and community interest but rather an institution's ability to be flexible and open in ways that are comfortable and inviting. Although OST sites are informal, community-based centers in some ways, in other ways they can incorporate dominant ideologies about the communities they serve, as well as dominant ideologies about science and STEM.[17] As the success of family and community engagement activities in STEM 3D suggests, changing the dominant assumptions about family engagement in STEM can catalyze new energy and excitement.

Finding 9: An evolving model for age-appropriate STEM inquiry and career-awareness activities. STEM 3D's final iteration of professional development and the Circuit City curriculum provide a usable model for career awareness for upper elementary school children.

As identified above, STEM 3D facilitators strongly articulated that their ideas about STEM have changed. Through this project, they have learned that science is all around them and accessible to everyone. Observations, interviews, and student surveys all indicate that over the years, STEM 3D facilitators have learned to facilitate PBL units in ways that corporate a variety of high-quality STEM practices. Throughout the project, STEM 3D facilitators have identified how the project can shape young people's careers. Although this has depended greatly on the approach of the individual facilitator, it is an area where STEM 3D has much to contribute. It implements an out-of-school project-based learning component within an ecological learning framework that situates children's development within intersecting contexts of home, community, and school. The final iteration of STEM 3D's activities and products solidified the project's approach to career awareness within a framework of youth voice and choice, STEM content and practice, and connections with family and community.

Review of ITEST's logic model for career development and other literature on career development for elementary school children indicates that there is a close alignment between these career

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[17] Shirin Vossoughi, Paula Hooper, and Meg Escude. "Making Through the Lens of Culture and Power: Toward Transformative Visions for Educational Equity," Harvard Educational Review 86:2 (2016): 206-232.

development frameworks and the STEM 3D framework.[18]

Areas of alignment between the Circuit City curriculum and themes in the literature about career development for elementary school children are:

- Early development of dispositions and skills to prepare for college and career.
  This would include traits such as persistence, curiosity, problem-solving, and the ability to collaborate, all of which are emphasized in the Circuit City curriculum. The development of general attributes for career success is one of the major recommendations to adults who are interested in helping young children prepare for successful careers.

- Early development of skills, knowledge, and interest that can lead to specific careers.
  In the STEM fields, this would include skills such as observation, experimentation, and measurement. These skills are cultivated in the Circuit City activities, as is excitement about exploration of STEM content. Becoming familiar and confident with scientific practices and content will help children from underrepresented communities gain an equal footing with more privileged children as they progress through the educational system.

- Awareness of career options.
  Young children have limited understanding of potential jobs and career options. Advice to parents and teachers about career education for young children includes increasing children's awareness of potential careers that might be of interest to them.

  Reflection activities in Circuit City ask students and facilitators to think about how potential careers might connect with the hands-on explorations they are doing. Background information for facilitators also provides details about a variety of career pathways related to STEM content in this curriculum unit.

- Connecting potential career interests to family and community.
  Making connections between potential career interests and the immediate environment of family and community is especially important for elementary school children. Often children identify careers based on what they see around them, but may not think of STEM embedded in the world around them as connected to possible jobs. The Circuit City curriculum is designed to help young children make connections between STEM content and practices in the context of their households and neighborhoods.

- Helping young children think about potential career choices that match children's interests and skills.
  Another important career development activity for elementary school children is helping them make connections between their interests and potential careers. Observational data about STEM 3D indicates that participating children are excited and talented when they have the opportunity to engage in open-ended STEM explorations. A variety of activities in the Circuit City curriculum are designed to help facilitators communicate the idea that many STEM professionals also have the opportunity to problem-solve and engage in open-ended exploration and investigations.

[18] America's Career Resource Network, n.d.; College Board Advocacy & Policy Center, 2012; Reider et al., 2016

Finding 10: Contributions to the field. STEM 3D's professional development framework evolved into a model for a community of practice that melds the expertise of informal science educators with the expertise of community-based OST staff in order to support STEM-rich, student-driven activities. This approach builds respect between professional STEM educators and people who previously felt excluded from STEM, and allows OST programs to tap into the often-unacknowledged resources that low-income minority communities can offer for supporting youth STEM engagement (Barton et al., 2004; McCreedy & Luke, 2006; Bevan, Ryoo, & Shea, 2015).

