Multi-**S**ite
Public **E**ngagement with **S**cience
Synthetic Biology

Final Evaluation Report

prepared by

Rockman et al

Research & Evaluation

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Introduction

The MSPES Synthetic Biology Project

The *Multi-Site Public Engagement with Science – Synthetic Biology* project (MSPES) was a three-year effort funded by the National Science Foundation and spearheaded by museum professionals and scientists dedicated to public outreach. The core goal of MSPES was to promote meaningful conversations and interactions between scientists and public audiences through outreach events hosted by informal learning institutions nationwide, using synthetic biology as the science topic of interest. The Museum of Science Boston (MOS) led the project, in partnership with the American Association for the Advancement of Science (AAAS), the BioBuilder Educational Foundation, the Science Museum of Minnesota, Sciencenter in Ithaca, and the Synthetic Biology Engineering Research Center (Synberc). The project brought together the expertise of scientists and their understanding of the field of synthetic biology with the expertise of informal science educators (ISEs) and their understanding of how to communicate with public audiences. The result was the creation of outreach opportunities that benefitted from the influence of both perspectives. The project team embraced "Public Engagement with Science" (PES) as their guiding model for these outreach opportunities. PES emphasizes two-way conversations between scientists and members of the public, and interactions that value the knowledge, opinions, and experience of both groups. Synthetic biology was chosen as the science topic of interest because it is an emerging area of science that raises societal and ethical concerns. With its many applications and implications that affect the lives of non-scientists, synthetic biology provided many avenues for promoting PES. The project built on previous efforts undertaken as part of the Nanoscale Informal Science Education Network (NISE Net) project – another NSF-funded initiative that brought together researchers, museum professionals, and the public around the topic of nanoscale science. This report provides findings from the external evaluation of MSPES, conducted by Rockman et al (REA), an independent educational research firm.

Project Activities and Timeline

Project Goals

In fostering PES conversations between public audiences and scientists, the MSPES team hoped to achieve a number of outcomes for the public, including an improved understanding of synthetic biology and the chance to interact with scientists on a new level. Scientists and informal science educators were the primary target for the project's efforts, however. MSPES aimed to build knowledge, skills, and self-efficacy regarding synthetic biology and public interactions. More specifically, the project aimed to impact these groups in the following ways:

1. ISE professionals and scientists will have a deeper understanding of the potential impacts of PES on both scientists and the public and of how best to engage participants in PES.
2. ISE professionals and scientists will have an increased understanding of various techniques of public engagement and how they can be used in the context of

socio-scientific issues relevant to civic life today, as well as ways to embed activities into the broader community, reach underrepresented audiences, and sustain the impact of PES beyond a one-time event.

3. ISE professionals and scientists will have an increased understanding of both the challenges and potential solutions to evaluating PES activities, where the goals may be different from those driven by public understanding of science perspectives.
4. ISE professionals will have increased knowledge of synthetic biology and the societal implications it raises as well as strategies for engaging publics in learning about both.
5. ISE professionals will have an increased ability to design, present, facilitate, and evaluate PES
6. activities, and to organize multi-site PES events that attract both the scientific community and a diverse public, including audiences underrepresented in participation in mutual learning.
7. Scientists will have increased ability in public communication and dialogue skills.
8. ISE professionals and scientists will increase their feelings that they are able to conduct or participate in PES activities.

Year 1

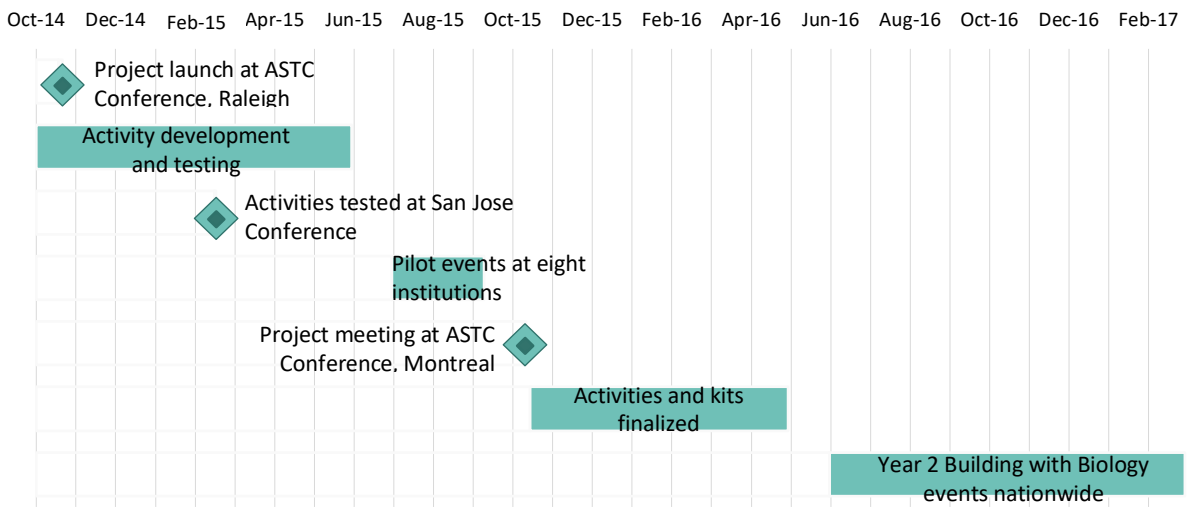
During the first project year, the MSPES team focused on creating partnerships between informal science educators and scientists that would serve as a model for the duration of the project. ISEs from 12 museums across the United States were matched with scientist partners and tasked with creating PES activities that could form the basis of public events centered on synthetic biology – dubbed Building with Biology events. MSPES project leads identified four key ideas on which the activities would focus:

1. Synthetic biology builds biological systems.
2. Synthetic biology generates new tools and knowledge.
3. Synthetic biology benefits from many voices.
4. Synthetic biology is interconnected with society.

Scientists provided expertise on the science content while ISEs provided expertise on developing activities for public audiences. Both groups participated in conference calls and online training to learn more about PES, synthetic biology, and how to incorporate the two together. These calls and webinars also provided an opportunity for different sites to collaborate with one another and exchange ideas with their peers. Limited testing of activity prototypes was conducted with public audiences in February of 2015 during the AAAS conference in San Jose. In addition, activities were tested with visitors through a Team-Based Inquiry process between February and June 2015.The teams made adjustments to their activities, and eight sites held Building with Biology pilot events in the summer of 2015 to do a final test of the activities. Several of these sites also

held Building with Biology forums, using topics and materials prepared by the core project team on two different topics related to synthetic biology. Pilot sites held training activities for their scientist facilitators prior to their Building with Biology events, providing them with a chance to learn about the Building with Biology activities as well as about PES as a different type of public outreach. The internal evaluation team gathered feedback from participants – including ISEs from the host sites, scientist partners, and event attendees – through online surveys and surveys distributed at the Building with Biology pilot events. Findings from these pilot events helped the project team make final adjustments to the activities and select the most promising ones to include in the final Building with Biology kits to be used during Year 2.

Figure 1. MSPES Project Timeline



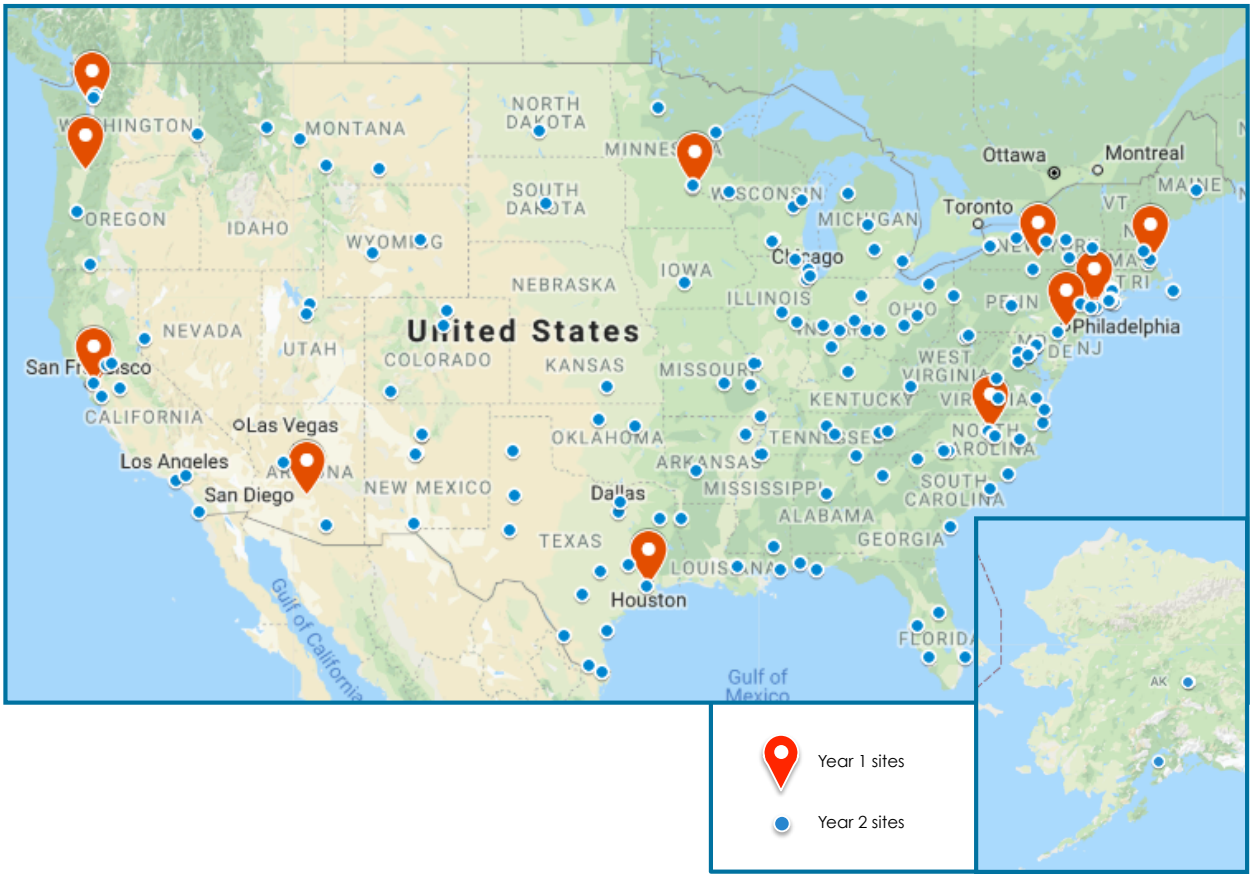
Year 2

Beginning in 2015, the MSPES team began recruiting host sites for the expanded Year 2 project activities, talking with ISEs and scientists at ASTC and other conferences. In early 2016, potential host sites filled out an online application, and the MSPES team began reviewing applications and awarding kits in March. The MSPES team mailed out the first wave of kits to host sites in the first week of June and continued to mail out kits as additional applications trickled in throughout the rest of the year. By the end of 2016, the team distributed 173 synthetic biology kits to sites across the United States. The remaining kits were distributed in 2017 after the time period covered by this evaluation report. Sites that elected to hold forums could apply for a stipend to offset the costs of organizing these events. A subset of sites also applied to participate in a data collection effort that measured the impact of events on public audiences, managed by the MOS internal evaluation team.

The Building with Biology kits included written guides for using the activities and hosting forums, planning and promotional materials for the events, and handouts on PES. In addition to these resources, the MSPES team produced a series of webinars for both hosts and facilitators as well as training videos accessible online. Specific webinars and training materials were also produced for those sites that participated in the evaluation of public audiences. Live webinars

were held from June through July of 2017, and recordings of the webinars were posted on the Building with Biology website for access at any time (www.buildingwithbiology.org).

Figure 2. Sites Involved in the MSPES Project



Finally, to ensure the long-term impact of the project and support PES efforts down the road, the project team developed a *Guide to Developing, Implementing, and Evaluating Public Engagement Activities or Programs* (accessible at www.mos.org/pes/guide). This guide is intended to serve as a resource for all institutions seeking to do PES in the future.

Key Findings

- Project efforts enabled institutions across the United States to hold at least 139 Building with Biology events and 40 Building with Biology forums as of February 2017. Additionally, many sites used Building with Biology materials to support other programs for the public. More than 1300 facilitators were recruited to assist in the events and forums.
- Hosts' understanding of PES improved through their involvement in the project, as did their knowledge and confidence for organizing PES events and training others in PES approaches.
- Synthetic biology was a challenging topic for participants due to its complexity and newness, but it also provided avenues for rich dialog around its applications and related societal and ethical issues. Host and facilitators' understandings of synthetic biology, perspectives on its use, and consideration of the public's views expanded as a result of the project.
- Facilitators were enthusiastic about the importance of engaging with the public over topics like synthetic biology. For many, participating in Building with Biology either sparked or renewed their interest in doing similar events in the future.
- Hosts' understanding of PES improved through their involvement in the project, as did their knowledge and confidence for organizing PES events and training others in PES approaches.
- Perhaps due to inconsistencies in training, more than 50% of those who took the facilitator post-survey said they either didn't know what PES was or that the project had not changed their definition of PES.
- Despite an apparent lack of understanding of PES as a concept among many facilitators, the vast majority (87% and upwards) identified key components of PES in their Building with Biology events – for example, that they learned from the public. Forums in particular seemed a successful format for PES approaches.
- Building with Biology events held during Year 2 were extremely varied in size, context, type of facilitators, and training provided to these facilitators. Ensuring consistency with project goals and expectations was a challenge during the scale up, as hosts had autonomy in planning and preparing for their events and encountered different challenges in their individual contexts.
- Although finding and recruiting scientist partners for Building with Biology was a challenge for some sites, hosts see the value in these collaborations for their institutions and their public audiences. They also felt the project did a good job of providing support for establishing these relationships and training scientists.
- Scientists saw the benefit of these collaborations as well. Facilitators who participated in Building with Biology events felt that the experience increased their skills for engaging the public in science and communicating about their work. Some talked about viewing their research in new ways.

External Evaluation

REA's external evaluation of the MSPES project dovetailed with the internal evaluation run by the Museum of Science. While the Museum of Science focused on outcomes for public audiences, REA focused on outcomes for the scientists and informal science educators involved in MSPES. Key questions for REA's evaluation included:

- How did the project team approach designing activities and forums designed to combine synthetic biology with a PES approach?
- What were the challenges and successes of using these activities with the public?
- To what extent was the team – both partners at the pilot sites and participants from secondary sites – able to bring a PES approach to their Building with Biology events?
- How did participants' understanding of PES and synthetic biology change throughout the project?
- What were the challenges and successes of creating partnerships between scientists and museums (or other informal education institutions)?
- How did the project tackle the task of recruiting, training, and collecting data from the 173 sites involved during Year 2?
- What did the Building with Biology events during Year 2 look like? How did they vary from one site to the next, and what were some of the common themes?

Year 1 Evaluation Findings

Evaluation findings from the first phase of the project are presented in the *Year 1 Evaluation Report*, delivered in January 2016. REA researchers found that participants in this first phase experienced some truly complex challenges and came away with many insights about the project. Participants from the pilot sites had a good understanding of PES by the end of Year 1, as did many of their partner scientists. Differentiating PES from PUS in practice, however, was more challenging, especially when outreach is focused on a very complex topic like synthetic biology. Another important finding from the initial phase of the project was that strong partnerships between museums and scientists take time, good communication, and a respect for one another's unique skill sets. When these factors are present, both sides have much to gain. Scientists from the most successful partnerships in Year 1 talked about developing their enthusiasm for outreach and looking at their research in a new light. Museum and ISE professionals talked about the tremendous value scientists can bring to outreach efforts: they make science and science careers seem more accessible, they keep outreach current, and they bring authenticity to the experience. Finally, the topic of synthetic biology opened the door to many interesting discussions on the societal and ethical implications of scientific research. This made the topic well suited to PES, which focuses on dialog that involves the audience's perspectives. Synthetic biology was also a challenging topic, however, due the complexity of the science involved. Participants noted that oftentimes the real conversations couldn't begin until audiences had received a certain amount of

information via a PUS approach. (For further discussion of Year 1 evaluation methods and findings, see the Year 1 Evaluation Report, available on informalscience.org.)

Year 2 Evaluation Methods

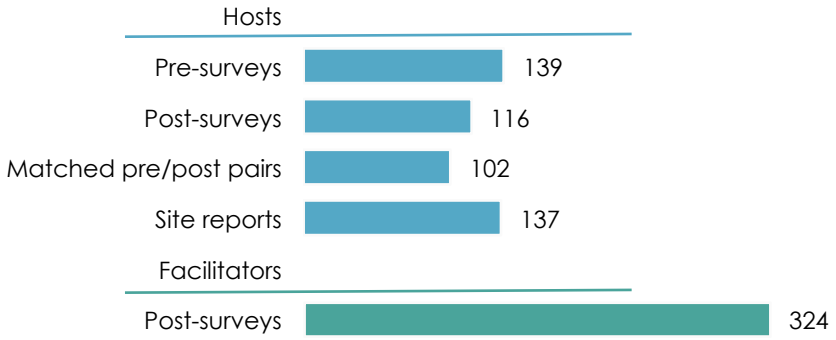
Interviews with Project Team

REA researchers conducted interviews with key members of the project team in March 2017, after most Building with Biology events at the secondary sites had concluded. These interviews were used as a time to talk about the logistics, successes, and challenges of scaling up the project in Year 2. Topics covered included the processes of recruiting, training, and supporting the secondary sites, and reflections on the project as a whole.

Surveys and Site Reports

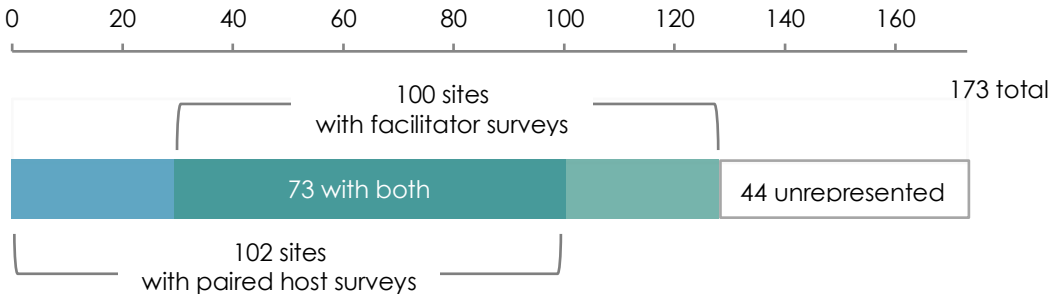
To understand the impact on Year 2 participants, the evaluation teams developed surveys for both event hosts and event facilitators. Hosts were those individuals representing the museums and institutions involved – usually the person who applied for the Building with Biology kit and organized an event or forum. Facilitators were those individuals who led the hands-on activities or participated in forum discussions as scientists. Ideally, facilitators were scientists recruited by the hosts, preferably individuals with some knowledge of synthetic biology. Hosts took an online pre-survey administered by REA after being selected to receive a kit. They were asked to take the survey before reviewing the contents of their kit, in order to get a true sense of their perspectives on PES and synthetic biology prior to their exposure to any of the activities or training materials. They received an online post-survey once their event had concluded. Since facilitators were identified and recruited by the hosts, they were another degree removed from the evaluation team in the chain of communication. Pre-surveys were not possible with this group; however, the MOS internal evaluation team administered a post-survey to facilitators after collecting their email addresses from host sites. These data were shared with REA for the external evaluation. REA researchers also referred to the site reports collected by the internal evaluation team for basic information on the events held at each site as well as contact information for facilitators. Completing these reports was listed as a requirement for those sites receiving a Building with Biology kit.

Figure 3. Survey and Site Report Response Rates



Of the 173 sites that received a Building with Biology kit in 2016, 102 responded to both the pre and post host survey – nearly 60%.[1] The post-survey for facilitators received 324 responses representing a total of 100 sites (averaging three facilitators per site). With some overlap in the sites submitting both host and facilitator surveys, a total of 129 sites are represented by the survey data – 75% of the sites receiving kits.

Figure 4. Site Representation in Surveys Collected



Site Visits

In 2016, REA researchers also visited seven of the secondary sites during their Building with Biology events (see Host Site Spotlights, p. 17). These visits allowed the researchers to see both the forums and hands-on activities in action in a variety of contexts, providing insights on what the scaled-up efforts looked like across the United States during the project's second year. They also allowed researchers to converse with facilitators at different sites and learn more about their backgrounds, their perspectives on public engagement, and their thoughts on participating in Building with Biology.

Interviews with Hosts and Facilitators

Finally, REA researchers recruited 13 hosts and 22 facilitators to participate in telephone interviews about their experiences with the Building with Biology project. Feedback was sought from individuals at the seven sites that researchers visited, as well as additional sites representing a spectrum of events and experiences. In particular, feedback was sought from hosts and facilitators of both events and forums. Hosts were asked about their initial interest in the program, the process of recruiting partner scientists, the utility of the training materials and other Building with Biology resources, the structure of their events, and the outcomes they perceived for themselves as well as for their scientist partners and the public. Facilitators were asked about their previous experience with outreach, their understanding of PES, the training they received as part of Building with Biology, the conversations they had with the public around the topic of synthetic biology, and the benefits and challenges of the overall experience.

[1] The evaluation team chose to close data collection and begin analysis at the end of February 2017. Some sites, however, continued to host events past this date and therefore were not included in the analysis.

Overview of Participants and Building with Biology Events

The project team aimed for a massive scale-up during Year 2, hoping to send Building with Biology kits to 200 sites nationwide. By the end of 2016, the team had succeeded in sending out 173 kits to a wide range of organizations across the country. The project welcomed applications from any organization doing public informal education and outreach, and few applications were rejected. Stipulations for receiving a kit included the following:

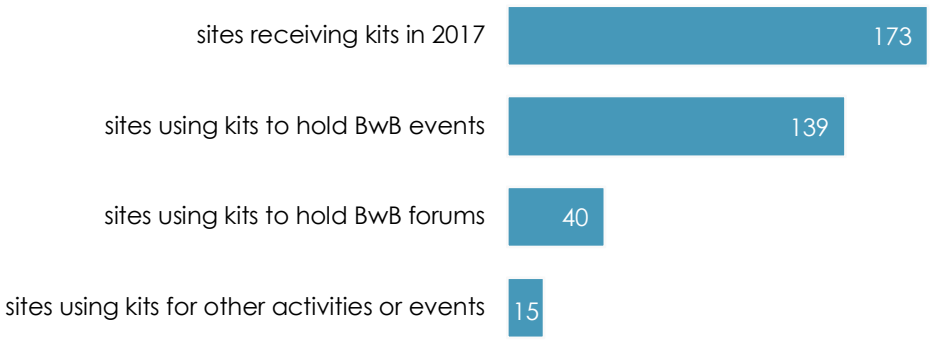
- hosting a Building with Biology event involving conversations between scientists or science students and members of the public
- [if a museum organization] collaborating with local scientists, science students, or individuals working in synthetic biology or related fields
- [if a scientists or university] collaborating with a local informal science organization (such as a museum)
- holding an orientation or training for volunteers who will facilitate activities at the event
- submitting an online report following event, including emails of volunteer facilitators

Building with Biology materials were also made accessible through the Building with Biology website at buildingwithbiology.org, for interested parties who didn't meet project criteria (e.g. located within the U.S.) or who couldn't comply with the above requirements.

A Range of Events

By the end of February 2017, 137 sites had filled out a final report and a handful of others had communicated with the MOS internal evaluation team, allowing for an approximate count of Building with Biology events and forums held during Year 2. This information shows that between June 2016 and February 2017, 143 of the 173 kit awardees (83%) held some form of event and/or forum using the resources provided. Additionally, some sites may have held events but did not submit reports, some sites delayed their events until the spring of 2017 or later, and many sites intend to use the kit resources at future events on a recurring basis. Unlike NISE Net, which had a specific date for all sites to hold events, the MSPES project allowed institutions to select dates that worked for them. One project team member felt that "in some ways it let people put things off." Therefore, while most sites had held events by February 2017, a few stragglers remained beyond this date.

Figure 5. Estimated Building with Biology Events Held During Year 2
(numbers based on data collection ending Feb. 2017)

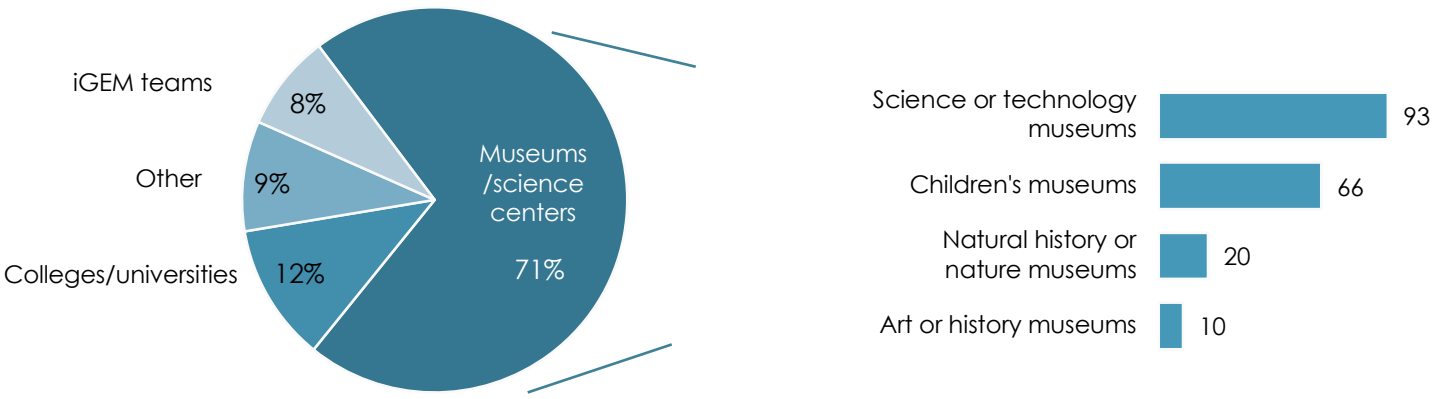


Implementation of the Building with Biology events and forums took many different forms during Year 2. Many sites followed the familiar format of the Year 1 partner sites – a small event with activity tables that visitors could rotate through. Sometimes the Building with Biology activities were incorporated into larger festivals or events, such as NanoDays fairs, and sometimes they became the central feature of rotating programs offered by a museum – for example, a monthly family science night. Other sites chose to incorporate the activities in outreach visits to schools, farmers markets, and summer camps.

Profile of Host Sites

The final group of awardees consisted primarily of museums or science centers (see Figure 6). Awardees from colleges or universities made up approximately 12% of the total 173 sites, high school or college/university iGEM teams accounted for 8%, and the remaining 9% of awardees consisted of other organizations including DIY bio labs, Girl Scout troops, and mobile science organizations or programs without dedicated public spaces (such as teen science cafes).

Figure 6. 2016 Kit Awardees by Institution Type (N=173)



Ninety-three of the applicants represented science or technology museums (roughly 54% of the sites), and 66 were from children's museums (38%).

Many of the host sites involved heard about Building with Biology due to their previous involvement in the NISE Net project and NanoDays events. In a few cases, the individual who initiated the application process for a Building with Biology kit was an industry or university scientist rather than an ISE. These individuals usually struck up a partnership with a museum or other informal education institution to carry out their Building with Biology activities – for example, the partnership between Dow AgroSciences and The Children's Museum of Indianapolis.

When asked what they hoped to learn from participating in Building with Biology, many hosts' responses aligned with the project's goals. Museums were often looking for new science content to offer their audiences and an opportunity to partner with scientists. Some individuals indicated interest in the PES approach, and scientists who received kits indicated interest in teaching the public about their area of research as well as learning to do outreach in general.

Profile of Facilitators

Because the facilitators were an extra step removed from the research team in the chain of communication, information on this group of participants must be pieced together from several sources: the host site reports, facilitator post-surveys, and interviews with both hosts and facilitators. Looking at all the information available, it appears that some facilitators (perhaps as many as a third) fell outside of the initial target audience intended by the project.

Pairing scientists with informal education institutions was an important goal of the MSPES project and one of the challenges for host sites during Year 2. Ideally, the scientists involved would be individuals with expertise in synthetic biology. The project team also hoped that the host sites would look beyond their current museum volunteers and employees – individuals who likely already have extensive experience doing public outreach – and find new participants who would benefit from PES training. The team also knew, however, that this may not be possible at all locations and encouraged sites to use supplement their newly recruited scientists with existing volunteers when needed. Both AAAS and NISE Net regional hub leaders also provided support to hosts searching for scientist facilitators. Project team members thought that graduate students were a particularly good target audience because the Building with Biology experience could "potentially influence the way they think about and carry out their own career" in terms of future outreach and interactions with the public. While not every Building with Biology facilitator met these criteria, the majority of hosts were able to recruit at least a few scientists who met these conditions. Of the 137 hosts who completed their site report, 83% said they were successful in recruiting scientists or students for their events and forums who had backgrounds in synthetic biology. An additional nine hosts (7%) said that although they didn't get individuals with synthetic biology experience, they were able to recruit scientists or college students with general science backgrounds.

Turning to the facilitators' survey data, respondents were coded based on whether they met certain characteristics of the project's original target group. Individuals were coded as "non-

target" if they were museum or informal education professionals. Facilitators were labeled "target" if they had science experience (whether as undergraduate or graduate students, science professionals, or retirees from a science career) but were not museum professionals. All others were labeled "non-target." Based on these criteria, 65% of survey respondents fell within the target audience for the project, and the remaining 35% fell outside the target. Thirty-one percent of survey participants were either studying synthetic biology or worked in the field of synthetic biology. Thirty-seven percent were involved in other STEM fields, either as students or professionals.

Figure 7. Facilitators' Alignment with Target Audience Criteria
(Post-survey data, n=308)

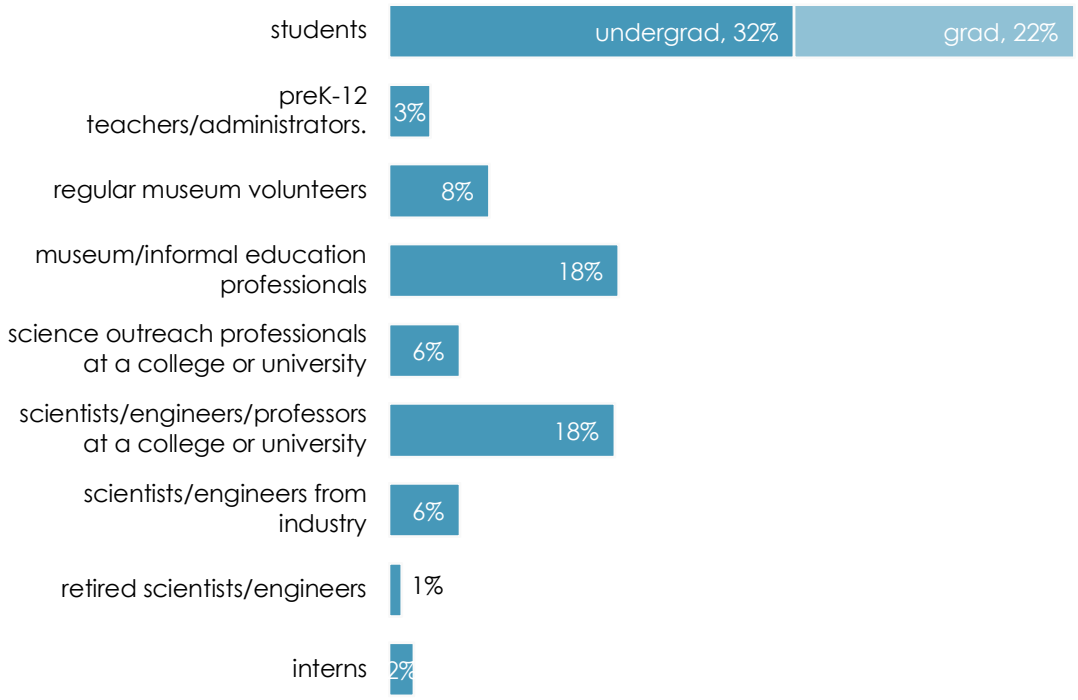
Figure 8. Facilitators' Science Backgrounds
(Post-survey data, n=224)

It's worth noting, however, that many facilitators did not take the survey, including facilitators from 73 out of the 173 sites receiving kits in 2016 (42% of the total). It's likely that if data were available on all facilitators, these numbers would shift. REA's interviews and site visits, however, tell a story about the facilitator audience that is fairly consistent. Hosts recruited scientists with synthetic biology experience when they could, but they supplemented these recruits with their existing volunteer base and other sources.

These additional participants may not represent the scientist archetype that project leads originally had in mind, but the project team was thinking of secondary target audiences as early as the 2015 ASTC meeting in Montreal. At that time, the group talked about undergraduate students in STEM fields as a potential audience. Since these individuals are usually at a turning point for making important career decisions, serving as a Building with Biology facilitator could be a valuable experience that shapes a student's future path. As shown by Figure 9 (next page), undergraduates made up a significant portion of Building with Biology facilitators.

In the end, REA found that even though many facilitators fell outside the primary target group, they benefitted from the project in ways that very much align with the spirit of the project. For information on facilitator outcomes, see p. 45.

Figure 9. Facilitators' Occupations
(Post-survey data, n=303)



Host Site Spotlights

Museum of Life and Science, Durham, North Carolina

Building with Biology – Museum of Life and Science, Durham, North Carolina

The Museum of Life and Science is a children's science museum that is situated in a prime location for developing partnerships with scientists. Just a few miles from the museum are several universities and Research Triangle Park – a 5,000-acre campus that is home to over 170 science industries and tech companies. The Museum's Building with Biology event was held on a busy Saturday at the end of August. Although several scientist partners cancelled their involvement with the event on short notice, the event organizer was able to pull together about 25 volunteers, including regular museum volunteers, university students, members of a local DIY bio lab, and an FBI agent who regularly does public outreach. Many of the regular museum volunteers present had advanced science degrees or were currently pursuing degrees in various science fields. Most of the facilitators had some prior knowledge of synthetic biology. Several of the student volunteers were members of a co-ed fraternity focused on chemistry. A few of the volunteers were able to come to a two-hour training session the week preceding the event, and the rest received the digital training materials via email as well as a briefing the morning of the event itself.

Tables for the event were set up in a space close to the museum's entrance, funneling guests past the activities on their way to other museum attractions. Although the host commented that visitation was down that day (possibly due to a broken A/C unit or the beautiful weather outside), the Building with Biology tables saw a steady flow of visitors throughout the day. Many participants chose to visit several tables, indicating that the activities were successful at hooking people into the event, even with the lure of the rest of the museum's exhibitions beyond.

The mix of Building with Biology activities alongside DIY bio demonstrations and the FBI presentation gave visitors a range of ways to engage. Facilitators using the Building with Biology kit activities were noticeably better at presenting their topics to novices, while some of the other facilitators' presentations (which were not part of the kit) were better suited to science enthusiasts or older audiences. Even so, a few Building with Biology facilitators commented that some of the discussion points raised by their activities were challenging to present and perhaps better suited to an older audience. Many of the younger visitors had difficulty grasping the scientific ideas behind the activities, but seemed to enjoy them on a surface level since many incorporated pictures, drawing, or colorful components. The Kit of Parts activity, in particular, seemed challenging in that it required participants to think in terms of abstract models. Ignoring the underlying science, however, a young child could still engage in a puzzle activity with the

multicolored pegs and blocks. Older children, however, could readily grasp many of the topics. One thirteen year-old boy at the Tech Tokens table spent a considerable amount of time discussing biofuels with a facilitator and the pros and cons using corn as fuel rather than food.

Due to the museum's proximity to Research Triangle Park, Duke University, and other schools, many of the adults at this event held science degrees themselves and were very engaged in the discussions and activities. One parent, who mentioned his own degree in biomedical technology, seemed especially into the Tech Tokens activity and talked at end with facilitators about the nuances of how different research topics are funded. One graduate student facilitator, who was experienced in outreach and had also helped at the prior year's event, said of this museum's audience, "It's kind of like preaching to the choir sometimes."

By the end of the event, each group of facilitators had developed strategies for scaffolding their activity up or down depending on their audience. One group described how they would first demo their activity for their audience, then invite the audience to do it with limited parameters, and finally give the audience the full activity (e.g. the Kit of Parts cards with more complicated goals). This seemed to work well for visitors' understanding, but the facilitators commented on how this approach required talking *at* the participant quite a bit on the front end of the activity – opposite of the goals of PES. In the end, however, these steps often led to interesting discussions with participants once a basic understanding was established. Facilitators talked about the ethical issues they discussed with visitors – for example, who should have access to certain types of technology.

The Children's Museum, Indianapolis and the Dow Science Ambassadors

STEM Lab – The Children's Museum, Indianapolis, Indiana

The Building with Biology event held at The Children's Museum of Indianapolis (TCM) emerged from an existing partnership between Dow AgroSciences and the museum. Dow AgroSciences is a subsidiary company of Dow Chemical that is based in Indianapolis. Dow AgroSciences has supported TCM in many efforts throughout its history, often by providing funding for science exhibits and programs. Dow AgroSciences is also home to the Science Ambassadors, a group of employees dedicated to public outreach focused on STEM. A leading member of the Ambassadors initiated the Building with Biology application and secured The Children's Museum as their partner and host site. In addition to the Science Ambassadors, several regular TCM volunteers helped run the event.

The Ambassadors regularly volunteer their time to run programs at science fairs and other events throughout central Indiana and were therefore more enthusiastic and experienced in public

outreach than scientists involved at some of the other Building with Biology sites. One Science Ambassador said she had worked as a high school teacher for fifteen years prior to working at Dow. Now she's part of the Ambassadors because she loves doing this kind of outreach. According to another Ambassador, Dow is also experienced in training its employees in outreach. For this particular event, the scientist lead held a training where the Ambassadors were able to try the activities and talk about the types of conversations and questions that might emerge when running the activities with different audiences.

Not all of the Ambassadors, however, had great familiarity with synthetic biology prior to the event. Many work in related fields such as biotechnology, but had to brush up on synthetic biology to run the activities. One facilitator commented that the cheat sheets included in the kit were especially helpful for this. The TCM volunteers who helped with the event in many cases had more to learn about synthetic biology than the Ambassadors. One TCM volunteer commented that working alongside the Ambassadors to facilitate this event was an interesting experience for her, because she is a proponent of organic food and opposed to GMOs. Despite her leanings, she said she was very open to learning about the science presented through the event and talking about it with others, showing that Building with Biology sometimes blurred the line between facilitator and audience and the outcomes intended for each.

Building with Biology – The Children's Museum, Indianapolis, Indiana

TCM and the Ambassadors scheduled their Building with Biology event on opening day of the newly renovated ScienceWorks exhibit (also supported by Dow) as well as the opening of STEM Lab – a lab space where museum staff lead hands-on programs with the public. This fortuitous timing was made even more apt due to STEM Lab's special goal of reducing the barriers between the public and science. STEM Lab is designed to feel welcoming and warm rather than cold and sterile like some labs, with the idea that all members of the public will feel at ease and can pictures themselves as scientists. The alignment of STEM Lab's goals and Building with Biology's goals therefore made for a fitting event.

The average visitor to The Children's Museum is under five years old, and the scientist lead therefore chose a selection of Building with Biology activities to use at the event based on what she felt was best suited for this young audience: Super Organisms, Bio Bistro, and Tech Tokens. These activities were set up at tables on the museum's second floor balcony. A version of the See DNA activity was also run in the STEM Lab itself on the fourth floor.

Similar to other sites, facilitators noted that there were some challenges in using the synthetic biology activities with a young audience. For example, although children enjoyed coloring superheroes for the Super Organisms activity, facilitators often had difficulty working the science content into the conversation. One facilitator commented that science terms like "genetic engineering" can be intimidating even to adults. Although presenting synthetic biology activities to young children brings challenges, one Ambassador talked about the importance of science engagement at an early age: "If you wait until kids are in high school to show them that science is not hard and it's really cool, it's already too late." She pointed out that the kids who did the Building with Biology activities, like extracting DNA, are learning at an early age that science is fun and not difficult.

Parents at The Children's Museum tended to stand back and let their children engage in the activities, particularly when children were coloring their Super Organism characters. They did, however, join in the conversations around the Tech Tokens and Bio Bistro activities. The "Would you eat that?" discussions spurred by Bio Bistro tended to draw in all audiences, showing that food is a good entry-point for conversations about science. One caregiver reacted to the activity card for a pill that serves as a meal replacement by saying, "I don't know. I like my food too much!" Parents who did get involved in the activities were also able to provide helpful scaffolding comments that made the activities more accessible for their children. This help was especially important for Tech Tokens, which is a text-heavy activity.

Another challenge of the event at TCM was the location of the activities. Although the chosen spot on the second floor balcony provided space and relative quiet away from more crowded areas, this also resulted is less traffic from visitors. Nevertheless, the facilitators were not deterred in their mission and seemed genuinely enthusiastic about the cause. The partnership between the Science Ambassadors and TCM is a valuable one that many other host sites in the project seek to foster at their own institutions.

Montana State University, Bozeman, Montana

Like the Dow Science Ambassadors and TCM in Indianapolis, the Building with Biology event hosted by Montana State University in Bozeman was an effort led by the scientists rather than an informal education institution. Extended University at MSU is a special department dedicated to providing learning opportunities and outreach events beyond the traditional campus classroom. Having previously run Nano Days events as part of NISE Net, Building with Biology was a natural opportunity for Extended University to pursue.

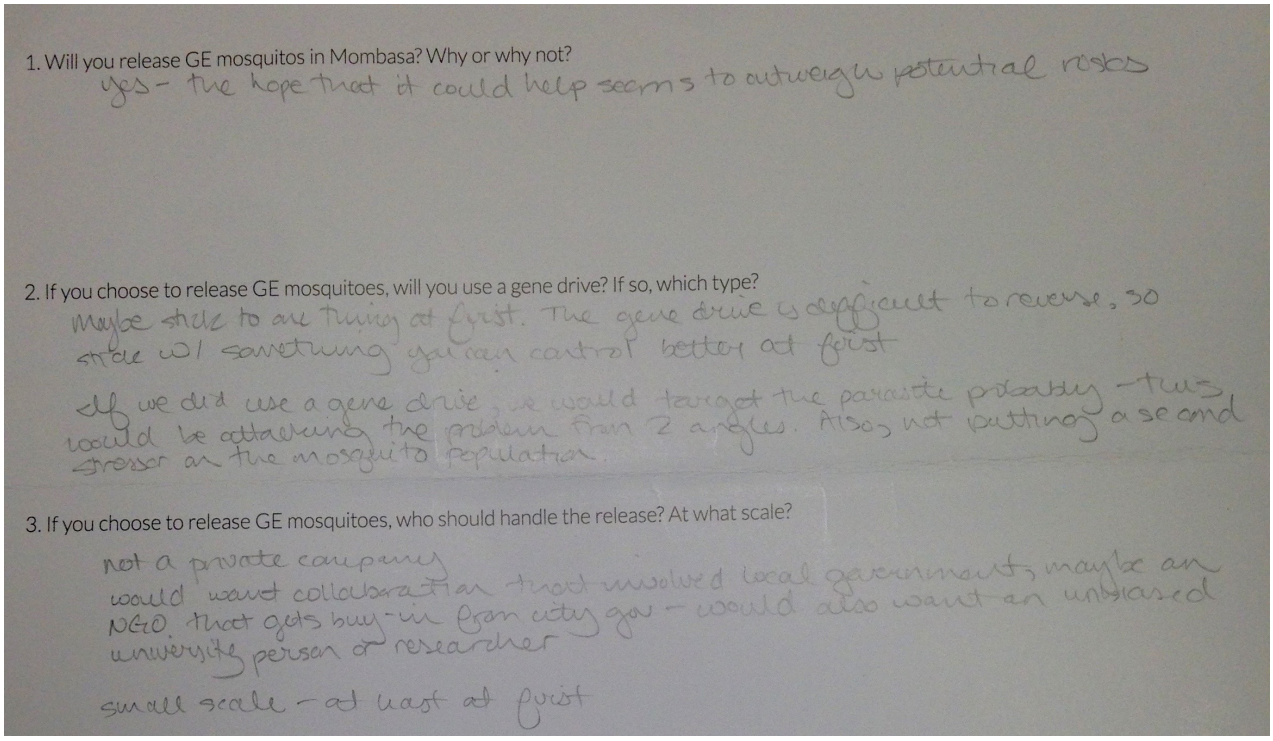
Part of Extended University's mission is to provide learning experiences beyond the community immediately surrounding the Bozeman campus, where families already have ready access to a variety of opportunities. For this reason, the site leader chose to partner with the Belgrade Community Library for the event. Belgrade is a satellite community of Bozeman and home to about 8,000 people. Although close to Bozeman, Belgrade has a more rural feel and does not have as many opportunities for partnering with university scientists. The Belgrade Community Library was therefore happy to be a part of the project by lending their space for both a Building with Biology event and a forum.