The professional development framework that focuses on building a community of practice and recognizes the ways that the strengths and knowledge of those in the OST world complement the strengths and knowledge of informal science educators suggests a valuable role that informal science institutions can play within the many different local contexts of out-of-school learning. Facilitator-led OST STEM practice can help connect facilitators more deeply to the children and communities that are served and tap into the many unrecognized resources that low-income minority communities can offer for supporting youth in STEM engagement and eventually in STEM careers.

The STEM 3D framework provides a model for building a community of support for STEM learning to engage grade 3-5 children in low-income, minority communities in year-round out-of-school STEM experiences. This community of support can be seen as a set of interlocking partnerships that cross over diverse contexts including families, neighborhoods, and informal science centers. The primary levers for change are professional development sessions for project-based learning in STEM and capacity-building activities geared to family outreach.

In the first two cohorts of this model, group facilitators for 3rd-, 4th-, and 5th-grade students learned how to develop and implement project-based STEM units after school and during the summer as they also implemented family engagement activities.

This project was motivated by a body of research demonstrating that science learning is a social activity that occurs in schools, neighborhoods, out-of-school centers, and other informal educational settings.

Over time, regularly participating community-based staff demonstrated a large shift in their ability to integrate STEM concepts and process into project-based learning units. This shift was supported by STEM 3D activities that tapped the expertise of community-based staff, as well as the expertise of museum staff, opening up space for dialogue about science. With changed attitudes about what science is and who can do it, most participants in Cohort I and Cohort II also began to act as formal and informal brokers who took initiative in integrating STEM learning into settings beyond their own classrooms.

CONCLUDING COMMENTS

These findings contribute to a growing body of research suggesting that low-income minority communities have many untapped resources for supporting youth STEM engagement. This literature indicates that parents and community members, as well as out-of-school educators, can move from feeling intimidated or excluded from the world of science to being enthusiastic science teachers and learners.

The STEM 3D initiative was framed by the argument that the integration of STEM learning across three dimensions (afterschool, home, and community) is essential to build positive science identities and create viable STEM pathways for Philadelphia children who would otherwise be disconnected from the city's STEM-rich institutions and opportunities. The successes of this initiative identified in reported findings indicate the value of an approach that crosses over various dimensions of children's lives.

The challenges and evolution of the initiative also highlight the value of integration across dimensions for the adults involved. Envisioned players in this initiative include museum staff, OST staff, family members, and community members, each of whom are active in different spheres of informal learning. A recent article by Rogoff, et al. (2016) suggests that each of these settings (households, communities, OST sites, informal science centers) promotes informal learning, but each is characterized by different sets of patterns and assumptions. In all informal settings studied by these authors, learning is "less constrained than the institutional structure of schooling. … In all of the settings [studied], innovation is valued." Patterns such as collaboration, amount of instruction, connection with a larger community, and children's engagement through observing and pitching in vary across different informal settings.

The STEM 3D initiative demonstrates that crisscrossing the boundaries of informal learning sites can be highly productive, but it is not a straightforward process for adults positioned in different roles. Within STEM 3D, new approaches to museum-OST relationships were created, as were new approaches to OST-family relationships. If the STEM 3D approach is to be deepened, scaled up, and disseminated, it will also be valuable to continue generating knowledge about how these cross-role relationships between adults develop, how adults in these different roles change their assumptions about informal STEM learning, and how adults in different informal settings continue to learn from each other.

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APPENDIX 1: EVALUATION METHODS

Overview of Data Collection and Analysis

Multiple methods were used to collect the data needed to answer questions relevant to each year of STEM 3D implementation, as well as for this overall final evaluation report. CR&E shared summary data, analyses, themes and recommendations with the STEM 3D staff and participants on a regular basis, including written evaluation reports and memos that were provided on an annual basis, or more often if needed.

With the exception of the analysis of student self-report data (discussed below), survey data were summarized using basic descriptive statistics. Qualitative data were coded and analyzed in order to provide thematic information about participant experiences, successes, and challenges. These analyses included assessments of how well specific project objectives were being met; assessments of change over time for individuals and sites; and analyses of contextual features at different sites that supported and inhibited project implementation. Wherever possible, multiple qualitative and quantitative data sources (observations, interviews from multiple subjects, questionnaires and/or surveys) were used to develop credible findings and surface potential discrepancies.[19]

Description of Methods and Tools

Pages 37 and 38 include more information about methods and tools.