The event leader recruited professors and graduate students from various departments on campus, including Biology, Neuroscience, and Engineering to facilitate the event. The location of Extended University's event also contributed to this being one of the smallest Building with Biology events in the project. Fewer than ten people came to the event, and six members of the public participated in the forum on a separate evening. As a result of its small size, however, this event led to deeper engagement between visitors and scientists, as each person had the opportunity to ask questions and converse in an environment that was neither rushed nor crowded. Not all of the kit activities had scientists to facilitate them, but visitors nonetheless circulated through each activity in turn, trying everything available. Child attendees ranged from approximately 8 to 13 years old and were therefore old enough to have involved discussions about the science concepts. Explanations about the size of DNA led to discussions about micro and nanoscales with facilitators drawing diagrams in visitors' passports. Children related the experience back to things they'd learned in science class, and others talked about what they'd do if they could change their DNA:

> Facilitator: "If you could change something about your DNA, what would you change?
> Child: "I'd make it so I can fly."
>
> Facilitator: "What do you like about synthetic biology?"
> Child 1: "Well, I don't like it that some people might use it to make a drug that does something bad."
> Child 2: "I like that it might help people."

Thanks to their interest, visitors at the Belgrade Community Library ended up spending 15 minutes or more on activities that were originally intended to take only a few minutes. One thoughtful child at the Tech Tokens activity debated the merits of funding synthetic flavorings versus cancer treatment versus crop production. "No one's gonna die if they don't get their vanilla in their cookies," he commented. He then went on to point out that although cancer is a terrible disease, it doesn't affect everyone the way that food does, and therefore investing in crop production might be better than investing in cancer research. "I just need more money," he declared. "More money for research." With the extended time groups spent at each activity, facilitators noted that they were able to bring the activity to its conclusion and discuss the deep ethical and societal questions underpinning it – something that was unlikely to occur in a shorter time span. Thanks to the enthusiasm of the participants, the library stayed open an extra half-hour past their usual closing time so families could continue talking with the scientists.

The library also extended the reach of the Building with Biology activities by keeping them on display during the weeks surrounding the event. Although not official facilitators for the event, the library staff took the initiative to study the activities and background material so that they could answer questions and facilitate for any library patrons who showed interest.



Participant worksheet from "Should we engineer the mosquito?" forum – Belgrade Public Library, Belgrade, Montana

Extended University held their Building with Biology forum – "Should we engineer the mosquito?" – at the library on a separate evening. Six members of the public attended, having come to the library specifically for this event, and a few extra facilitators from the university sat at each table. The lead facilitator for the evening was an entomologist from MSU who specializes in risk assessments for agricultural technologies and integrated pest management theory. He opened the evening's discussion by relating the topic back to something local – Lewis and Clark's expedition and their battles with malaria. From there, the evening followed the flow dictated by the forum instructions and cards. The public participants were attentive and engaged, asking many thoughtful questions. Several of these individuals had careers or degrees in science fields, such as entomology and microbiology. Although they were interested in the science concepts presented, the group became particularly engaged when the discussion turned to the ethical issues at hand. They were particularly concerned about who should make the decisions regarding pest control and how local communities should be approached and involved:

> Participant 1: "If you lived there, would you be willing to have genetically engineered mosquitoes released on you?"
> Participant 2: "Yes, but who should do it?"
> Participant 3: "If an NGO did it, you would still want buy-in from the local government. You couldn't just force it on them…It's hard to say how local people might react. You'd think they'd want to try any solution available, but there's also likely to be distrust. You would want a community liaison."

The night ended with the group discussing similar issues in their own community, such as fluoride in their drinking water. Although the number of participants was small, the event was remarkably successful in fostering the type of dialog that is a core goal of the MSPES project.

The Tech Museum of Innovation, San Jose, California

The Tech Museum of Innovation in San Jose is a large and dynamic institution that takes pride in its location in Silicon Valley, described on their website as "one of the most inventive places on Earth." During this project, The Tech also had the benefit of working with Synberc, a renowned synthetic biology research program at U.C. Berkeley and one of the core MSPES partners. Approximately fifteen graduate students from the Synberc program volunteered to facilitate The Tech's Building with Biology event and also took part in a training session just prior to the event itself.

The Tech is home to an exhibit called BioDesign Studio, which provided the perfect context for the Building with Biology event. This exhibit – which focuses on synthetic biology, bioengineering, biological design and DIY biology – complemented the Building with Biology activities and provided visitors with additional ways to engage with the concepts being presented. The event utilized all six kit activities at stations manned by pairs of facilitators.

Building with Biology - The Tech Museum of Innovation, San Jose, California
Photo courtesy of the Tech Museum

Because most of the volunteers had some experience working with public audiences, interactions with visitors were relaxed and conversational. Volunteers seemed at ease talking about synthetic biology and easily made connections to real-life examples to help visitors contextualize the information. The Synberc volunteers needed very little facilitation assistance from The Tech staff. They provided many personal anecdotes to humanize the topics, connect more readily with visitors, and offset typical stereotypes about scientists. Visitors were interested in the volunteers' course of study and in their opinions about scientific research. By speaking about their own research, volunteers were able to scaffold content about science before initiating the formal activity.

Some of the activities required the Synberc volunteers to adopt more of a "lecture" approach, but for the most part they were successful in facilitating conversations and communicating in a manner that made visitors feel comfortable and interested to learn more. The volunteers conducted a good deal of peer-peer training on the fly (e.g. suggestions on how to present content, questions to ask, issues to present). This method appeared to help volunteers ease into each activity, and resulted in the development of some excellent on-the-spot engagement strategies.

The majority of visitors to the event were family groups, and in many cases parents also became facilitators of the conversation, scaffolding the material for their children in a manner observed at other Building with Biology events. Adults also seemed eager to talk to the scientists while their children were occupied with the activities, leading into more advanced discussions of the science topics. Similar to other events, the Bio Bistro activity was particularly successful in stimulating conversation. Volunteers asked questions such as "How will synthetic biology impact the food market" and "Do you think synthetic biology would make this food nutritious?" Visitors often brought their own experiences into the conversation. For example, one woman from Spain talked about her country's issues with synthetic milk, and a group at the See DNA activity brought up their concerns about the Zika virus.

Overall, audience engagement at the event was high and volunteers were happy with their experience. As with other sites, volunteers did experience some issues facilitating the more complicated activities with young children. Facilitators viewed the Kit of Parts activity as the most difficult in this regard. Despite this difficulty, museum staff were eager to employ the activities at future events, and most of the Synberc volunteers expressed enthusiasm about pursuing similar outreach opportunities in the future.

The Buffalo Museum of Science, Buffalo, New York

The Buffalo Museum of Science is a small science museum located in an industrial area of Buffalo, NY. Running public programs out on the museum floor was a relatively new undertaking for staff at the museum, but their new CEO supported the endeavor. The Building with Biology activities were set up on either side of a large hall that serves as the main thoroughfare to various exhibit areas. The Buffalo Museum of Science tends to attract locals, but since the museum's Building with Biology event was held the Saturday after a huge festival at the museum, there was little foot traffic for the first few hours of the event.

Building with Biology – Buffalo Museum of Science, Buffalo, New York

The host site was able to recruit one scientist in chemical and biological engineering from the University of Buffalo to facilitate the event along with six regular museum volunteers. Unfortunately, the scientist did not engage much with the public throughout the event. He may have been unfamiliar or uncomfortable with the events' format. It is also possible that the host site did not clearly communicate their expectations for his role. He had not previously participated in any Building with Biology webinars or in-person training, and it was unclear if any training was offered to him by the host site. Although he brought posters highlighting his students' research to the event and hung these on display, these did not become a

catalyst for conversations. He did, however, have one substantive discussion with an adult visitor who approached him wanting to know more about the process of extracting DNA, how scientists know what to extract, and whether they currently have the ability to influence traits.

In contrast, the museum volunteers who manned the Building with Biology activities had a variety of backgrounds and previous experience in public outreach. Four had science backgrounds that included the areas of biology, physics, chemistry, math, anthropology, geology, and paleontology. Two had education backgrounds. The volunteers had previously participated in a training session at the museum to review the Building with Biology activities. Three of the volunteers indicated that they had done some reading on synthetic biology previously. One volunteer noted that she was looking forward to having conversations with visitors about science and becoming more at ease with the topic of synthetic biology because she felt that the issues surrounding synthetic biology will become more prevalent in the future. Another facilitator, the Science Learning Director at the Museum, also expressed the opinion that the topic was an important one to cover with visitors: "I don't think that our region is aware enough of what synthetic biology is, its applications, and what it can be, the origin on many products."

Although the event was not well attended, visitors who did engage tended to visit multiple Building with Biology activities. The most popular activities appeared to be Super Organisms, See DNA, and Bio Bistro. In particular, conversations at the Bio Bistro seemed to generate the most discussion around the ethical implications of synthetic biology. The facilitator of the Bio Bistro activity positioned synthetic biology as a fast and effective solution to a societal problem. He made a point, however, not to take sides on whether synthetic biology is positive or negative, instead focusing on the "coolness" factor of scientists' ability to manipulate genetic code. Here the facilitator talks about the pros and cons of genetically modified foods with one mother:

> Mother: "I've heard there's genetically engineered foods."
> Facilitator: "It's had different uses for years. This uses genetic code that modifies food. Synthetic Biology is the fastest, most effective way to get to a problem. I don't have an opinion on it personally or professionally."
> Mother: "It's weird."
> Facilitator: "Synthetic flavoring happens every day. You wouldn't need a coffee plantation, so less environmental impact."
> Mother:" I don't know what chemicals I'd be putting into my body."
> Facilitator: "Not fertilizers because its in a lab manipulating genetic code." [The facilitator goes on to explain golden rice.]
> Mother: "It's still actual rice."
> Facilitator: "They take the genetic code missing from other plants to genetically make rice that tastes like rice. Science is improving health and nutrition. People claim it tastes funny."
> Mother: "It's interesting."

Some Building with Biology activities, like See DNA, Super Organisms, and Kit of Parts tended to attract very young visitors. Volunteers sometimes used these interactions as opportunities to talk about the science in more depth with parents. For example, one volunteer indicated to parents that the Kit of Parts activity was a model using blocks to represent how synthetic

biologists use cells. Volunteers at these activities also tried to define synthetic biology and DNA in simple terms for visitors. In contrast, the volunteer running the Tech Tokens activity felt that it was suited to older visitors because it required them to take on different roles in order to make decisions about how they would allocate research funding.

In sum, although the event did not attract a large crowd, volunteers felt that they had had good science-related conversations with visitors and that visitors had enjoyed participating in the activities.

Oregon Museum of Science and Industry, Portland, Oregon

The Oregon Museum of Science and Industry (OMSI) is a large science museum near the river in an industrial area of Portland. OMSI decided to hold a forum and catered lunch with an invited group of museum visitors in the late morning and then transitioned to the Building with Biology tabled activities in the afternoon. The space for both events was located off the beaten path of the museum in an auditorium that does not receive heavy traffic. The forum event took place in the center of the room at seven round tables, while the kit activities (plus a Building Immunity demonstration created by OMSI) were distributed around the sides of the room.

Building with Biology – Oregon Museum of Science and Industry, Portland, Oregon

Nine graduate students and one professor from Portland State University and Oregon Health and Science University facilitated the forum and the hands-on activities. Most facilitators were scientists in biology or chemistry and had experience with synthetic biology through their coursework and/or research. The scientist volunteers were interested in learning more about what the public thinks about synthetic biology and how to best address some of the misconceptions that surround the topic: "Interfacing with the public, educating the public is important in technology fields, which have a high bar in terms of background. It takes that much more work to see how members of the public can evaluate technology and how it should be used in a realistic sense as opposed to fear or a superstitious sense." Several noted that they get to discuss synthetic biology issues with their lab mates, but not with public audiences. While some had experience talking to the public before, others wanted more experience communicating around scientific issues: "I like science outreach. It will make me a better scientist to learn how to communicate my ideas and get them [the public] interested in science. Science is shrouded in mystery, and it's hard to trust."

OMSI chose to offer the forum, "Should we edit the genome?" and distributed their scientist facilitators among the tables with the public as well as some museum volunteers. Public participants represented a range of age groups, with mostly adults, a few elderly couples, and a few teenage children. The

forum began with an introduction to the forum format by an OMSI educator. Next, the lead professor asked members of the public to talk with others at their tables about what CRISPR is and later share that information out to the larger group. He proceeded to go through various concepts using a PowerPoint presentation and showed a short video about CRISPR. The scientist used a lot of jargon without unpacking the terms, but the audience seemed to enjoy the lecture-like format. Afterwards, each table was tasked with selecting a synthetic biology application to discuss and to make recommendations about its use, potential risks, regulation, and marketability. The various groups selected different applications, such as mosquitos, spider silk, genetically modified wheat, and HIV. Group conversations tended to weigh the benefits of the application with the ethics of its use. Groups also talked a lot about who should be the regulatory body for such applications. One scientist noted, "It's not the responsibility solely of scientists to decide how technology can be used. It could lead to negativity if other voices aren't heard." Another group reported out,

> "Wheat has parasite resistance, water efficiency, and impacts gluten intolerance. Monsanto has had public backlash and shows the dangers of commercialization. There's a responsibility of popularizing the rest in the hands of a company, not just a university lab. Is it ethical to hike prices during a drought? Four companies currently regulate it. We'd use the current model, but it could be optimized to balance regulation with public education."

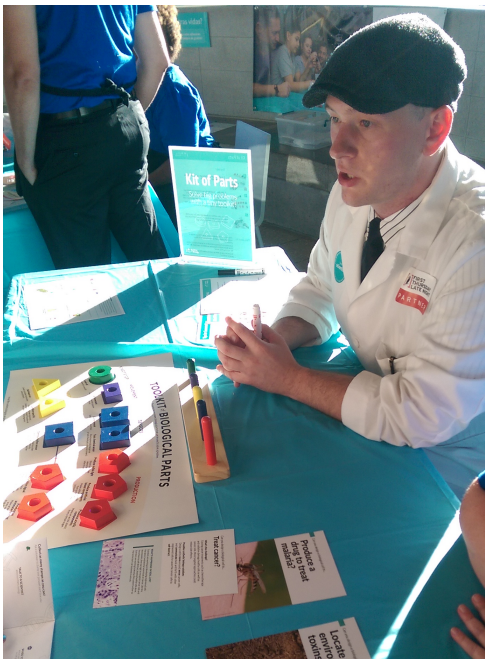
After the forum concluded, scientist volunteers reflected on the experience. One scientist shared that she was "more interested now in educating the public and improving relationships between scientists and the public." Another noted that she liked hearing participants' opinions. "Normally I'm locked up in a lab. I don't hear what people have to say," she stated. A few volunteers had suggestions for future forum events, such as holding a forum at a restaurant or inviting environmental groups or skeptics to take part in the conversation.

Ten forum participants stayed to explore the Building with Biology activities. At the event's peak in the early afternoon, there were 25 museum visitors exploring the Building with Biology activities and engaging with facilitators. Scientist volunteers alternated between offering lecture-like presentations, often seen at the See DNA and Building Immunity demonstrations, and conversing with visitors about the societal and ethical implications of synthetic biology, often at the Tech Tokens or Bio Bistro stations. For example, one scientist at the Bio Bistro station shared the pros of consuming a food pill with visitors: "What makes you feel full is the act of eating (con). That meat would not be raised from an animal, so there would be no animal suffering (pro)."

The scientist volunteers later reflected on the strengths and weaknesses of various Building with Biology activities. One scientist liked the Tech Tokens activity because it allows visitors to take on the perspectives of others. Others liked the Bio Bistro activity because it let them hear dissenting opinions because people have strong opinions about where their food comes from. Scientists at the VirEx Delivery station liked providing visitors with a fun analogy and something to take home. Overall, participating scientists enjoyed talking with visitors. As one facilitator put it, "Hearing the public talk about science is fascinating."

Perot Museum of Nature and Science, Dallas, Texas

The Perot Museum of Nature and Science is a large science museum located in downtown Dallas. The Museum is open late on the first Thursday of each month and holds popular themed events paired with an IMAX movie during those times. The Building with Biology event was scheduled for this time slot, and the kit activities were prominently displayed on tables in the lobby. A large number of people flowed through this space during the event's two-hour block. During the first hour, there were approximately 50-65 visitors across the space, and numbers were still robust (approximately 32 people) in the last half hour. One volunteer noted that the event drew the Museum's typical summer audience, but that there were more activities available for Building with Biology than they typically had out on the floor (eight compared to the typical five).



Building with Biology – Perot Museum of Nature and Science, Dallas, Texas

Six graduate students from the University of Texas, Dallas facilitated the Building with Biology event. Most studied biomedical engineering and did not have prior experience working with public audiences. The scientist volunteers were excited to have an opportunity to talk about a complex topic with visitors and to learn about the public's thoughts and reactions. Most scientists were paired with 1-2 museum volunteers during the event but tended to lead the interactions with the public themselves. The scientists all wore white lab coats and "I'm a Scientist" stickers to identify themselves to visitors.

During the event, some Building with Biology activities lent themselves to more lecture-style interactions with the public (e.g. Kit of Parts, VirEx Delivery, and See DNA), whereas other activities elicited more two-way conversations that took visitors' perspectives into account (e.g. Bio Bistro and Tech Tokens). For example, the volunteer scientist facilitating the Bio Bistro activity brought up the pros and cons of genetically engineered meat and asked for visitors' opinions on the topic. He also asked visitors to justify their different food selections ("What made you choose X?"). Regardless of the format, most interactions around Building with Biology activities lasted 3-6 minutes.

When participating scientists did engage in two-way dialog, it was often with the adults in the visiting group. These conversations were usually initiated by the visitor or by a museum volunteer rather than the scientist facilitator, perhaps indicating that the facilitators were uncertain how to generate this type of dialog. For example, at the Tech Tokens activity, one mother engaged a scientist in a discussion of where the money in synthetic biology is currently being spent. Once the museum volunteer at this station indicated that the visitor was talking to a real scientist, the scientist then shared about his own research. However, such an interaction (detailed below) was the exception rather than the rule.

Scientist: “We can use synthetic biology to do this.”
Mother: “I don’t think we should be putting ethanol in our gas.”
Mother (to child): “Where do you think you would make the most money?”
Mother (to scientist): “Have you been following Monsanto and the pest control issue? They sold an aggressive soybean to farmers. They were supposed to sell with fertilizer.”
Scientist: “There are cool studies in pest control to reduce mosquito populations.”
Mother: “Especially with Zika now.”
Mother (to child): “The businessman wants to make money.”
Scientist: “A lot of money in synthetic biology is in cosmetics, growing extracts for perfumes.”
Mother: “Oh! I didn’t know that.”
[The child selects biomedicine and cancer treatment for the role of the US government.]
Museum Volunteer: “He’s a real scientist!”
Scientist: “I work in the lab and tutor in my free time. I’m studying cancer using synthetic biology to see how it affects how it grows.”
Child: “Which is getting the most investments? Cancer and biomedicine?”
Scientist: “Flowers and cosmetics.”

After the event ended, participating scientists indicated that they would definitely do public outreach like Building with Biology again, and were particularly interested in testing out the forum format.

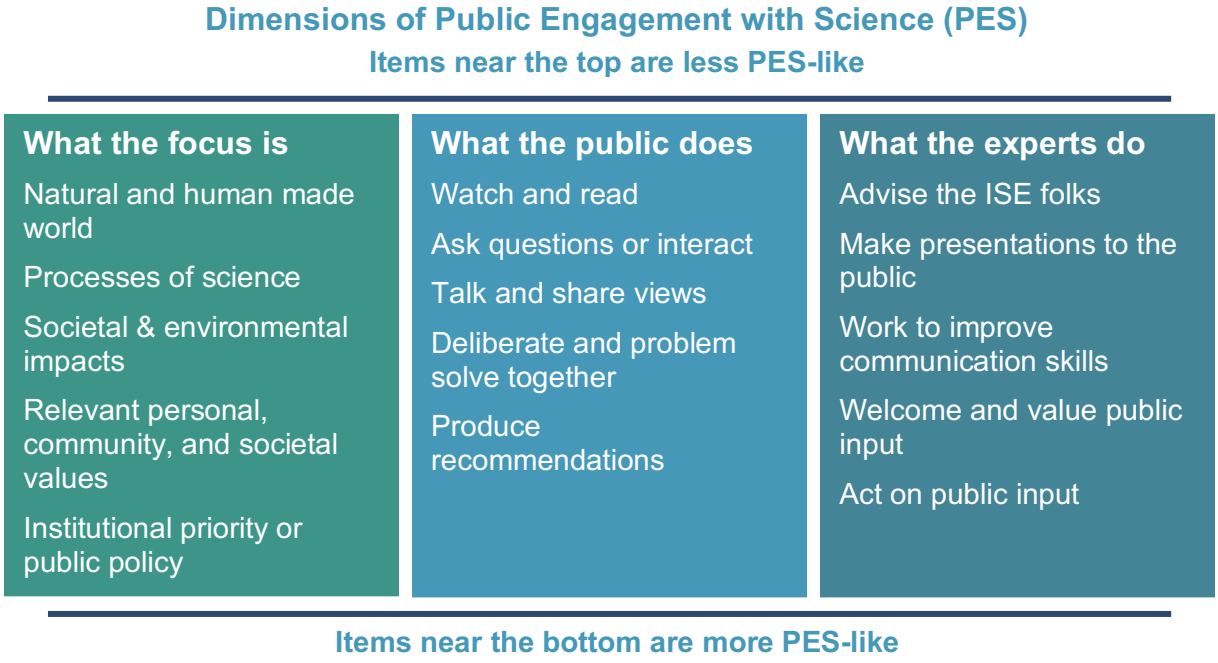
Outcomes for Host Sites

With the far reach of the MSPES project in Year 2, outcomes for host sites varied based on their level of involvement and their previous experience with PES, synthetic biology, and organizing outreach events with scientists. On the whole, hosts reported increased knowledge of PES and synthetic biology, as well as greater confidence with skills related to hosting the Building with Biology events. In addition to new skills for Building with Biology hosts themselves, people reported positive outcomes for their institutions, including new relationships built with scientists and ideas for future programming.

Public Engagement with Science

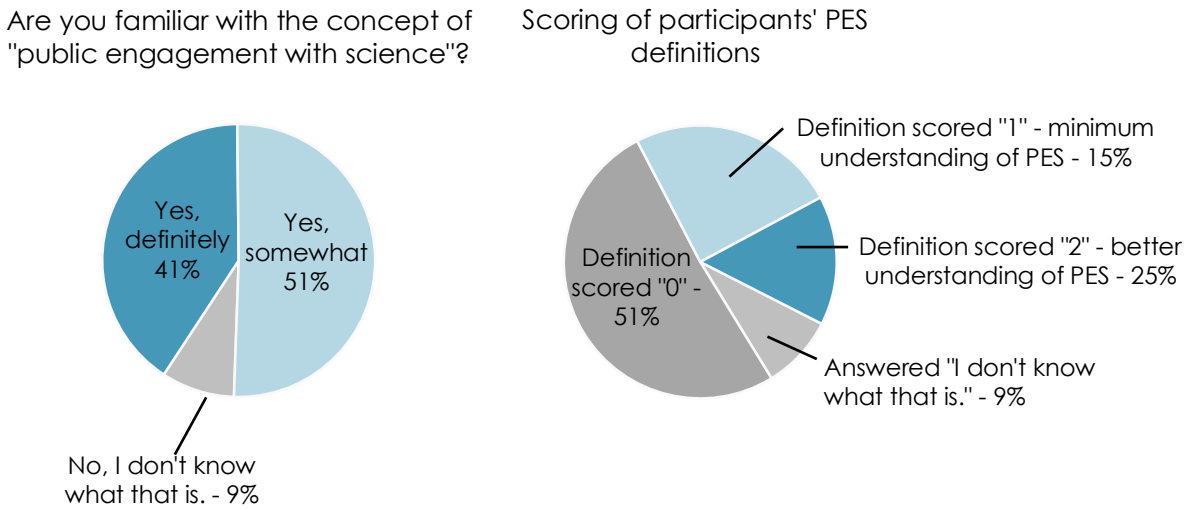
"Public Engagement with Science" is a term that may seem self-explanatory, but it refers to a very specific set of practices in the context of the MSPES project. The Building with Biology website refers to Public Engagement with Science as "creating conversations between scientists and publics that both value and learn from." The term PES stands in contrast to PUS, "Public Understanding of Science" – the more traditional approach to public outreach that treats the public as learners who receive information from more knowledgeable individuals such as scientists or other experts. The different facets of PES are represented in the diagram below (also from the Building with Biology website).

Figure 10. Dimensions of PES
(from Building with Biology website)



Prior to any training they received from the MSPES project, 91% of hosts reported at least some awareness of PES. Over half of these individuals said they were "definitely" familiar with the concept.

Figure 11. Hosts' Prior Experience with PES
(Pre-survey data, n=137)



When participants were asked to provide a definition of PES, however, their answers frequently did not align with the goals of the project and its definition. Many participants, for example, defined PES as any kind of outreach where the public encounters science topics. Others referred to hands-on or inquiry-based learning, for example, "'Public engagement with science' refers to improving the public's understanding of science by meeting scientists, engaging them on their current research methods and topics, and participating in learning activities that relate to such research." Participants' responses were coded based on alignment with the project team's definition of PES. Using a simple scoring system, participants received a 1 if their definition made any reference to conversations, dialog, or discussions between scientists and the public. We considered this the minimum threshold for counting as a PES experience. Examples of definitions that received a 1 include:

> "Interactions that promote communication between scientists and the public."
>
> "Providing information to and having conversations with the public on scientific issues. Bringing scientists and lay people together to discuss science."

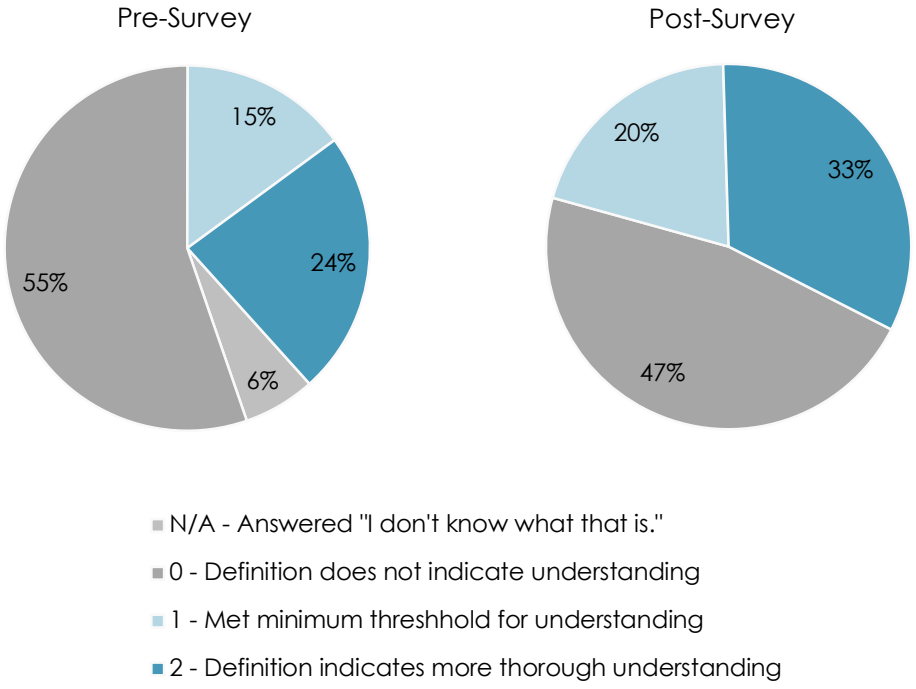
Participants received a "2" if their definition specified that the discussion was a two-way dialog, if they referenced mutual learning, if they talked about the public getting to share their own opinions and ideas, if they mentioned discussion of societal implications, or if they talked about

the public shaping policy or other advanced stages of PES. Some definitions that indicated a more advanced understanding and received a 2 include:

> "public and scientists engaging with each other, knowledge being shared in both directions (from public to scientists and from scientists to the public)"
>
> "bringing the public and scientists together in a multi-directional conversation that doesn't assume that scientists are the only ones to have something worthy to share"

Reviewing respondents' definitions of PES using these criteria showed that understanding of the concept according to the project's definitions was substantially lower (Figure 12). Comparing matched pre and post responses to the question showed a 14% increase in the number of hosts whose definitions were scored a 1 or 2. Nineteen percent of the total matched pairs (18 individuals) increased their scores by one point from pre to post, while 11% increased their score by two points (10 individuals).

Figure 12. Hosts' Definitions of PES
(Matched pre/post surveys, n=94)

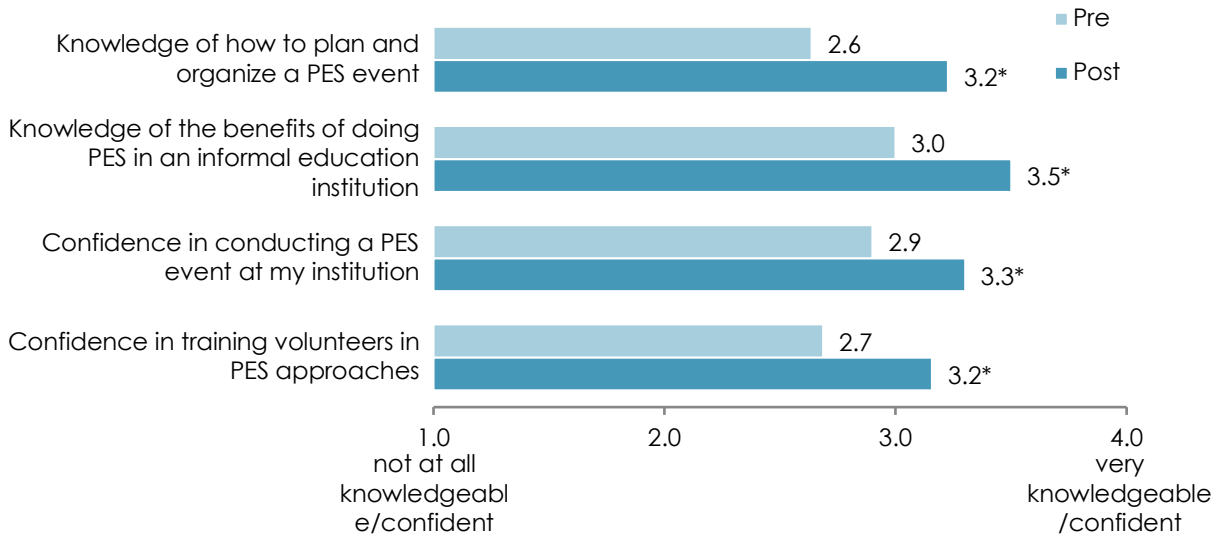


Post-survey participants who said they had participated in a project webinar generally gave better definitions of PES. Fifty-seven percent of these individuals gave a definition of PES that scored a 1 or a 2 (n=70), compared to 42% of those who hadn't participated in a webinar (n=24). Participants who had watched two or more webinars were even more successful in giving correct definitions, and those who watched three or more were better yet. Hosts' responses show that

PES can be a tricky thing to define. The name itself does not necessarily capture the full meaning of the concept and can suggest a number of broader ideas related to outreach. The more invested a host was in their training, however, the more likely that they gained a better understanding of PES by the end of the project.

Regardless of whether hosts could adequately express the meaning of PES in a written definition, their survey responses showed a significant increase in confidence in and self-reported knowledge of PES (Figure 13). Prior to their participation, average confidence and knowledge scores for several items relating to PES fell at a 3.0 or lower (where 1=not at all knowledgeable/confident and 4=very knowledgeable/confident). Following their participation, however, scores on each of these items rose by at least 0.4 points, placing respondents firmly within the positive end of the rating scale.

Figure 13. Changes in PES Knowledge/Confidence for Hosts
(Matched pre/post surveys, n=101)



**Using paired sample t-tests, comparison of hosts' responses showed a significant increase in confidence/knowledge from pre to post on the four survey items above ($p<.05$).*

Hosts who were interviewed about their experience generally said they already had some understanding of PES coming into the project and that participating in Building with Biology solidified and built on their previous knowledge of the concept. Some hosts had previous experience with PES through the NISE Net project or as pilot sites in the first year of MSPES. These individuals didn't necessarily learn new things about PES in the abstract, but they did gain additional experience in running PES events. The forum was also a new PES format for some hosts. Another host who had not been involved with NISE Net or Year 1 of the project said that although she was previously familiar with the term, "PES," this project gave her a greater

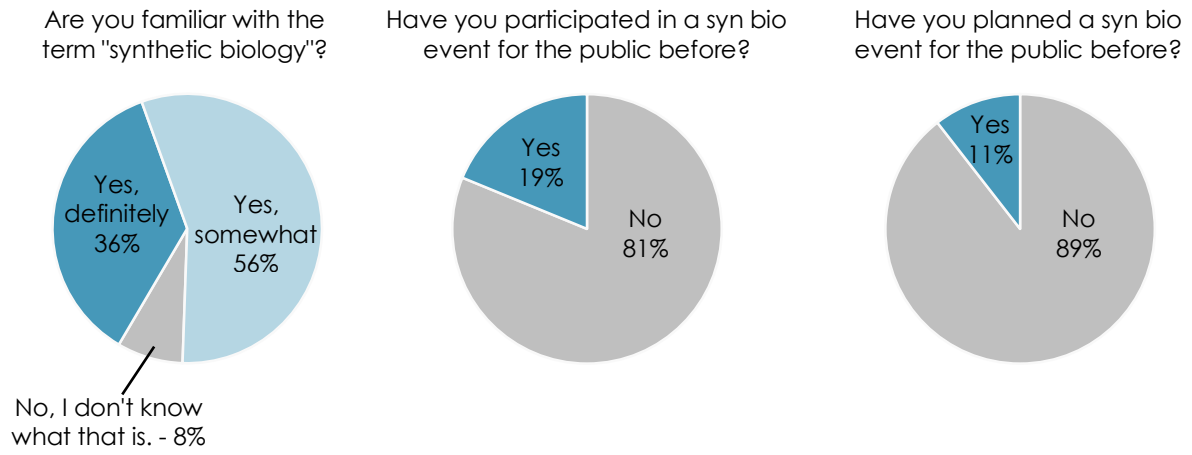
understanding of the concept and the difference between bringing scientists to her institution to give lectures and having a two-way dialog with the public.

When asked if their confidence in doing PES had changed, about two-thirds of interviewees responded "yes." Some talked about their increased confidence working with scientists and providing them with training. Those who said their confidence had not increased cited their existing comfort with PES from previous projects or the fact that they did not help facilitate activities for this particular project and therefore did not build their PES skills.

Understanding of Synthetic Biology

Unlike PES, most participating hosts had little prior experience with synthetic biology – at least when it came to presenting this science topic to public audiences. On the pre-survey, 92% said they had at least some familiarity with synthetic biology, but only 19% had participated in a synthetic biology event for the public, and only 11% had planned one of these events (Figure 14).

Figure 14. Hosts' Prior Experience with Synthetic Biology



The project team initially thought that hosts and the public might be wary of synthetic biology and perhaps even fearful of its implications, whereas they felt scientists might have a more optimistic perspective on the topic. They sought to balance these two extremes by including both the benefits and potential concerns relating to synthetic biology in the kit and forum activities:

> "I think some people hear 'synthetic biology' and maybe don't know what it means, or when they start to learn a bit more about it, they start to think about frankenfoods or genetic engineering or things that have been perceived in society as scary things, things that are sort of out to harm us. I think the Building with Biology project took a really positive approach to generating conversations. It tried very hard not to present an 'everything is great,' rosy, wonderful picture. It definitely acknowledged some of the issues with synthetic biology, societal concerns, ethical concerns, and trained scientist

and museum practitioners in how to have those conversations." – *MSPES project team member*

When asked what they hoped to learn from their experience hosting Building with Biology events, developing a better understanding of synthetic biology was a top goal for many respondents. Hosts wanted to learn more about this topic themselves, as well as how to present it to the public:

> "I hope to gain a stronger knowledge of synthetic biology fields that I may use to educate the public and my peers in future programming."

> "I hope to greatly increase my knowledge and understanding of synthetic biology. I expect to create and strengthen relationships with scientists in the community. I hope to learn how to explain synthetic biology technology to visitors, including children."

Hosts were also asked to provide a definition of synthetic biology on both their pre and post surveys. Interviews and observations during the first year of MSPES showed that defining synthetic biology is no easy task, even for those who make up the central project team. It is a difficult topic to describe concisely, and considerable debate exists within the scientific community about what exactly does and does not constitute synthetic biology. For this reason, hosts' definitions were not scored by degrees of correctness in the same way as their PES definitions. Some definitions clearly showed confusion about the topic on the pre-survey, with improvements on the post. Examples of these are shown in Figure 15 below.

Figure 15. Hosts' Definitions of Synthetic Biology
Examples of improvement

Pre-survey	Post-survey
I would define it as body parts built with non-biological materials by scientists. The bionic man/woman type of thing.	Creating biological parts or systems with new materials.
Machine-made	Engineering and Biology together to produce something useful and/or helpful.
Man-made organic compounds	Manipulating biological material to redesign organisms to meet the changing needs of human populations.

Hosts' definitions were also reviewed for references to engineering, since members of the MSPES project team agree that synthetic biology utilizes principles or practices from that field. Looking at matched responses, the number of definitions that include mentions of engineering increased from 45.5% on the pre-survey to 64.4% on the post-survey (n=90). This jump suggests the project had success in conveying this important aspect of synthetic biology to many of the hosts involved.

Hosts' post-surveys show that they thought the MSPES project was highly successful in providing information on synthetic biology – both what it is and how to discuss it with public audiences (Figure 16). Matched pre and post responses also showed significant increases in all measures related to synthetic biology confidence and knowledge (Figure 17).

Figure 16. Success of Project Support
(Post-survey data, n=114)

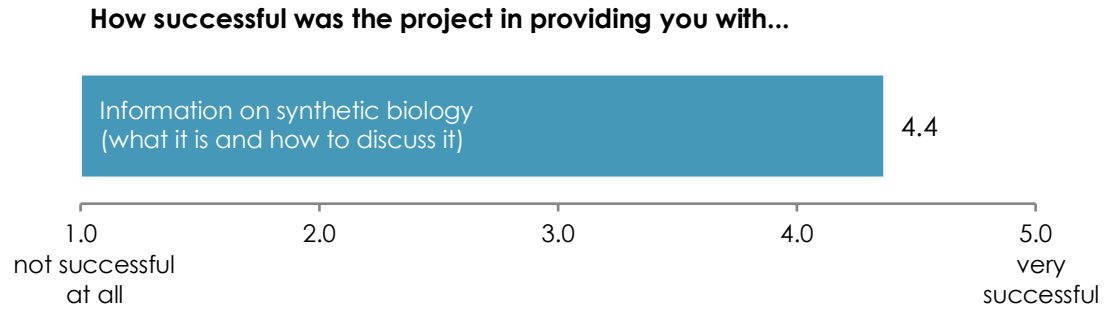
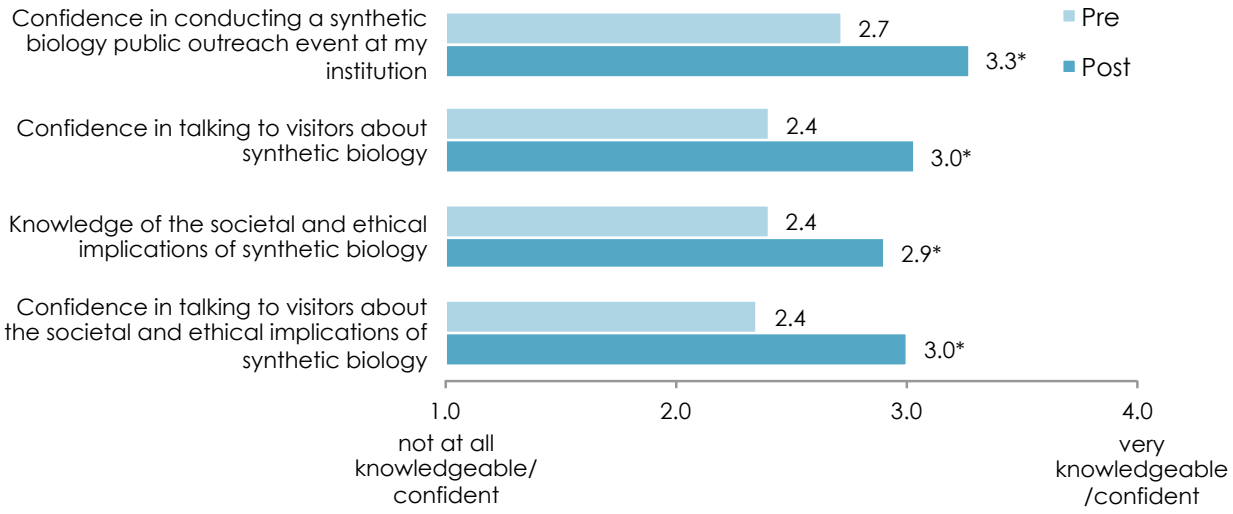


Figure 17. Changes in Synthetic Biology Knowledge/Confidence for Hosts
(Matched Pre/Post Surveys, n=101)



**Using paired sample t-tests, comparison of hosts' responses showed a significant increase in confidence/knowledge from pre to post on the four survey items above ($p<.05$).*

During their interviews, most hosts emphatically agreed that being involved in Building with Biology taught them a great deal about synthetic biology. Aside from one individual who already had extensive experience with the topic, most individuals said they had only a basic understanding of synthetic biology prior to the project, and some said they had no knowledge of the topic at all. Some individuals, having little previous understanding of synthetic biology, described great increases in their knowledge and confidence surrounding the topic:

> "I actually learned a lot. I feel I was very much on the same level as our general public. Going through this process and exploring the kits myself and with scientists was very beneficial in expanding my understanding on the topic."

> "I'm certainly more confident in talking about the content. Before I wouldn't have had a clue of how to start a dialog with audiences…not having the scientific expertise. But I can facilitate some of these activities and be confident with the content enough to get across the main learning objectives.

Other individuals, however, had backgrounds in science and therefore a better understanding of synthetic biology from the start. Even these hosts, however, said that the experience expanded their knowledge:

> "I usually just talk about transgenic animals…just taking one gene. Synthetic biology is taking all these different genes to make a new organism. We hadn't really thought or talked about it."

> "I really like how they lay things out in such accessible terms, like, 'synthetic biology combines new technologies using biology and engineering to make products or materials.' I think that has really helped me, and to think about the different applications is really cool. I have a degree in Biology, but I didn't get into the really extensive molecular details about. It's been really informative."

Overall, hosts said that the experience left them with a better understanding of synthetic biology as well as a better understanding of how to present it to public audiences.

Collaborating with Scientists

Making Connections

Building relationships between scientists and informal science educators was another primary goal of the MSPES project, and one that was at the forefront of many hosts' minds:

> "[I hope to learn] more about the field itself, tips for working with experts and supporting experts with speaking to public audiences."

> "Biological sciences are currently a gap for my organization. We hope to develop working relationships with the biology department of our local university as a resource for future programs and exhibits."

Hosts' survey feedback showed that these outcomes were achieved for most participants. Only three hosts reported being unable to find scientist partners, and 82% reported success in recruiting synthetic biology scientists, researchers, or graduate students.

While most sites were able to secure scientist volunteers, the task was not always easy. One project team member acknowledged that "trying to centrally coordinate people in an emerging field to show up to a museum they have never been to before and recruited by people they've never met" was a challenge. The project team noted that past NISE Net projects had not had a scientist participation requirement as a condition of receiving a kit, so the MSPES project contained an extra ask. Sites that had pre-existing relationships with scientists or researchers had the advantage over those who had to find new connections. Some sites also had access to local iGEM teams, groups of synthetic biology graduate students already involved in public outreach through their labs. Even with existing connections, however, many sites encountered issues with scheduling conflicts and attrition. Hosts reported that scientists would indicate initial interest, but there was a tendency to drop off as dates were solidified, trainings took place, and the event drew near. The response below was typical of many hosts' experiences:

> "Having NISE Net provide contacts was helpful when recruiting for the event(s). There was a lot of interest from volunteers in the beginning. However, very few people attended the orientation that was held prior to the event(s). It was helpful to send video links and orientation materials via email to those that did not attend orientation. Follow through of volunteers was also problematic because I had several people sign up for volunteering, but as the dates approached several people cancelled or didn't show up. Luckily, museum staff were also assigned to facilitate activities, but having scientists in the field share in dialog about their work is what elevated the experience."

Other hosts cited difficulty finding individuals with experience related to synthetic biology, since it is a fairly specific field as well as an emergent area of research:

> "It seemed like there is not much synthetic biology going on in my area. I contacted many professors and science departments, and no one seemed willing. I also contacted the outreach department at our largest private research firm and they did not have anyone, and those that worked with genetics loosely were not interested in facilitating activities that they don't specialize in. I was so pumped to bring in scientists for this program, but it was so much harder than I thought."

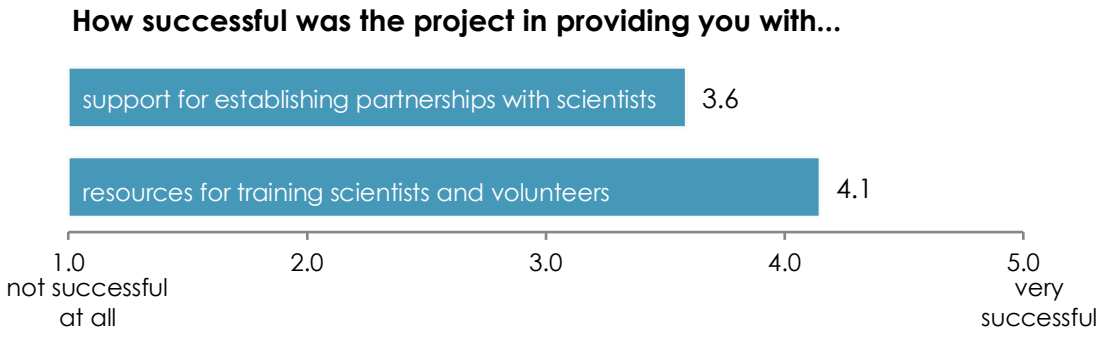
> "I discovered that synthetic biology is not a term that is used within the university where I was trying to recruit. I tried genetic engineering, molecular biology, genetics and other terms to help describe the type of science involved, but didn't get very far with my usual contacts within the university."