Timeframe for Data Collection

Figures A1 – A5 (pages 39-42) specify the time frame of project implementation and data collection activities during each year of the project.

Examples of Instruments

Examples of interview protocols, surveys, and observation protocols developed by Creative Research & Evaluation LLC can be provided by request to sblanc@creative-evaluations.com. Additional information PEARS tools can be found athttps://www.thepearinstitute.org/.

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[19] S. Blanc. "Not Just an Anecdote: Systematic Analysis of Qualitative Evaluation Data " http://www.evalu-ate.org/blog/blanc_aug2017/. See also M.B. Miles, A.M. Huberman, & J. Saldana, J. Qualitative data analysis: A methods sourcebook. Thousand Oaks, CA: Sage. 2014. M.Q. Patton, M. Q. Qualitative research & evaluation methods: Integrating theory and practice: The definitive text of qualitative inquiry frameworks and options (4th ed.). Thousand Oaks, CA: Sage. 2015.

Description of Methods and Tools

Major methods and tools for collection evaluation data were the following:

A. Observations of project implementation in lead facilitators' classrooms. All observations were guided by the Dimensions of Success (DoS) Observation Tool developed by the Partnerships in Education and Resilience (PEAR) program at Harvard University. Observations conducted in the Fall-Winter 2015 and subsequent periods were conducted and rated by an observer who had trained at certified to use this tool.

As described on its website, The Dimensions of Success observation tool

> DoS, pinpoints twelve indicators of Science Technology Engineering and Math (STEM) program quality in out-of-school time. It was developed and studied with funding from the National Science Foundation (NSF Award #1008591) by the Program in Education, Afterschool and Resiliency (PEAR), along with partners at Educational Testing Service (ETS) and Project Liftoff. In 2014, a technical report was released, describing the tool and its psychometric properties. The DoS observation tool focuses on understanding the quality of a STEM activity in an out-of-school time learning environment and includes an explanation of each dimension and its key indicators, as well as a 4-level rubric with descriptions of increasing quality. (https://www.informalscience.org/news-views/dimensions-success-dos-observation-tool. Accessed September 25, 2017)

B. Common Instrument

The Common Instrument is a tool that was designed under the leadership of Dr. Gil Noam at the Program in Educational Afterschool and Resiliency to assess outcomes in OST STEM programs. OST sites manage and administer the survey. Student responses are provided to PEAR staff, and PEAR gives a report, including assessment of statistical significance, back to participating sites. STEM 3D sites were given information about this tool. Seven out of nine participating sites chose to administer the survey and shared the results with the evaluator.

The form of the Common Instrument used by STEM 3D used the "retrospective change method." As described in the Guide to PEAR STEM Tools [20]

> The retrospective change method also asks students to reflect on how much they feel they have changed, except that the survey is only administered once at the end of the program and students only need to answer each question once. More specifically, students are shown a sentence and are asked to think back to the beginning of the program and rate whether they do/feel things less or more because of the program. This survey is typically on a 5-pt Likert Scale from "Much Less Now – About the Same – Much More Now… As the PEAR Guide

[20] The Pear Institute: Partnerships in Education and Resilience (2016). A Guide to PEAR's STEM Tools: Common Instrument Suite and Dimensions of Success.

notes, the retrospective design method avoids what is called a "response-shift bias." This refers to a phenomenon in which participants may rate themselves lower on particular items after participating in an intervention than they did before the intervention because they have a deeper understanding of what these items mean. In addition, the retrospective design is less time intensive than a pre-post model for students and facilitators in OST settings.

C. Ethnographic observations of family and community activities. Running records were written by an evaluator during or immediately after every observation of family and community activities.

D. Focus groups with parents. Two parent focus groups were conducted during the first program year. One focus group was conducted in English. One focus group was conducted in Mandarin and translated by a native Mandarin speaker who was also familiar with out-of-school programming.