Several hosts also noted that university professors and graduate students often have very busy schedules that are arranged months in advance. This makes securing volunteers difficult, even if the host were to start recruiting a month or more before their event. Sites in rural areas also had

extra difficulties, with few local scientists to draw on. As a result, several sites utilized scientists with different specialties and museum volunteers to round out their pool of facilitators.

Those who had difficulty recruiting scientists did not generally place blame on the project. Instead, hosts responded that the project was fairly successful at providing support for establishing partnerships with scientists and even better at providing training resources for scientists and volunteers (Figure 18).

Figure 18. Project Support for Working with Scientists/Facilitators
(Post-survey data, n=91)



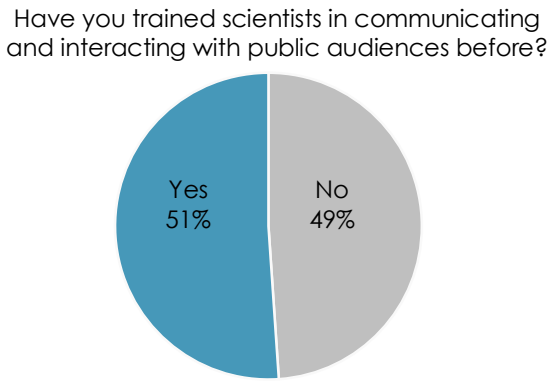
Some hosts provided suggestions for ways the process might have been made easier, such as providing a stipend to the scientists or having access to sample recruitment materials (such as drafts of introductory emails) or lists of potential contacts. Project team members also had a few ideas, including being more strategic about reaching out to interested scientists on behalf of sites before museums requested their contact information, going beyond email invitations to specific scientific societies, and providing early PES training to potentially make scientists more receptive to collaborating with museums later on in the process.

Training Scientists in PES

Almost half of the host participants said they had not trained scientists in communicating and interacting with public audiences prior to Building with Biology (Figure 19). While holding a training session for scientist facilitators was a key requirement for hosts involved with Building with Biology, these trainings varied highly from site to site. Some sites, such as the Tech Museum of Innovation in San Jose, opted to do a brief training session on the same day as their event in order to maximize turnout. These sessions generally last about an hour, with most of the time devoted to familiarizing facilitators with the kit activities. Other sites arranged a training session on a separate day with additional time devoted to using the training resources prepared by the MSPES team and sometimes the host sites' own resources as well. During more thorough trainings, the hosts would often use the AAAS PowerPoint and show some of the videos provided. Facilitators had time to try out the activities and do mock presentations. Sometimes these included discussions on how to field different types of questions from visitors. Many sites also sent the resources out to their facilitators ahead of time.

Often, the format of the training depended less on the hosts' preferences and more on logistical constraints such as facilitators' schedules. Several hosts commented that they weren't able to get volunteers until the last minute, which greatly affected the training they were able to offer. Project team members hypothesized that the time commitment, conflicting schedules, or an inability to find interested scientists in the first place may have resulted in less on-site trainings overall: "I'm sure some of it was that it felt like a big ask if you're already asking for a half day to do the activities. Scientists giving up time for the training - some sites felt like that was too much."

Figure 19. Hosts' Previous Experience Training Scientist Facilitators
(Post-survey data, n=139)



Regardless of how their training session was structured, most hosts felt that this orientation was successful. Almost all facilitators had the chance to review the activities ahead of time, which hosts saw as a great benefit. As one host said:

> "One of the most important parts is actually seeing and touching the demos and trying them. That also gives them [facilitators] a chance to ask really good questions and talk about what we might need to add or change….And then also a chance for them to see peers – other volunteers – presenting demos is also really good."

Testing the activities, watching others use them, and talking about how the activities might play out with the public were all helpful experiences. For some this was an opportunity to talk about general skills for engaging with the public. Some talked about scaling activities up or down for different age levels, and some talked about ways to extend activities with additional questions and conversations. Other groups tackled the more difficult issues of handling controversial subjects, should they arise. One host said that a great benefit of the training was having the opportunity to allay scientists' fears about talking with audiences who might have conflicting views:

> "Because we're in the Midwest, people [facilitators] were afraid that we would have confrontation and protesters. But the training, besides just being prepped with the kits…just how to have conversations and how to deal with

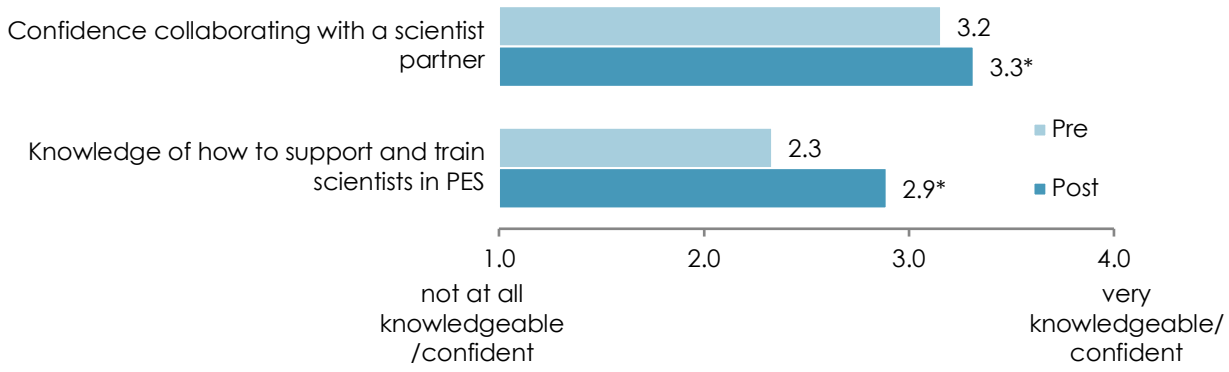
confrontational people. We really focused on that it was a conversation, and that because it's open-ended there are no right or wrong answers, and just to let people talk. And they didn't have any difficulties whatsoever."

Additional benefits for the scientists and facilitators as outcomes of the training are discussed in the following section, p. 45.

Long-Term Benefits

When their events were completed, hosts on average reported greater knowledge of how to support and train scientists in PES as well as slightly better confidence for collaborating with scientist partners (Figure 20). Both increases were statistically significant. One host interviewee who had organized a forum said he was glad for the experience in training facilitators for this new style of program delivery.

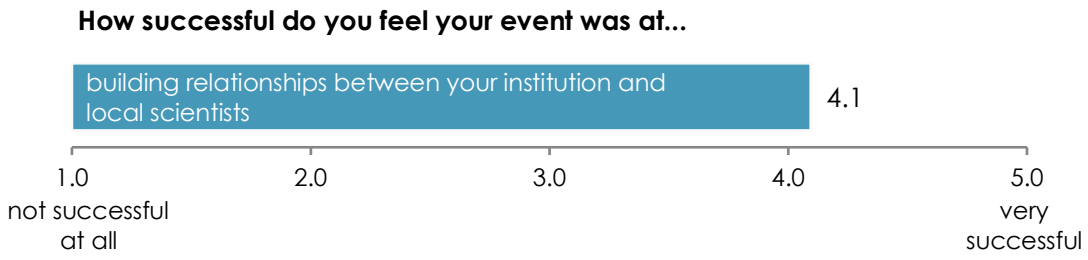
Figure 20. Changes in Hosts' Knowledge/Confidence for Training and Collaborating with Scientists
(Matched pre/post surveys, n=101)



**Using paired sample t-tests, comparison of hosts' responses showed a significant increase in confidence/knowledge from pre to post on the two survey items above (p<.05).*

Many hosts also referred to the benefit of having established new relationships with scientists that can continue into the future. This was a goal for many hosts, and generally hosts reported that their events were successful in this regard (Figure 21). Hosts talked about having a new pool of knowledgeable volunteers and experts to draw on – people who could have a positive impact on public audiences and also on other volunteers at their institutions. One host mentioned that some of their scientist facilitators had already volunteered again for future events. These are the types of continuing collaborations that the MSPES project team hoped to see.

Figure 21. Building Relationships Between Scientists and ISE Institutions
(Post-survey data, n=91)



All of the hosts said they would be interested in pursuing future partnerships with scientists. Many had already begun thinking about future events where scientists could contribute, either using the Building with Biology activities or facilitating in other ways. As one host stated:

> "I think they [scientists] bring tremendous value. They're the experts with the content. We're the experts with education. It just makes sense that we come together, and they help us with the content and we help them with how to present the content. This also serves as an opportunity to break down stereotypes of what a scientist is, what they do, and that they are just ordinary people…But it's also a chance for them to learn about the public, so I think there's great value in it on both sides of the coin."

This outlook, which values the perspectives and skills of both scientists and informal science educators, was central to the MSPES project.

Building Capacity for Evaluation

A secondary project goal was to explore different methodologies for collecting data from the public, and to build capacity for host sites to collect participant feedback and assess the impact of their programs. The MOS internal evaluation team provided instruments for data collection at both the events and forums: "Through the evaluation of the events and forums, we wanted to understand not just how visitors learned from activities about synthetic biology, but what they learned about others' viewpoints, what they valued about the experience, and how to potentially motivate future behavior around PES or synthetic biology." These included post-surveys to be administered in-person and a graffiti board, where visitors answered questions about the societal and ethical implications of synthetic biology.

The internal evaluation team piloted various tools and approaches with a small subset of museums during the first year of the project to weed out unsuccessful methods and better hone the ones that seemed suited for individuals with different levels of experience running evaluations with the public. The team noted that a passport activity, which had originally been designed to drive visitors to take the post-survey, did not work for its intended purpose since the kit activities often took place in open spaces where visitors could come and go as they pleased.

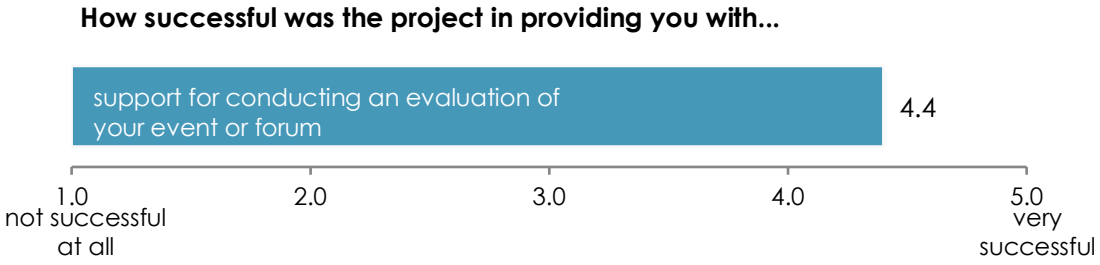
Instead, the team found that the passports were more effective at encouraging visitors to engage in PES behaviors like interacting or having a discussion with a scientist. Pilot use of the graffiti boards showed the team that visitors' responses could help scientists better understand the public's "initial thoughts, concerns, fears and hopes around synthetic biology" with limited prompting. Thus, the graffiti board continued to be used during large-scale kit dissemination in Year 2.

The project's internal evaluation team took several steps to encourage the use of best practices for the public audience evaluation and to facilitate data collection and reporting. The team provided host sites with training materials on conducting evaluations and the use of the various data collection instruments. The training resources included written materials as well as two webinars – one dedicated to evaluating events and the other to evaluating forums. These webinars walked participants through the instruments they would receive and the expectations for using those materials. Data collectors were required to go through human subjects training and to watch a series of how-to videos. Data collected by the host sites as part of this effort contributed to the internal evaluation team's study of the project's impact on public audiences (which was not a part of the external evaluation, reported here).

In their original kit applications, a total of 113 sites indicated interest in running an evaluation of visitor experience at their site. Sixty-five of these sites were selected to carry out the MSPES evaluation activities at either their event, forum, or both. Fifty-one sites (78%) provided feedback on this experience through their host site post-surveys. Additionally, sites that received a stipend to host a forum were required to collect evaluation data from their participants.

The subset of hosts selected for these evaluation efforts were asked to reflect on how the project influenced their knowledge and confidence in conducting evaluations. They were also asked how well the project supported them in conducting their evaluation. The majority of host respondents were in agreement that the MSPES project was successful at providing enough support for sites to conduct their own evaluations (Figure 22).

Figure 22. Support for Evaluation
(Post-survey data, n=51)

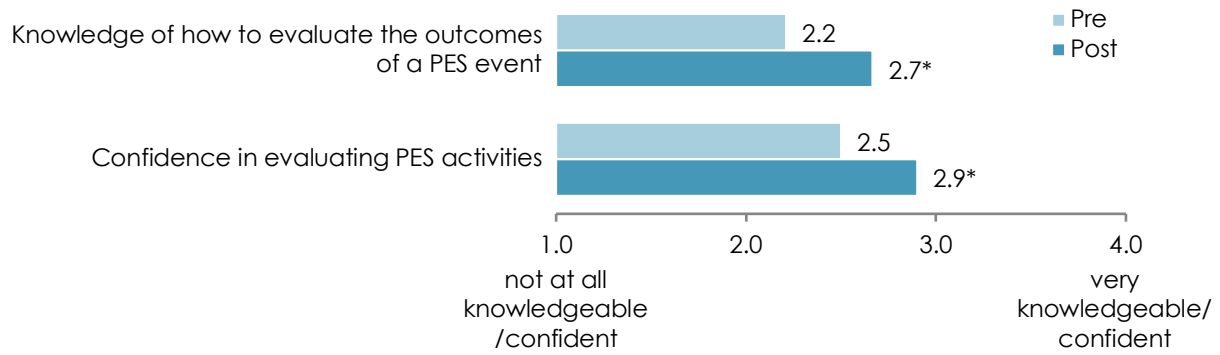


Additionally, host sites showed a significant increase in confidence and self-rated knowledge related to evaluations as a result of their participation in the MSPES program. Figure 23 illustrates the average rating scores hosts provided for their "knowledge of how to evaluate the outcomes of a PES event" and "confidence in evaluating PES activities" before and after their

MSPES experience. On the post-survey, host sites believed that they were more confident and knowledgeable about conducting evaluations.

Follow-up analyses using a 2x2 ANOVA did not find any significant relationships between hosts' knowledge and confidence ratings for conducing evaluations and whether or not hosts attended any of the webinars on evaluating events and forums. Therefore, engagement in the evaluation process may have been a greater influence on hosts' confidence and evaluation knowledge than their participation in the evaluation webinars.

Figure 23. Changes in Evaluation Knowledge/Confidence for Hosts
(Matched pre/post surveys, n=51)



**Using paired sample t-tests, comparison of hosts' responses showed a significant increase in confidence/knowledge from pre to post on the two survey items above (p<.05).*

Seven host sites were subsequently interviewed and asked to provide more detailed feedback on their evaluation experiences. While most of the sample reported that they didn't learn anything new because they already had extensive prior evaluation experience, a few sites indicated that the MSPES evaluation protocol did introduce some new techniques. Specifically, they appreciated learning how to format questions and judge the content of participants' feedback, learning how the public perceives museum programs, and being more reflective on how they design their programs.

All sites felt prepared to run the evaluations, were able to collect sufficient survey responses (~20-30), and didn't encounter any major challenges. The only minor difficulty that some sites faced was getting shy researchers or participants to engage with each other, but the hosts also acknowledged that this process gets easier with more experience. One site even considered providing more desirable incentives to attract participants (beyond the DNA strand temporary tattoos provided). In the end, the sites that were newer to the evaluation process acknowledged that the MSPES project made them feel a "little more confident" in their ability to conduct evaluations.

Outcomes for Facilitators

As discussed above (Facilitator Profile, p. 14), the facilitators involved in Building with Biology events during Year 2 covered a broad spectrum – from research scientists with extensive knowledge of synthetic biology to undergraduates in STEM fields, to museum volunteers with no formal background in the sciences. Although many facilitators fell outside the target group the project had initially envisioned, responses to the post surveys and interviews show positive impacts across the board.

A New Type of Outreach Experience

Project leads hoped that Building with Biology would provide scientist facilitators with new experiences and outlooks on conducting public outreach – particularly by introducing them to the PES model: "I think sort of that lens of wanting to give researchers the vocabulary or help them develop a vocabulary and ease of sharing work that they're so excited about and passionate about, especially around a topic like synthetic biology that can be a little volatile…was really exciting." Facilitator feedback shows that the project was successful in this regard, whether or not individuals fell within the primary target group.

Although most Building with Biology facilitators (86%) had some form of previous experience interacting with the public around science topics, just 17% had previously participated in a public event on synthetic biology (Figure 24). For many, the style of outreach was new as well. Thirty-seven percent of respondents had never facilitated a hands-on activity at an outreach event and 57% said they had never participated in a group discussion or forum with the public (Figure 25). The majority of facilitators (63%) had never done outreach at a museum before – most facilitators cited outreach experience in more formal settings such as universities (50% of respondents) and schools (48%).

Figure 24. Facilitators' Prior Outreach Experience: Science Outreach and Synthetic Biology Outreach
(Post-survey data, n=309)

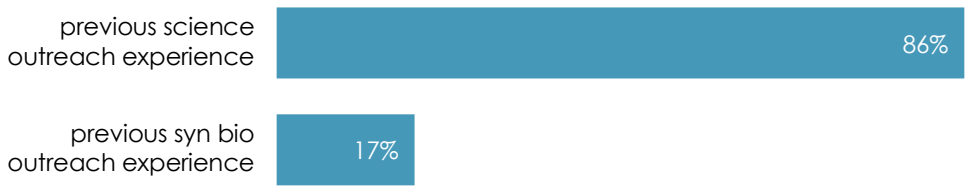
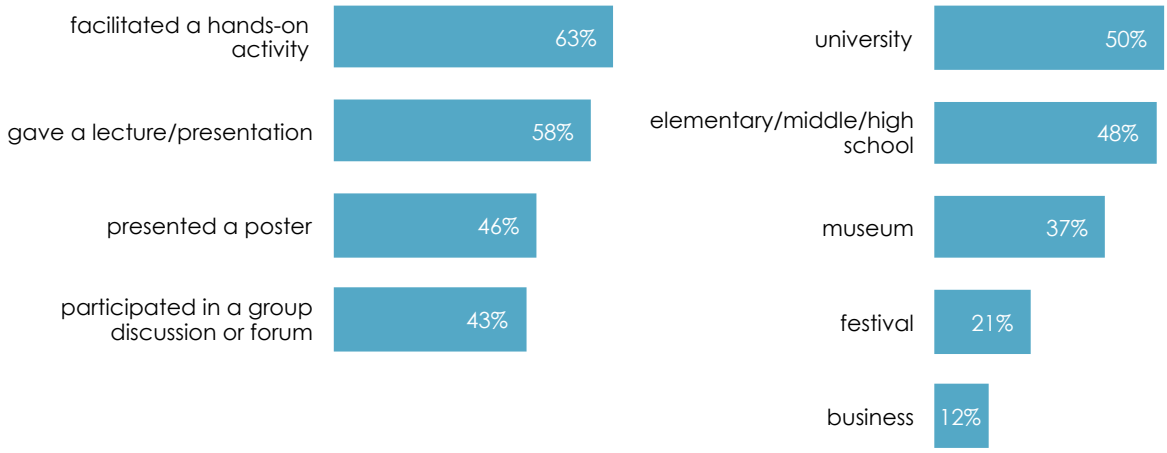


Figure 25. Facilitators' Prior Outreach Experience: Types of Outreach and Locations
(Post-survey data, n=309)



These results show that for many involved, Building with Biology was an introductory experience to a new type of outreach experience and hopefully the foot-in-the-door these volunteers may have needed to participate in future events for public audiences.

Understanding of Synthetic Biology

Not every facilitator involved in the Building with Biology events during Year 2 was a synthetic biology expert. Although 92% of facilitators had backgrounds in a science field, only 42% had a synthetic biology background (see Figure 24). As a result, Building with Biology was an opportunity for many facilitators to learn more about this area of science – in some cases even those who were already fairly knowledgeable.

In response to a series of statements about synthetic biology, over 70% of facilitators agreed or strongly agreed that their Building with Biology experience increased their understanding of synthetic biology (Figure 26). Facilitators were also asked how the experience affected their definition of synthetic biology, which allowed them to elaborate in an open-ended format. A summary of these responses can be seen in Figure 27. Facilitators' answers show that for 11% of participants, Building with Biology was their first real introduction to synthetic biology. About a third of the other respondents who already had some familiarity with synthetic biology talked about how their understanding of the topic had been expanded – particularly through new awareness of its many applications, its interdisciplinary nature, and its relationship to genetic engineering:

> "I didn't realize it was so interdisciplinary in that many aspects of the different sciences are necessary for the continuing growth of this topic."

> "I learned more about the applications of synthetic biology, which is helpful in describing it to other people."

One facilitator, who participated in the event at The Children's Museum in Indianapolis, even mentioned that prior to the event she had a negative outlook on synthetic biology, particularly as it related to the modification of food sources. She talked about how the event expanded her understanding of how synthetic biology works and how it is applied, changing her perspective on GMOs and making her more amenable to the topic.

Figure 26. Facilitators' Changing Understanding of Synthetic Biology
Agreement with Likert Scale Statements
(Facilitator post-survey data, n=301)

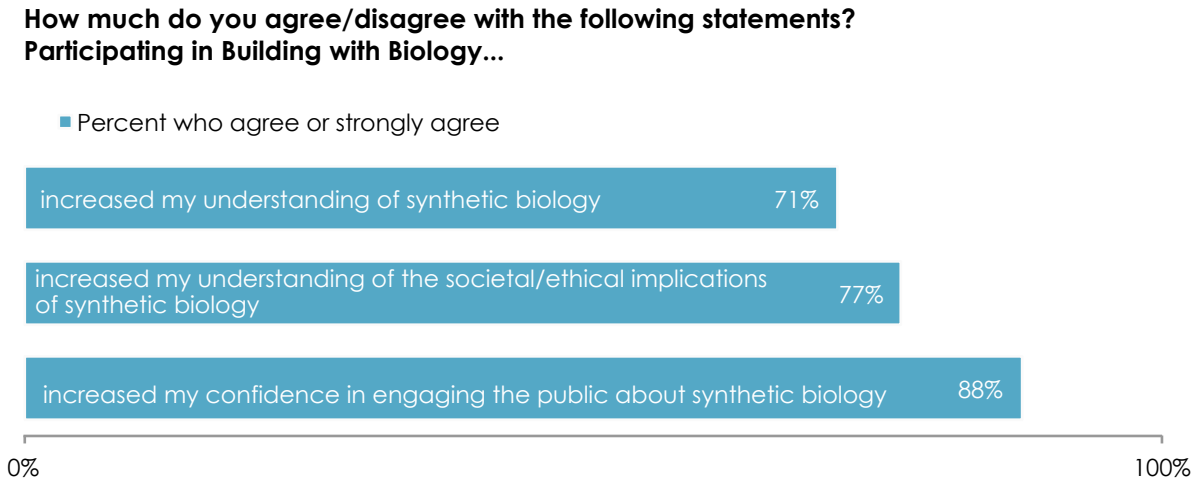
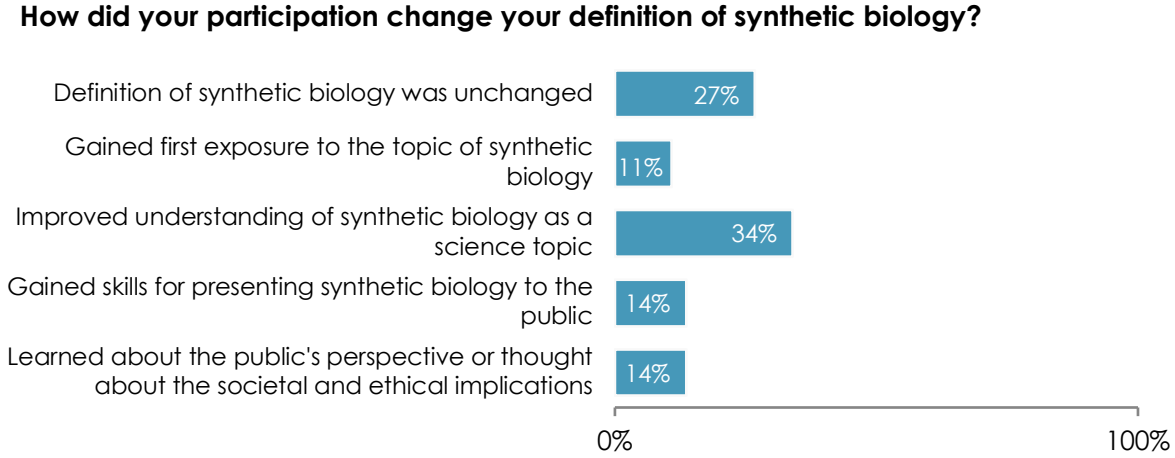


Figure 27. Facilitators' Changing Ideas about Synthetic Biology
Responses to Open-Ended Prompt
(Facilitator post-survey data, n=250)



In addition to an expanded understanding of synthetic biology as a science topic, 77% of respondents said that the event increased their understanding of the societal and ethical implications of synthetic biology, and 88% said it increased their confidence in engaging the public around synthetic biology. Examples provided through their written responses include the following:

> "I participate in research in this area of science. I would not say that my overall perception has changed; however, my understanding of how the audience perceives this subject has changed quite a bit. Moving forward, this event will help shape the way I interact with others when explaining the science behind this concept (especially children)."

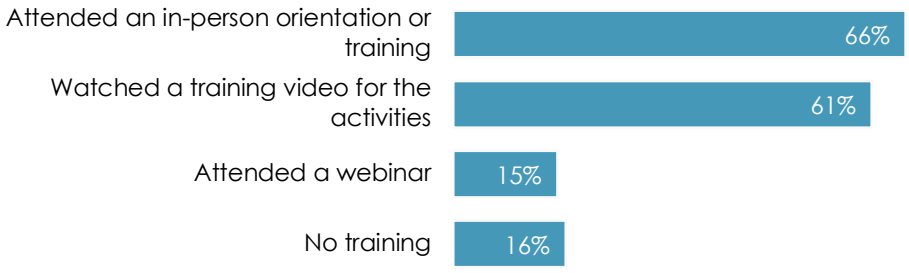
> "The basic definition remained the same, but it did help me see how it involves all of society more than I had grasped before."

Overall, facilitators came away with a richer understanding of synthetic biology – from the scientific details to its relevance to society – and how to discuss these topics with public audiences.

Training in PES

As discussed above, the training that facilitators received to prepare them for the Building with Biology events varied highly from site to site. The training also varied within each site, depending on which trainings a facilitator was able to attend and which online resources they were aware of and chose to use. Sixty-six percent of respondents said they attended an in-person orientation or training prior to their Building with Biology event (Figure 28). Of those who didn't attend an in-person training, 18% prepared by watching one of the webinars or an activity training video. The remaining 16% did not participate in any training activities. These differences in preparation were taken into account when looking at outcomes for facilitators – particularly regarding their understanding of PES (see Figures 31 and 34).

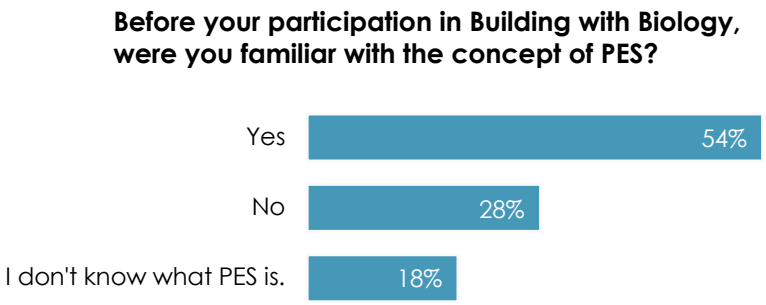
Figure 28. Training Received by Facilitators
(Post-survey data, n=324)



Similar to the Building with Biology hosts, facilitators were asked about their familiarity with PES prior to their participation. More than half of the facilitators reported that they were previously familiar with PES (Figure 29). This number seems surprisingly high, and it may be

inflated (similar to host survey responses) due to misunderstandings about the term and the fact that it refers to a specific type of outreach rather than any type of interaction with the public around science topics. Facilitators outside of the target audience were also slightly more likely to say they were previously familiar with PES than those within the target audience (58% versus 53%).

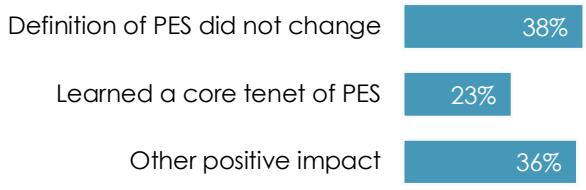
Figure 29. Facilitators' Prior Awareness of PES
(Post-survey data, n=306)



Eighteen percent of respondents said that they didn't know what PES is. Surprisingly, these were not just individuals who hadn't participated in a training event, but included a fairly even mix of those who had attended in-person orientations, watched webinars, or watched training videos.

Facilitators were next asked to describe how the experience changed their definition of PES. Thirty-eight percent of participants said their definitions and understandings hadn't changed (Figure 30). Twenty-three percent of respondents gave answers that clearly demonstrated a new awareness of one of the key components of PES – for example, that the facilitator should take the public's viewpoint into consideration or that it involves a two-way dialog. One facilitator commented, "It made me realize that there's a lot more value in two-way conversations than straightforward lectures. In order to engage the public, it's necessary to involve them, rather than just try to impress them."

Figure 30. Changes in Facilitators' Understanding of PES
(Facilitator post-survey data, n=154)



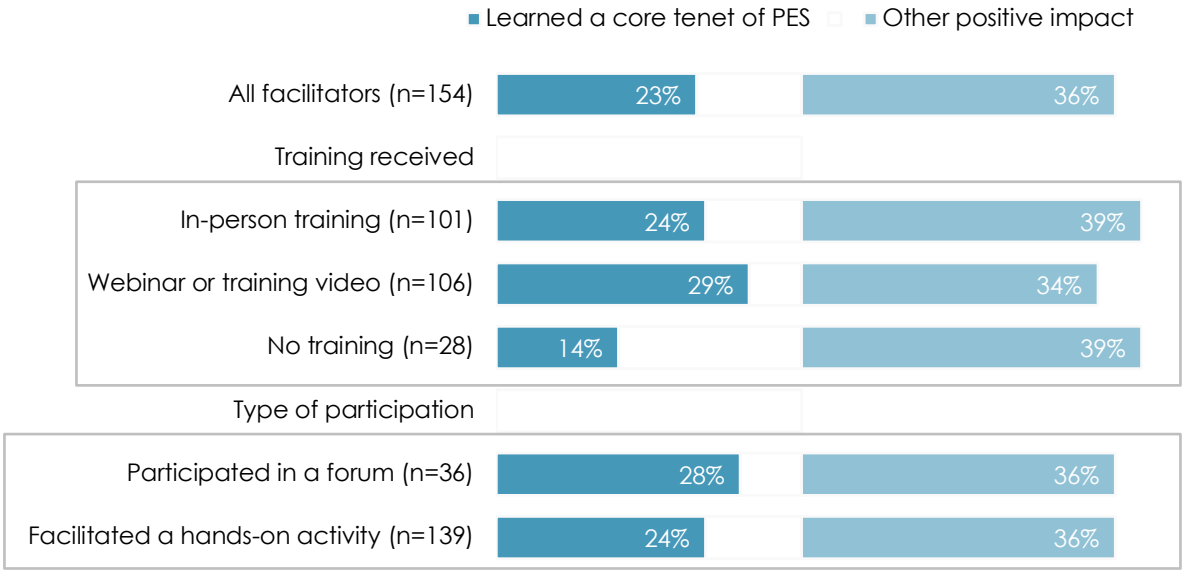
Many more participants (36%) gave responses that indicated some other positive effect, although not necessarily one that could be linked to a better understanding of the tenets of PES. These individuals talked about a wide variety of changes in their perspectives, including a renewed sense of the importance of PES and an increased comfort interacting with the public. Others

simply said that the event was their first introduction to PES and that they now had a definition for it where before they had none:

> "It helped me learn what it is!"
>
> "It made the concept of PES less intimidating because the Building with Biology activities were very user-friendly and engaging."
>
> "I was familiar with it before, but every time I get in front to present and interact with especially children in the community I learn how important it is to help people understand science."

Many individuals commented that the kit activities made a big difference, showing how difficult science topics could be made more approachable and appropriate for all ages. Facilitators' responses were also compared to the type of training they had received and their participation in hands-on activities versus forums. Although small differences were found, none of these were statistically significant. Slightly more facilitators who had seen a webinar or training video indicated that they had learned a core tenet of PES than those who had attended an in-person training (29% versus 24%), indicating that these online resources may have been more reliable in conveying the themes of PES than the in-person trainings, which were variable from site to site. Forum participants also had a slightly better understanding of PES than those that facilitated the hands-on activities (28% versus 24%). Forums involve deeper and more extended engagement on the part of the public and may therefore have done a better job of underscoring the meaning of PES for facilitators.

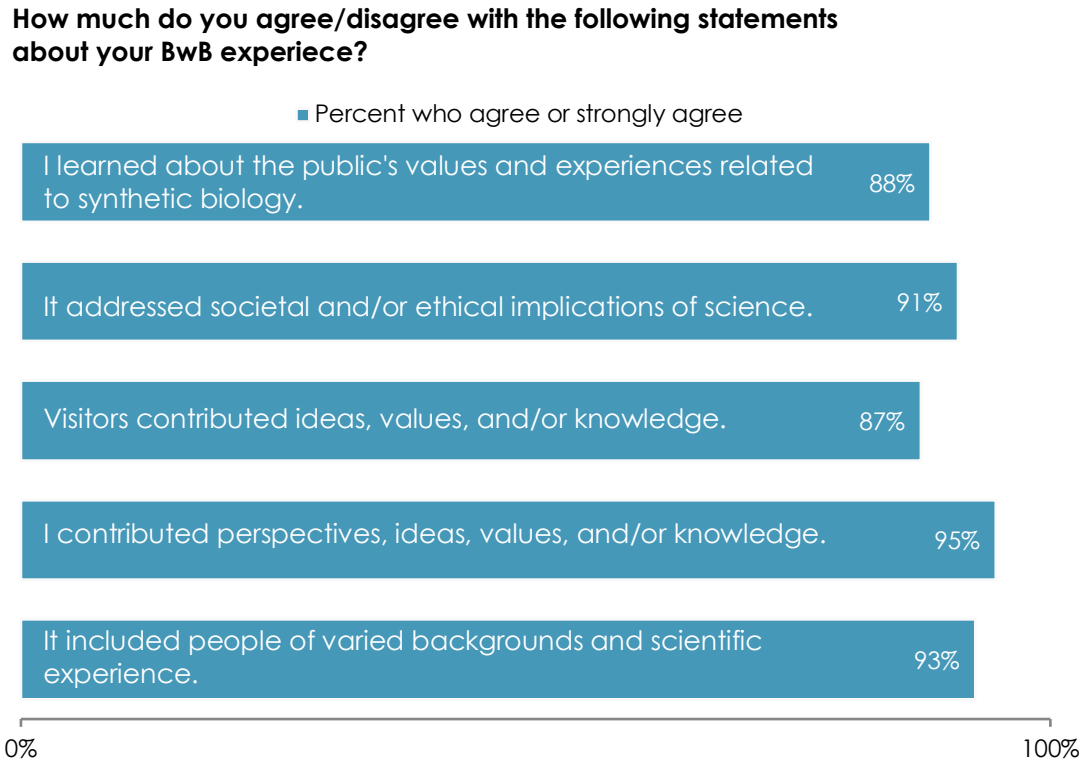
Figure 31. Changes in Facilitators' Understanding of PES Breakdown by Training and Type of Participation
(Facilitator post-survey data)



One-way ANOVAs did not show any significant differences (p>.05) in facilitators' responses to the two survey items above based on the training they received or activities they facilitated (hand- on or forum).

Regardless of whether facilitators gave clear definitions of PES, their responses to further survey questions indicate that they observed characteristics of PES during their Building with Biology experiences (Figure 32). Between 87 and 95% of respondents said they "agreed" or "strongly agreed" with several statements about the presence of PES characteristics at the events they facilitated – for example, that visitors contributed ideas and knowledge.

Figure 32. Presence of PES Features at Building with Biology Events
(Facilitator post-survey data, n=301)



These responses demonstrate that in most cases, facilitators were taking part in PES even if they were not always aware of the fact or able to give the practice a precise definition.

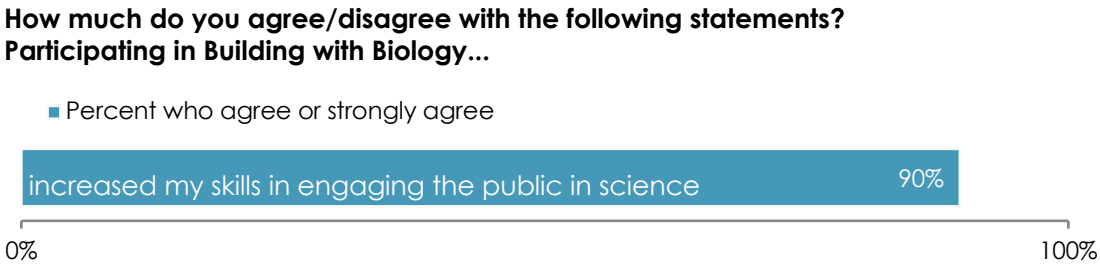
Building with Biology facilitators represented a spectrum of experience when it comes to engaging with public audiences around science topics. On one end of the spectrum were those who were new to outreach and may only have been familiar with Public Understanding of Science approaches, where the scientist serves as an expert who delivers information to the audience. Those further along may have had more training or experience in outreach. Their approach might have included asking participants questions and some of the basic practices of PES, even if they weren't aware of PES as a defined set of practices. Furthest along the spectrum were those who were more fully aware of PES and who actively tried to incorporate its practices

when they interact with public audiences. Most facilitators involved in Building with Biology were able to progress along this spectrum.

Communicating with the Public

Facilitators' progress toward PES practices can be seen in their many comments about the communication skills they built through their participation in Building with Biology. Ninety percent of facilitators agreed or strongly agreed that their participation increased their skills for engaging the public in science (Figure 33).

Figure 33. Effect of Building with Biology on Facilitators' PES Skills
(Facilitator post-survey data, n=301)



Facilitators were also asked to describe what they learned about communicating science in an open-ended question. One thing that many facilitators mentioned was the need for different approaches for different age levels. Many individuals commented on the difficulties in communicating science with young audiences. Some facilitators noted in their surveys and interviews that children might not always have the learning experience you hope for when doing an activity. Instead of understanding or discussing the science involved, a child's primary take-away from one activity might just be the fun of drawing and coloring a superhero, for example. Other facilitators felt that it was a very worthwhile experience for young children. One stated, "It's never too early in the educational experience to introduce complex topics." Other comments from facilitators that demonstrate different perspectives on this topic included:

> "[I learned] that even though kids aren't necessarily actively interested or asking questions in a hands-on activity, they may be incredibly interested and just shy. Asking the right questions to engage in such a short time is difficult, but worth figuring out to inspire future scientists."

> "These activities are probably best for children over the age of 8. We had a lot of children under the age of 5 and it is very difficult to explain these topics to children at a younger age with no understanding of biology."

Comments by facilitators on the difficult nature of communicating this material to children were ubiquitous throughout the site visits, interviews, and surveys, suggesting that facilitators might have benefited from additional resources or training on how to work with young audiences. Respondents who may have been better prepared sometimes mentioned their own strategies for making the topics accessible, including reducing jargon from their speech and finding ways to

simplify concepts. Additional techniques that were mentioned included using stories or personal experiences to make things relatable:

> "A lot of the public based their ideas on what was occurring in their lives at the moment. So it was important to be able to make connections with relatable subjects."

Overall, 18% of the individuals who gave responses to the open-ended question on science communication (N=95) talked about the importance of considering your audience's background when communicating science, whether that includes factors like age, previous understanding of the topic, career, misconceptions, or other factors. Having this awareness can be an important step toward successful PES.

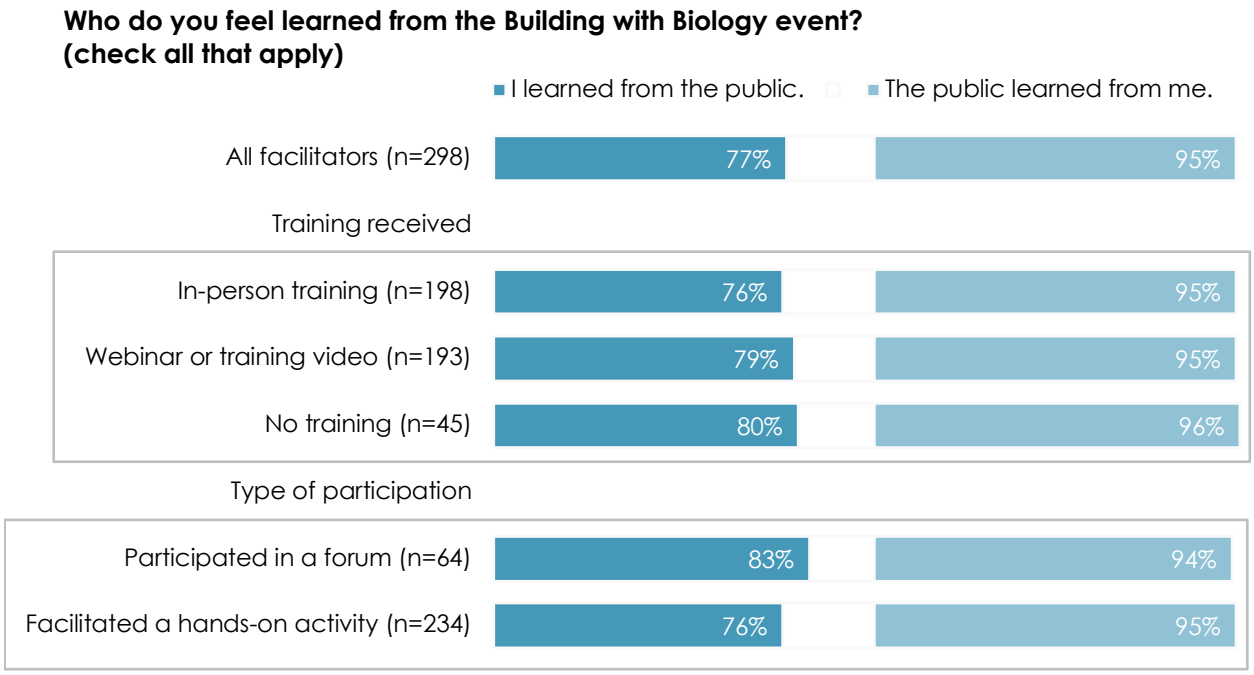
Learning from Scientists, Learning from the Public

Another core principle of PES is that all parties have the opportunity to learn from each other, no matter what their background. This tenet is a potentially difficult point to get across to scientists who are extremely knowledgeable in their content areas and who are used to instructing others. Some members of the project team felt that graduate students tended to be more receptive than older scientists in terms of seeing value in public perceptions of their work:

> "Thinking there is what you call in social science, 'the deficit model.' There's a novice deficit, and you just need to give them information and they will see things the way you see it. That's a barrier. One has to make it a more bi-directional conversation, and then seeing the value of it."

To understand whether or not facilitators moved beyond this "deficit model" through their Building with Biology experiences, the post-survey asked respondents to identify who they felt learned during the event (Figure 34). Overwhelmingly, facilitators responded that the public learned from them (95%), but fewer facilitators felt that they had learned from the public (77%). The percentage of facilitators who said the public learned from them did not vary much based on the training they had received or whether they facilitated a hands-on activity or a forum. The percentage of facilitators who said they learned from the public did vary slightly, however, based on whether they had facilitated the hands-on activities from the kit or participated in a public forum. Although the difference was not statistically significant, more forum facilitators said they learned from the public than did facilitators of hands-on activities (83% versus 76%). This difference can likely be attributed to the extended length of the forums and the format, which provided structured opportunities for public participants to offer their points of view.

Figure 34. Learning from Building with Biology Events Facilitators Versus the Public
(Facilitator post-survey data)



One-way ANOVAs did not show any significant differences (p>.05) in facilitators' responses to the two survey items above based on the training they received or activities they facilitated (hands-on or forum).

Some facilitators' explanations of their answers suggest that they took a narrow interpretation of the statement in the survey question, which also may have influenced the results. "The younger students we taught didn't know anything about synthetic biology," commented one individual. Facilitators like this one may have been focusing on science learning alone, rather than considering what they learned about the public's perspectives or values.

Still, the majority of facilitators *did* think they learned from the public. When asked, "What, if anything, did you learn from the public?" facilitators gave many positive responses. Several talked about the public's excitement and willingness to learn about science – something that came as a surprise to some facilitators. One facilitator commented, "I was overwhelmed by how deeply and creatively many members of the public are thinking about science." Facilitators also talked about the diversity of opinions and content knowledge among the public, noting some are distrustful of GMOs while others aren't, and some are knowledgeable about genetic engineering while others know very little about it. Other facilitators talked about the value of learning from visitors' diverse perspectives. One individual stated, "Working with the children - their unique and creative ideas and perspectives opened my eyes to ideas I hadn't considered." Another talked about the knowledge gained on both sides: "There were people who left the activity with a different perspective than when they entered, and I know that it was very informative to listen to how different people felt about some of the applications."