E. Anonymous audio-recordings that did not disrupt the flow of children's activities were used as a method at one site during one unit to document student voice and enthusiasm

F. Facilitator interviews about perceptions of science and about STEM 3D experience and implementation were conducted twice with Cohort I and once with Cohort II.

G. Surveys and open-ended reflections provided information about participants' prior experience and about their experience and learning through professional development activities.

FIGURE A1: FY 2014 STEM 3D SITE IMPLEMENTATION & EVALUATION DATA			
STEM 3 Program implementation:	Summer 2013	Fall –Winter 2013	Winter -Spring 2014
	Cohort I: - Pilot implementation of PBL activities (Making a Water Blaster) (4 sites)	Cohort I: -Implementation of PBL Unit (Creative Switches) (4 sites)	Cohort I: -Implementation of PBL Units (Automata, Doing a Fair Test) (4 sites) -Family Showcases (2 sites)
STEM 3D Evaluation Data Collected	Summer 2013	Fall –Winter 2014	Winter -Spring 2015
Observation of PBL Activities and Units (4 sites)	X	X	X
Observation of Family Science Showcases (2 sites)		X	
Focus groups with family members (2 sites)			X
Facilitator surveys and written reflections about professional development activities		X	X
Participant-observation at professional development	X	X	X

FIGURE A2: FY 2015 STEM 3D SITE IMPLEMENTATION & EVALUATION DATA			
STEM 3 Program implementation:	Summer 2014	Fall –Winter 2014	Winter -Spring 2015
	Cohort I: - Site Developed Project Based Learning Units (4 sites)	Cohort I: -Implementation of Tinkerbot PBL Unit (1 site) - Family Science Showcases and Community Events (1 site) -	Cohort I: -Implementation of Tinkerbot PBL Unit (4 sites) -Planning for family engagement activities (4 sites)
STEM 3D Evaluation Data Collected	Summer 2014	Fall –Winter 2014	Winter -Spring 2015
Observation of project implementation (4 sites)	X	X	X
Observation of student demonstration at community event (1 site)			X
Interviews with Cohort I participants (n=6, 3 sites)			x
Participant-observation at professional development sessions	X	X	X
Facilitator surveys and written reflections about training activities		X	X

FIGURE A3: FY 2016 STEM 3D SITE IMPLEMENTATION & EVALUATION DATA			
STEM 3 Site implementation:	Summer 2015	Fall –Winter 2015	Winter -Spring 2016
	Cohort I: - Site Developed Project Based Learning Units (4 sites) -Family Science Night (1 site)	Cohort I: -Site Developed Project Based Units focused on Career Awareness (1 site)	Cohort II: -3 Project Based Units (5 sites) -Culminating Showcase for families (5 sites) -Student projects at Philadelphia Science Festival (4 sites)
STEM 3D Evaluation Data Collected	Summer 2015	Fall –Winter 2015	Winter -Spring 2016
Observation of project implementation (Cohort I and Cohort II) (8 sites)	X	X	X
Family Science Night parent surveys (Cohort I) (1 site, n=22)	X		
Student surveys (Cohort I and Cohort II, n= 104)	X	X	X
Facilitator surveys about training activities		X	X
Pre/post facilitator surveys (Cohort II)			X
Facilitator interviews (Cohort II, n=5)			X

FIGURE A4: FY 2017 STEM 3D SITE IMPLEMENTATION & EVALUATION DATA			
STEM 3 Program implementation:	Summer 2016	Fall –Winter 2016	Winter –Spring 2017
	Cohort I: - Site Developed Project Based Learning Units (3 sites)	Cohort I: -Site Specific PBL Implementation (3 sites) - Family Science Showcases for Lights on Afterschool (2 sites) -	Cohort I: -Circuit City Implementation (3 sites) Cohort III: Training (implementation in FY 2018)
STEM 3D Evaluation Data Collected	Summer 2016	Fall –Winter 2017	Winter –Spring 2017
Observation of Circuit City project implementation (2 sites) and Observation of Family Showcases (2 sites)			X
Interviews with Cohort I – participants directly involved with STEM 3 (n=9)) (3 sites) Staff not directly involved with STEM 3D implementation (n=4) (3 sites)			X
Baseline and Post-Workshop Surveys (Cohort III)(n=53)			X