A few facilitators' comments had a less positive tone, referring to public audiences as uneducated or misinformed. These facilitators sometimes seemed frustrated by the misconceptions that exist or by the public's opposition to certain applications of synthetic biology:

> "Our event was in ____: a town populated by hippies and health nuts. Most of the town doesn't think we should even spray for mosquitoes. They weren't so happy about bioengineered mosquitoes."

These facilitators made comments such as, "I learned that they have many misconceptions," and "Most people only have a limited understanding of applications of synthetic biology, if they have any familiarity at all." Even those who felt the public was uninformed, however, frequently said that they still learned from the public. Facilitators also often made comments that suggest they are thinking more deeply about *why* people think and feel the way they do about scientific topics, including themselves:

> "I think the main thing I learned was the level of understanding of the public on synthetic biology. Sources of information for the public are drastically different than information sources for scientists."

> "I got a more accurate insight into how the public thinks of things like cancer, GMOs, etc. I've been involved in science for years so my perspective of these topics is pretty skewed, and I have been given a lot more information about them in an educational setting than most people."

> "Our event was a professional development workshop for Connecticut educators, so we gathered an interesting group of participants with a wide range of foundational biology knowledge. Communicating the Building with Biology forum & hands-on activities offered the opportunity for people to articulate their personal values/morals/beliefs along with their background scientific understanding. I learned about that complex interplay and that people often hold two (or more!) contradictory opinions about scientific research at once!"

Rarely did a facilitator seem to have a negative experience. In some cases, facilitators talked about situations in which they dealt with visitor misconceptions and were able to continue the conversation. One facilitator talked about having an hour-long discussion with a visitor who was at first firmly opposed to synthetic biology. By the end of their discussion, the visitor's mind was not completely changed, but she was interested in learning more about the topic so she could better formulate her opinion. Whatever their individual experiences might have been, facilitators seemed to value the experience, and many talked about the importance of doing these types of activities:

> "It was a great time, and I'd love to help again. I am really glad these events exist for myself and for the field of synthetic biology."

> “I learned that one guest really valued research because a microbiologist (not an MD) had developed a nutrition plan for her diabetic (type I) son that resulted in his no longer needing to take insulin.”

> "I learnt about different opinions and how the participants change their mind after explaining to them what is the meaning of specific scientific words, such as GMO."

One facilitator went further, talking about the importance of doing these types of events regardless of whether everyone agrees:

> “There's a wide range of people with different mind sets that are willing to participate: those unwilling to discuss and only wish to tear us down (mosquito bots, anti-vaccines, etc.), those that don't agree with synthetic biology (GMOs) but are willing to learn and possibly compromise, and those that are experts in scientific fields I barely even understand. They each imparted upon me the importance of discussion. We are all very vocal but most of us only talk to our peers.”

Seeing these types of comments from facilitators is encouraging, given the project’s aim of breaking down the barriers between scientists and the public and stimulating discussions that benefit all parties.

Promoting PES on a Nationwide Scale – Lessons Learned

Some members of the project team viewed MSPES as a transitional project, taking best practices from the NISE Net project, which developed kits and exhibit activities around nanotechnology, and applying what worked well to a new topic. While the MSPES project was able to leverage many of the relationships and processes built during the NISE Net project, it also contained its own unique components, such as pairing scientists and museum educators together to co-create materials and requiring sites to recruit scientists to help facilitate kit and forum activities using a PES model. Many team members felt that the MSPES project was proof-of-concept that collaborations between scientists and museum educators can be successful. In forging this new path, the project team encountered many challenges and learned valuable lessons that can be carried on to future projects.

The Importance of PES and the Role of ISEs

REA's interviews with key members of the MSPES project team at the close of Year 2 revealed that although PES can be challenging in practice, it nonetheless remains an important and worthwhile goal:

> "I really think that shifting away from that one-person view of, 'This is what you need to know, and this is it – nothing more' to an expert saying, 'This is what we know. Let's have a conversation about it. What do you know? How does it relate to you?' I think that is overall important for moving forward in science in terms of educating the public, in terms of making the public feel that their voice is heard, their concerns are heard, their interests are heard."

Many project team members saw PES as a way to recognize that science-related decisions could be made via a combination of "personal experience, social values, and scientific evidence." They felt that both scientists and the public were necessary voices in the decision-making process: "The idea of having a values-based discussion of how science and technology fits into our lives and having a two-way conversation around that is something that brought me into this project in the first place." Several thought that such discussions might even influence the direction of a scientist's research:

> "I'm proud we went beyond saying, 'Synthetic biology is an important field that visitors need to think about ethical implications in own lives,' but can create conversations that can help inform future priorities of scientists as they continue in career and continue PES later and work to shape their scientific field."

Furthermore, the project reinforced the belief that museums are a prime location for these two-way conversations to take place:

> "ISEs have a unique and important role to play that I don't think others are playing as these issues unfold…The idea of positioning ISEs as a common space accessible to the public and scientists – I think that happened. There's interest in

synthetic biology and other scientific communities in doing more of this and learning more from it."

In this way, the MSPES project positioned ISEs as boundary organizations, brokering and fostering relationships between scientists and the public.

Tackling a Tricky Subject

As discussed previously, using synthetic biology as the project's science topic brought both challenges and benefits. The field of synthetic biology is exciting and new. Its applications and implications can draw public audiences into rich discussions that incorporate their values and ideas. At the same time, the complexity of the topic can make synthetic biology seem daunting for both museums and their audiences. Even scientists sometimes have difficulty clearly defining it.

The topic of synthetic biology also presented challenges in obtaining buy-in from Year 2 host sites. Key members of the MSPES project team talked about difficulties communicating the importance of the project's topic and approach to these sites. One project partner, whose site served as a regional hub, noted that there is always a "ramp up" to holding a museum event around a new topic, as participating museums can be both excited and apprehensive about bringing new content into their spaces: "People were excited about it, but needed to understand the actual science on their own a bit more or understand how to sell it to their public as an event to their audience." Initially, some museums questioned whether they should apply or whether they were "the right kind of museum" for the Building with Biology kit. Helping sites see the relevance of the topic to their institution was therefore a challenge, and may be one reason the project team did not meet its goal of distributing 200 kits to informal learning institutions within its original timeline.

Rather call this a loss, however, the project team repositioned their situation as an opportunity to broaden the project's impact. The project team reached out to other groups who run informal science programs, such as science cafes, universities, and iGEM teams, in order to find homes where the kits could reach new audiences. Team members noted that earlier efforts around nanotechnology had also taken a long time to get museums on board, so a longer time span may be necessary to solidify buy-in to a particular topic.

In sum, when trying to create buy-in around an unfamiliar topic, future projects need to:

- Explain the importance of the topic to museum venues (Why is the topic exciting? Why does the topic matter?)
- Describe the science behind the topic in layman's terms to help museums better communicate concepts with public audiences
- Allow time for museums to get comfortable with the topic
- Explore alternative venues for potential alignment

Providing Support for a Nationwide Effort

One of the greatest challenges of the MSPES project was finding ways to support secondary sites in preparing and implementing their Building with Biology events and forums. With 170+ sites spread across the United States, the project team could not provide on-the-ground support to all participants. Regional hub leaders were appointed to help sites in recruiting their scientist facilitators. In addition, members of the MOS internal evaluation team mentored 60+ sites in how to collect data from the public around the kit activities and provided stipends to 30 sites to conduct and collect data from forum activities. This mentorship increased the reach of the internal evaluation to a large and diverse range of sites.

The project team also provided a series of webinars and other online resources to support both host institutions and the facilitators they recruited. These resources communicated the mission of the MSPES project and Building with Biology events, reviewed kit activities and the process for running events and forums, gave overviews of PES and synthetic biology, and offered guidance on running evaluations of both forums and events. Some of these webinars were developed specifically for MSPES, while others were more general resources on PES. One set of webinars was aimed specifically at Building with Biology hosts, while a separate set was aimed at facilitators (Figure 35).

Figure 35. Webinars for Hosts and Facilitators

Hosts	Facilitators
• Communicating Synthetic Biology • Engaging Audiences through Building with Biology Public Forums • Evaluating the Public's Experience at Building with Biology Events • What's in Your Building with Biology Kit • Evaluating Building with Biology Forums	• Public Engagement Fundamentals • All about Audiences • Communicating Synthetic Biology

Hosts and facilitators could participate in the live webinars or watch recordings uploaded to the Building with Biology website once the webinars had concluded. The project team hoped that hosts would at minimum participate in "Communicating Synthetic Biology" – a webinar designed for all kit recipients as an introduction to the project. Ideally, scientists would participate in all three facilitator webinars to provide them with background on PES and how to communicate about synthetic biology with public audiences. These webinars were designed to be especially helpful to those who had little experience doing public outreach.

In practice, not all hosts or facilitators took part in the webinars or watched the recordings at a later date. Since hosts could choose how much they wanted to utilize the various support materials (if at all), there was no consistency across sites in the dosage of training delivered. As one project lead stated, "I'm sure some of the sites used the materials more thoroughly, and some just said, 'Here's this thing if you want to watch it.'" Post-surveys for both hosts and facilitators asked participants which webinars they had attended, and results are compiled in Figures 36 and 37. Participation rates were calculated based on the number of intended participants – for example, the webinar "What's in Your Kit" was intended for all hosts, whereas "Evaluating Building with Biology Forums" was intended for hosts that planned to both hold a forum and participate in the evaluation (a much smaller group). The facilitator webinars were intended for all participating facilitators.

Figure 36. Host Webinar Participation Rates
(n's adjusted to reflect intended audience who took post-survey)

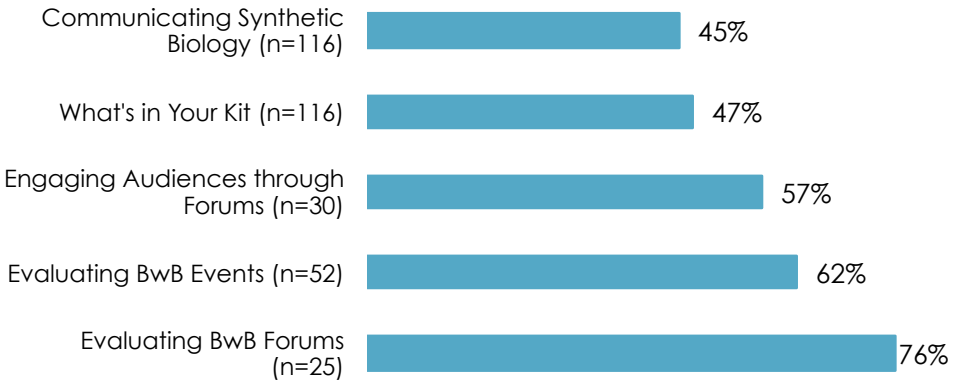
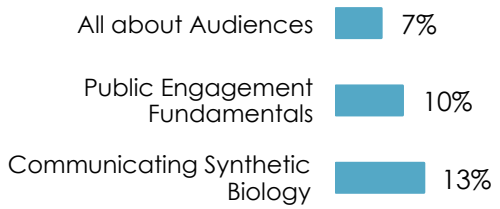


Figure 37. Facilitator Webinar Participation Rates
(n=324, all post-survey participants)



Webinar participation rates were fairly low among hosts and even lower among scientists. Less than half of the host participants participated in the two main webinars intended for all hosts. One challenge for those designing the webinars was transforming in-person workshop content into an online experience that individuals could do on their own time. Unlike AAAS's previous science communication training, webinar viewers did not get personalized feedback during the webinars themselves, which may have made them seem less useful.

Attendance was better for the webinars focused on hosting forums and the webinars on evaluating events and forums. These webinars might have had higher participation because their intended audiences included individuals who were more invested in the project. Organizing a

forum or participating in the evaluation both required extra commitments on the part of the hosts, and these groups may also have been more diligent about preparing themselves for these tasks. The project team also put additional effort into encouraging participants to attend these webinars.

Webinar participation also relied on participants having knowledge of the webinars in the first place. Although all hosts received notifications about the webinars via email, one host interviewee said she was unaware of the webinars. The project team also relied on hosts to advertise the webinars to the facilitators they recruited. It's likely that some sites did not follow through on this and focused on other training materials instead (such as handouts), which would partially account for the low numbers of scientist attendees. A project team member acknowledged that there was also some confusion over the purpose of the various webinars, which may have led to them being under-utilized.

Finally, the scheduling of the webinars also posed a challenge – especially since sites held their events all the way from June of 2016 through the spring of 2017. For the handful of sites that held their events in early June, the summer webinars came too late. For the sites that held their events in the fall or later, the webinars might have come too early. Even if they attended the live webinars, by the time they began organizing their event the information may have been forgotten. And although the webinar recordings were available for later viewing, this option may not have had as great an appeal as watching live.

Hosts who were interviewed had mixed reviews regarding the webinars. Some could not remember which specific webinars they had attended. Others said the webinars were very helpful – particularly those that gave a general overview of the project and its expectations, reviewed the kit's contents, or described the evaluation expectations and materials. Several interviewees said they found the webinars somewhat helpful but also somewhat basic. They described the content as "simple," "broad," or a repeat of information they already knew.

Reflecting on how to improve these online training materials, the project team wondered if the webinars could have been promoted better or offered at different times. Some wondered if webinar recordings were less helpful than live webinars. One team member suggested that future training materials could be provided as videos within the kits themselves, so that they would be more difficult to overlook. Others felt that future webinars should be more specific to the project rather than generalizable, and contain new content rather than repeat information available through other resources on topics like PES.

Hosts spoke more positively about the other supporting resources provided in the kit, particularly the general orientation PowerPoint. One host said the facilitator guide was very helpful and served as a checklist for her in planning her event. Hosts also liked the videos and the handouts for scientists. One host praised the handout with tips for engaging conversations, saying this was particularly helpful in training his volunteers. In the end, it appears that hosts picked from amongst the suite of resources provided by the MSPES team, choosing those that appealed most to them and worked best with the time they had available and other logistical constraints. While hosts may not have used the resources as thoroughly as the project team originally intended, having a variety of options gave the hosts flexibility – an important factor considering the wide variety of institutions involved and the many different types of events they organized and

facilitators they recruited. Aside from one host who seemed to be unaware of these resources, all of the interviewees said they would use the materials for future events and trainings.

Developing Effective Hands-on Activities

Project team members felt that the co-creation of the kit activities by scientists and museum educators was instrumental to their success. While the participation of scientists who had helped develop activities during Year 1 waned over time (i.e. most did not serve as facilitators at Building with Biology events), project team members hoped to find ways to keep this sub-group active and engaged in the future.

Team members also noted that the kit prototyping process had been robust: "I think it's a nice model for how the development process can succeed following the Building with Biology model, having one site sort of develop an activity and iterate on that, and sending it to another institution and kind of refining the activity and modifying it."

Project team members noted that, in general, future kit materials should:

- Include materials familiar to the public to help them feel more comfortable with unfamiliar topics
- Include more real phenomena or materials, rather than models or analogies, to better ground the science
- Contain practical materials to put into a kit and use on the museum floor (e.g. not contain perishable items or small parts that are easily lost)
- Be relevant to public values
- Contain up-to-date information (but also be updated with recent findings)
- Contain built-in opportunities for conversation
- Take lessons learned from the success of the forums and incorporate those into kit activities

Team members also talked about the possibility of providing a sequence of kits with activities that increase in depth. This format might help sites ramp up their participation as they become more familiar with the science topic and PES.

Some facilitators also provided helpful feedback and suggestions on how specific kit activities could be further improved. For example, one individual suggested placing the DNA necklace activity closest to the event entrance and using it as the introductory activity. This format would give visitors an introduction to DNA before they move on to the other activities that touch on more complex science topics. Another individual talked about expanding the list of genetically modified food in the Bio Bistro activity, specifically including food items that have been in the media recently. Collecting feedback to improve the activities was not an objective for the facilitator surveys, but participants' interest in adapting and adding to the activities shows their intellectual investment in making Building with Biology a success.

Developing Effective Forums

Choosing topics for the forum activities was also initially viewed as a challenge. The project team wanted to select topics that appealed to participating scientists as important issues, even if the scientists' own research wasn't directly related. They also wanted to choose topics that would appeal to public audiences and be relevant to their lives. One team member felt that topics like the spread of diseases like malaria via mosquitoes drew local community members because they could connect to this topic easily, especially given the recent Zika outbreak and news coverage.

Another element that may have contributed to the success of the forums was the presence of scientists. Traditional forums tend to have the public talk amongst themselves, whereas the Building with Biology forums included expert scientists in these conversations. One project team member elaborated on this decision, noting the scientist's presence is related to the goals the forum is trying to achieve:

> "Is the aim to give visitors practice engaging in these kinds of concepts? - in which case you may not need scientist there for that. If it's to get advice from the public that you're going to present to decision-makers or a group of scientists, you may just want scientists to speak and provide information and then recede to the background, so they aren't overly influencing the conversation. Or is the goal of this project interaction between scientist and public, learning informally from each other?"

The goal for the Building with Biology forums was to encourage this informal learning between scientists and the public, and the active role of both in the forum conversations was thus instrumental to their success.

Overall, project team members felt that the forums had also been successful, sometimes beyond their initial expectations: "The forums had more potential than we originally thought." Following the pilot activities during Year 1, many members of the project team were concerned about how museums would attract participant to their forums. Many visitors come to museums with their families, and the forums require an extended time commitment and aren't an appropriate format for young audiences. Year 1 sites that held their forums at daytime events alongside the hands-on activities often had low participation rates.

However, project team members shared that Year 2 sites were excited to test out the forum format. To combat the challenges that sites experienced during Year 1, many sites held their forums on separate days from their other Building with Biology events and advertised them in different ways to attract the age-appropriate participants. Some forums were scheduled as evening events, and some were held at local breweries or other venues suited to stimulating conversation among adults. The project team also noted that providing a small stipend to participating forum sites helped build momentum for the effort. Some team members thought that sites who hosted forums felt more comfortable presenting the kit activities as a result and partners who did both the kit activities and a forum were more engaged collaborators, in general. Others shared that some museums were planning on conducting their own forums around new

topics based on the positive experience they had with Building with Biology, helping to build "a potential community of practice that we could grow in the future."

Project team members also have ideas for improving future forums. Several team members noted that the timeline for forum development was compacted. In future projects, they hope to have more time to pilot and learn from the forum content and format, perhaps incorporating forums earlier on in the process. They also noted that the forums had been developed separately from the kits, and that both types of activities might have benefitted from sharing resources and lessons learned.

Project Management and Decision-Making

The project's large scope and quick timeline was a major challenge in terms of collaborative decision-making. Some team members felt that scheduling a time for all of the core project leadership to discuss pieces of the project was difficult and sometimes led to some voices being left out of the decision-making process:

> "I think there's always a challenge with personalities, timing, schedules, all of those sorts of things, especially when you're trying to get different perspectives in order to have a conversation. It's important to model what we are hoping to try to get out of the participants, and I wish that had happened more transparently."

A few team members felt that the synthetic biologists were driving more of the conversation at times than the informal science educators. Others thought that, although it took time, they were able to get everyone to reflect on the kit materials "to make sure everyone bought into the review process." Regardless, team members acknowledged that it was difficult to think about how to represent an entire field of science based on how a small subset of scientists defines it: "There's this idea that if you want to engage a field in talking with the public, how do you come up with questions that are comfortable, accessible, and not safe, but relevant and useful for the scientist in that they feel like they can talk about it?"

Due to the fast timeline to develop kit materials, fabricate them on a large scale, and then disseminate them, some wondered whether projects like this one spend too much time on "the making of the stuff" and not enough time "thinking about the stuff" or justifying why they are employing particular strategies. Furthermore, the management structure of large projects is often such that people volunteer for the parts of a project that interest them, rather than where the needs are. Thus, future projects of this scope should continue to think through the different strengths of project team members and match those strengths with various project needs.

Regardless, most team members felt that the project had done a good job of approaching synthetic biology from different perspectives: "There are social scientists as well as hard scientists involved in this - natural scientists - and there are a lot of people who aren't scientists who work with scientists as practitioners and communicators." Team members were particularly proud of being able to map out the four core synthetic biology concepts that drove kit and forum development: "That was a really important activity for reframing and contextualizing what synthetic biology really meant in the history and present state of science and technology." They

appreciated that the iterative process that led to those core concepts teased out some of the political issues around the field of synthetic biology. Several noted that coming up with a shared definition was complicated because scientists in the field use the term "synthetic biology" to refer to different kinds of activities: "Science is sloppy, iterative, changeable, constantly changing, filled with failures, all of that. So, synthetic biology, I think, is going through all sorts of changes both in terms of how we perceive it and in terms of how it's being done."

In their interviews, the project team mentioned several best practices that they felt could be utilized for future projects like MSPES:

- Involving scientists as co-creators of informal science education activities is important.
- Prototyping tangible activities helps ground ideas, and helps team members determine what is working and what isn't.
- Drawing in increasing numbers of participating sites through multiple stages of prototyping can help scale up project efforts and invites more participants into the conversation.
- Building in time for various stakeholders to meet allows team members to better understand each others' interests and models ways for ISEs to interact with and listen to their different audiences.
- Bringing in different types of partners builds institutional capacity to share collective assets beyond the life of the project.
- Making timelines, expectations, and tasks explicit helps move multi-faceted projects forward.

Conclusion and Next Steps

Although Year 2 of the MSPES project has come to an end, Building with Biology has not. The core project team continues to work on the important task of dissemination and is actively thinking about how to ensure the ongoing impact of MSPES. The many sites who held Building with Biology events during Year 2 are also continuing the work of the project in their own way.

Ongoing Building with Biology Events

As mentioned previously, many of the sites that received Building with Biology kits talked in their surveys and interviews about continuing to use the materials in the future – whether through repeat Building with Biology events or other types of outreach and PES opportunities. In some cases, this has already happened. Team members noted that:

> "Some of our most active NISE Net members and some who were new to the project this year, but who were engaged in the Building with Biology project, have already been using the hands-on activities and forums multiple times in other outreach events they do with Boys and Girls Scouts, Boys & Girls Clubs, and other festival activities they do. Through online and social media, we are able to see when partners are using the activities and tagging us in those activities, so we're sort of able to see how many are using them beyond that one event last summer."

They also mentioned that some sites were using the Building with Biology activities in classroom settings. All of the Building with Biology resources also continue to be available through the project website. Anyone who is interested in running an outreach event focused on synthetic biology can download a digital kit, which includes promotional materials, training materials, printable activity cards and handouts, materials checklists, forum guides, and videos. Building with Biology events can be replicated by participants beyond the project, even if they don't have access to a physical kit.

A few discussed potential avenues for expansion:

> "The next step might be the co-creation of PES materials at a community scale or among these institutions that are part of the network and networks that could co-create their own engagement materials either around a question that's of local relevance or that a researcher really wants to hear back from the public on with her local community or in her field."

Sustainability and Dissemination

Another concern for the project team is ensuring the long-term utility of the resources they have developed and continuation of the project's ideas and goals. Team members reflected on ways to keep the project going beyond its current three-year funding cycle: "I think sustainability is really difficult, and you need champions that can explain and keep the philosophy alive in the

program. Any project that doesn't have a clear sustainability plan afterwards misses key opportunities to partner with other organizations that can continue to develop and refine the materials."

Team members noted that the support network that currently advocates for the project and helps sites find scientists will not be around after the end of the grant. One project team member worried that participating museums might not do Building with Biology kit activities or forums in future years because they are no longer receiving updated information about synthetic biology, new kit materials, or mentorship. The current nature of the forum topics was key for stimulating discussions, and bringing timely examples to the kit activities was also important. There is hope among team members that future opportunities will provide funding for multiple kit cycles and create a "built-in mechanism of a team responsible for collecting, curating, and updating the materials that are used and a process for facilitating what works and what doesn't."

Team members also feel that dissemination to diverse audiences is a key project deliverable and one that can help bolster the long-term impact of MSPES. These audiences include the host sites who participated in the project, particularly those who contributed to the evaluation of public audiences. Since host sites collected this public data on a volunteer basis, the MOS internal evaluation team felt that it was important to share out the findings collected from visitors with participating institutions and scientists: "It felt like if we were going to ask for something like that, we needed to give something back, and we wanted to make sure that they understood that we knew and we felt that this was not just data for us, that this is your data too, and we wanted to give it back to them." At the conclusion of the project, team members held a webinar summarizing their interpretation of the overall dataset and also provided individual reports to each site with their specific visitor data. The internal team noted that sites appreciated these personalized reports to inform future events and better understand their audiences: "They can share [that report] with their higher-ups to show the impact of one of the programs they do. There's some value in that, to build capacity and interest in doing evaluation in the future." Preparing these individualized reports took significant time and effort, but the internal evaluation team felt that providing these to sites was important to the overall project goals.

Another important audience for dissemination is the larger PES community. Team members mentioned dissemination mechanisms such as a project profile on the AAAS website and continuing to provide information on the Building with Biology website as ways to share information about the MSPES project with others. Another important dissemination effort, currently in the works, is a PES Guide. This resource will be designed for all individuals and institutions interested in learning more about PES or facilitating their own PES activities. The guide will draw on examples from MSPES and other PES-oriented projects:

> "I would like to see AAAS work with MOS to highlight the lessons from this project and find ways to share them with the larger PES community and also help scientists who are doing synthetic biology, help them find these resources and help them find the story of how to engage with the public around this topic, so they can see some examples of successful engagement on synthetic biology."

This quote highlights a third core audience for dissemination: scientists. Team members feel that it is important for this group to understand not just what the project did, but also the concepts and theories behind studying scientists/public interactions and scientist/museum professional interactions. One team member said they would like dissemination efforts to include "a piece to say why we involved scientists to the extent that we did for this project, what value that gave, what we learned from that, what worked and what didn't work." To that end, team members have written field-focused articles in publications like *BioCoder Magazine* and presented at a wide array of professional meetings, including AAAS, Engineering Biology Research Consortium, and Biological Weapons Concessions.

Future Projects and Lasting Influence

To keep the momentum from the MSPES project alive, team members are considering new projects and funding opportunities that can build on MSPES the same way MSPES built on the efforts of NISE Net. A meeting of various project stakeholders at the 2017 AAAS conference focused on two potential avenues for continued involvement. One option was to take lessons learned from the MSPES project and apply them to different science content areas. Another option was to determine ways to share new synthetic biology content with other potential audiences. One scientist felt that the project team should focus on "adjacent technology areas that face a similar challenge [in terms of societal and ethical implications]." Another project team member suggested that the team find additional ways for scientists interested in synthetic biology to connect with museum practitioners who are trying to translate the research for the public. One extension of the project is already underway thanks to supplemental funding. Through this supplement, the team will develop two additional forums that address human genome editing. The team will distribute the forum materials and provide training to host site sites in 2018.

Not all efforts to keep the goals of MSPES alive necessarily have to come from this project team, however. As stated previously, some of the host sites from Year 2 are carrying these goals forward in their own institutions. Furthermore, one project team member noted that the concept of PES was beginning to take hold within the larger scientific community, attributing that growth to the MSPES project:

> "I've definitely seen more of the scientific community, especially within synthetic biology, really adopt conversations around engagement, particularly engagement instead of saying outreach. I've seen through the iGEM competition people who weren't even versed in what engagement was or even the idea of having dialogues have become champions of that concept. It's really exciting to see and it's become institutionalized in those settings is a large influence from this project."

She noted that, as a young field, synthetic biology is poised to include PES practices from the beginning. Evidence suggests there is diverse interest in keeping the MSPES project's resources and philosophy alive in future years.

Addendum: Editing Our Evolution

Introduction

In the fall of 2017, the MSPES team began work on a new project supported by a supplementary award to the original NSF grant. The goal of this supplementary project was to develop a forum focused on the topic of human genome editing – in part as a response to the 2017 report on human genome editing published by the National Academy of Sciences.[2] Human genome editing is also tangentially related to synthetic biology and was touched on in certain Building with Biology activities, making it a natural bridge for the project team.

Similar to synthetic biology, human genome editing is a rapidly developing science field that raises many important questions for scientists and non-scientists alike. The MSPES team saw the Editing Our Evolution forums as an opportunity to push the PES model further by focusing on a topic with even trickier societal and ethical implications. REA served as the external evaluators for the Editing Our Evolution forums in a similar capacity as Building with Biology, focusing on the project's impact on hosts and scientists.

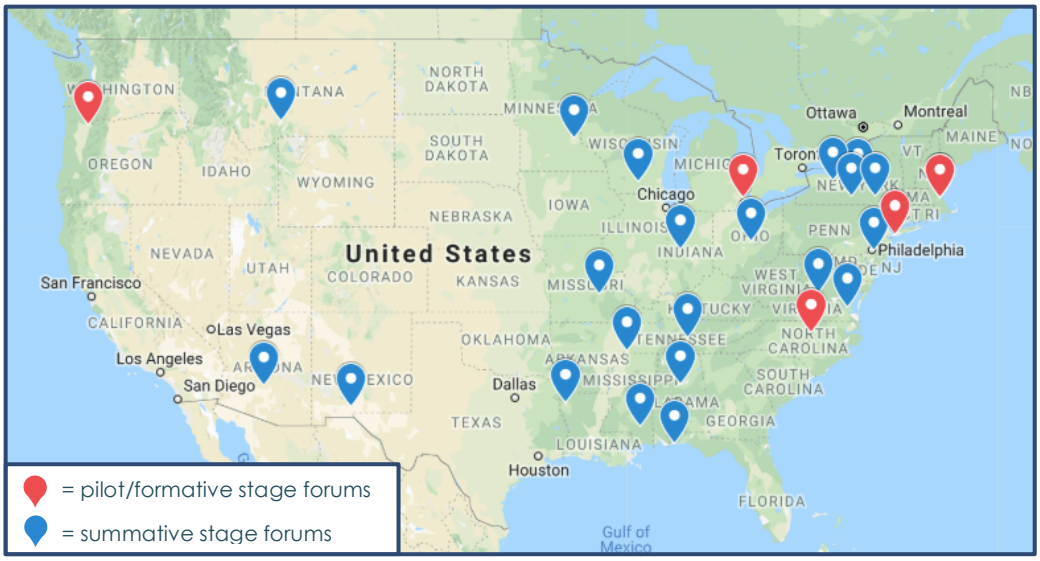
Supplementary Project Activities

Because Editing Our Evolution was funded by a smaller supplementary award than the full MSPES project, the project team chose to focus on producing a single forum and distributing it to 24 sites for implementation. All but one of these sites had previously participated in Building with Biology, and 19 of the sites had previously held a Building with Biology forum. The project team began drafting the forum materials in the fall of 2017, and the Museum of Science held the first pilot forum in January of 2018. The team revised the materials based on this first pilot, and a second pilot was run at an additional four sites in February. After a final round of revisions, organizers from the 24 host sites involved in the summative phase attended a training workshop in Boston and witnessed an Editing Our Evolution forum being held live at MOS. They then went on to hold their own forums from April through September at institutions across the country. At the time of this writing, all but two sites had completed their forums. This addendum therefore provides feedback from 22 of the total 24 sites.

Unlike Building with Biology, scientists recruited for the Editing Our Evolution forums were not provided with PES training in advance of the event (although they may have received this training if they had previously participated in Building with Biology). Instead, the goal was for scientists to participate in the forums in the same manner as other members of the public. In this way, the supplement was able to explore the impact of PES-style forums on scientists who did not receive advance preparation. Each site, however, had one or more scientist presenters who helped introduce the topic of the forum by giving a brief overview. These presenters may have had a slightly different experience in the forums on account of having a more central role in the proceedings and delivering some of the content to the public audiences.

[2] National Academy of Sciences, *Human Genome Editing: Science, Ethics, and Governance*. Washington, DC; The National Academic Press, 2017. https://doi.org/10.17226/24623.

Figure 38. Sites Involved in the Editing Our Evolution Project



Evaluation Questions and Methods

REA's evaluation of the supplement activities focused on measuring outcomes for hosts and scientists at the final forum sites after the pilot forums had concluded. Research questions were similar to those that guided the larger MSPES evaluation and included the following:

What are the project's impacts on forum hosts?

- Do hosts gain a better understanding of how to organize and lead a forum?
- Do hosts perceive the value of hosting PES events in informal education settings?
- What do hosts know about synthetic biology or human genome editing, and how does this change as a result of their involvement?
- What do hosts know about the societal and ethical implications of this area of science? Does their experience in the project improve their confidence in talking to the public about these implications?
- What are the challenges of hosting forums and what recommendations can hosts make improving the process in the future?

What are the project's impacts on scientists?

- What kinds of discussions took place at the forums? What information and opinions did different participants share, and where did scientists' perspectives fit into the discussion?
- What impact did the experience have on scientists' confidence and strategies for engaging the public in science?
- Who do scientists think learned from the experience and why?
- Did the forum discussions have an impact on how scientists view the public's ability to engage with science?
- Did the forum discussions change the way scientists view their own work and research?
- Did the experience encourage scientists to engage in similar efforts in the future?

The evaluation methods employed for Editing Our Evolution were also similar to those used to evaluate the Building with Biology forums, and similar instruments were used where possible in order to provide comparable results between the two projects. Hosts took part in both pre- and post-surveys, while scientists received just post-surveys. Both groups were contacted for phone interviews, with a total of five hosts and five scientists participating, each from a different site. Scientists who participated in the interviews included individuals who had served as presenters as well as individuals who served only as discussion participants.

General Nature and Success of the Forums

Compared to the Building with Biology events and forums, the Editing Our Evolution forums appeared to be more consistent from one site to the next. Editing Our Evolution hosts had closer contact with the project team through the onsite training in Boston and also had the opportunity to attend a forum to get a better understanding of the intended format. The materials provided by the MOS team also gave very specific details on how to structure the forums, and most sites followed these instructions without any major departures. One site incorporated activities for children into their event in order to make it family-friendly and another chose to have humanities scholars rather than scientists as their opening presenters, but these were the only significant departures from the format set by the Museum of Science.

Both hosts and scientists gave predominantly positive feedback on the forums and their experiences. Their survey and interview responses suggest the forums were very successful in achieving many of the goals of PES, such as having two-way dialog between scientists and members of the public (

Figure 39 and Figure 40). Reflecting on the experience, one host commented, "I think everybody walked away respectfully with an understanding of other people's perspectives and kind of the pros and cons of this new technology." They described a particular incident which illustrates the types of positive discussions that were had:

> "We had a young professional in their 30s and then somebody who maybe was in late their 40s, with very different backgrounds, upbringings and political and economic and social ideas about the world. And at the end talking with each other and being part of the discussion, they actually thanked each other for sharing, and they expressed that they had learned something from each other. And that was a really cool thing to learn – that people were willing to learn from somebody else's ideas and experiences, and be open to that new information."

Another host noted that the conversations varied from one table to the next and sometimes got drawn into interesting tangents, but that the conversation always came back to the core questions raised by the forum.

Figure 39. Hosts' Overall Forum Feedback
(Host post-survey, n=24)

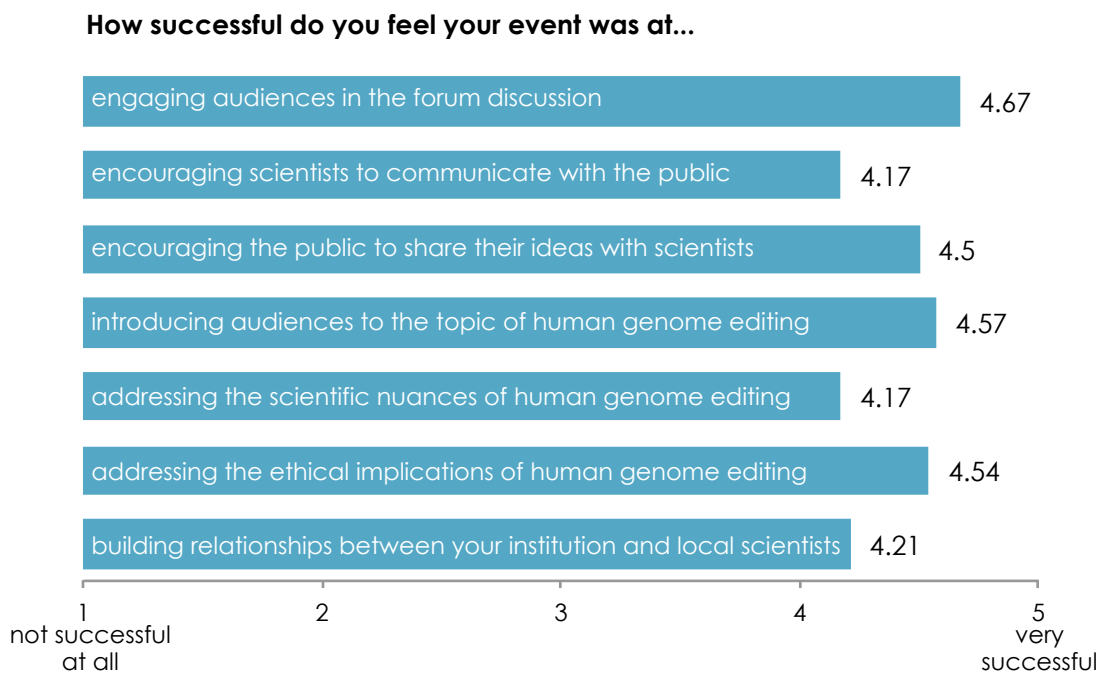
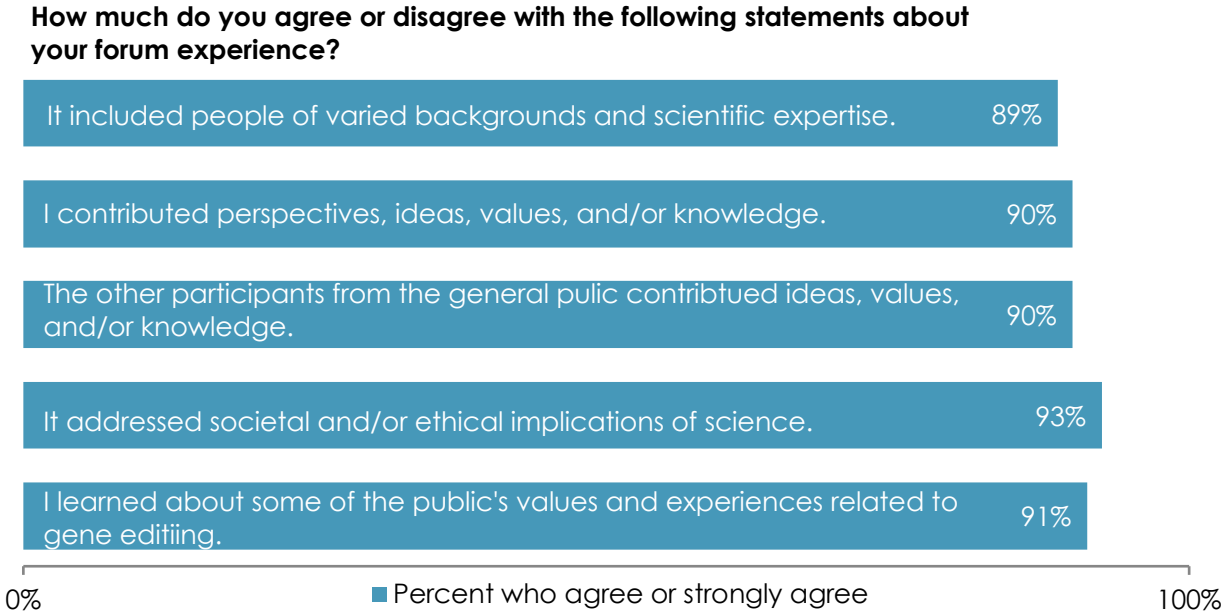


Figure 40. Presence of PES Features at Editing Our Evolution Forums
(Scientist post-survey data, n=76)



Hosts said they enjoyed the forum format and felt that the topic worked very well with their participants. "The topic was an engaging one," one interviewee noted. "It gave everyone the opportunity to contribute their perspectives and ideas." Another interviewee said they had trepidation that the topic might lead to contentious conversations, but instead they found that the participants were very respectful of different opinions and no difficulties were had. They also commented on the forum's success in focusing on the societal and ethical issues at hand: "What I really enjoyed was that it wasn't a *science* conversation. It was all about the point of doing what's right rather than focusing on the technology and how it happens. Talking more about *should* it happen."

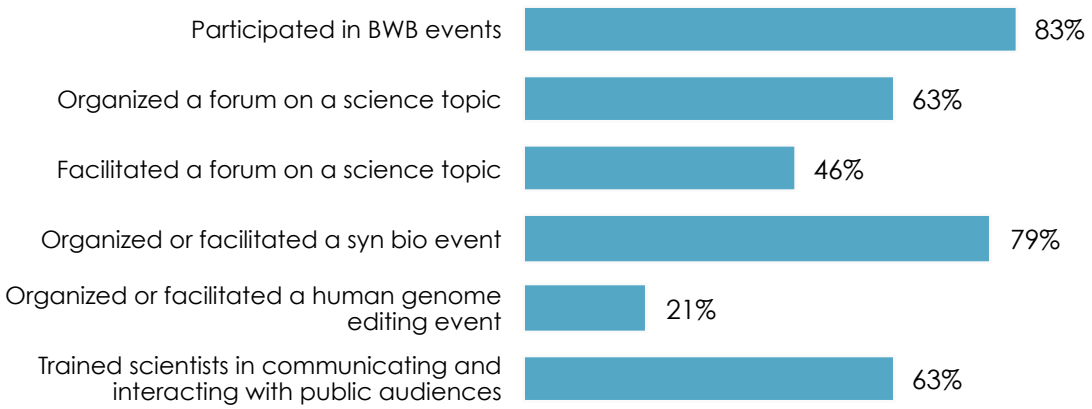
Several hosts also commented that they had interesting discussions during their forums because their audiences included individuals from different countries. At one forum, this led to a discussion of how healthcare systems differ. In another, participants had a deep conversation about how the societal concerns of the issue would be interpreted differently in different parts of the world.

Outcomes for Hosts

Host Profile and Prior Science Engagement Experience

In some cases, Editing Our Evolution forums were organized by more than one key individual, and as a result a total of 24 individuals responded to the pre- and post-surveys, representing a total of 22 sites. Most of these individuals had prior experience organizing or facilitating science engagement events for the public, often through their experiences with Building with Biology (83% of respondents). Sixty-three percent had organized a forum specifically, as opposed to an event featuring the hands-on Building with Biology activities. A subset of these (46%) had facilitated those forums (as opposed to serving in a more administrative capacity). Building with Biology had provided hosts experience with synthetic biology events, but only a fifth of the hosts had prior experience organizing or facilitating events related to human genome editing.

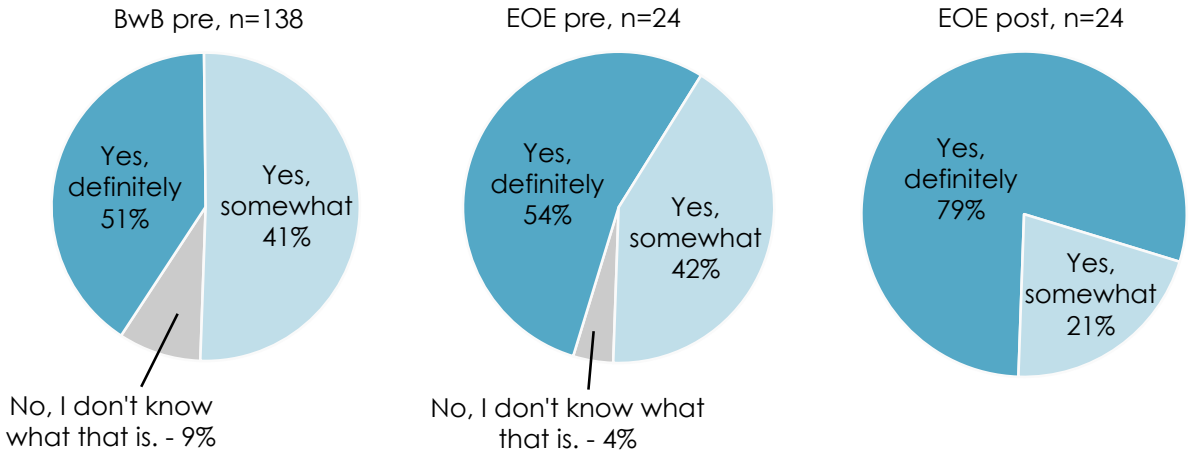
Figure 41. Hosts' Prior Science Engagement Experience
(Pre-survey data, n=24)



Understanding of Public Engagement with Science

Because most sites involved with Editing Our Evolution had previously been involved with Building with Biology, most hosts also started with a good understanding of PES and its potential benefits. According to survey responses, hosts' familiarity with the concept of PES was slightly higher at the beginning of Editing Our Evolution compared to the beginning of Building with Biology (Figure 42). By the end of Editing Our Evolution, the percentage of hosts who said they were definitely familiar with PES jumped from 54% to 79%, and none of the hosts responded "I don't know what that is." The Building with Biology post-survey did not include this question and instead asked hosts to provide their definition of PES in an open-ended question.

Figure 42. Hosts' Surveys - Are you familiar with the concept of PES?



Hosting PES Events and Forums

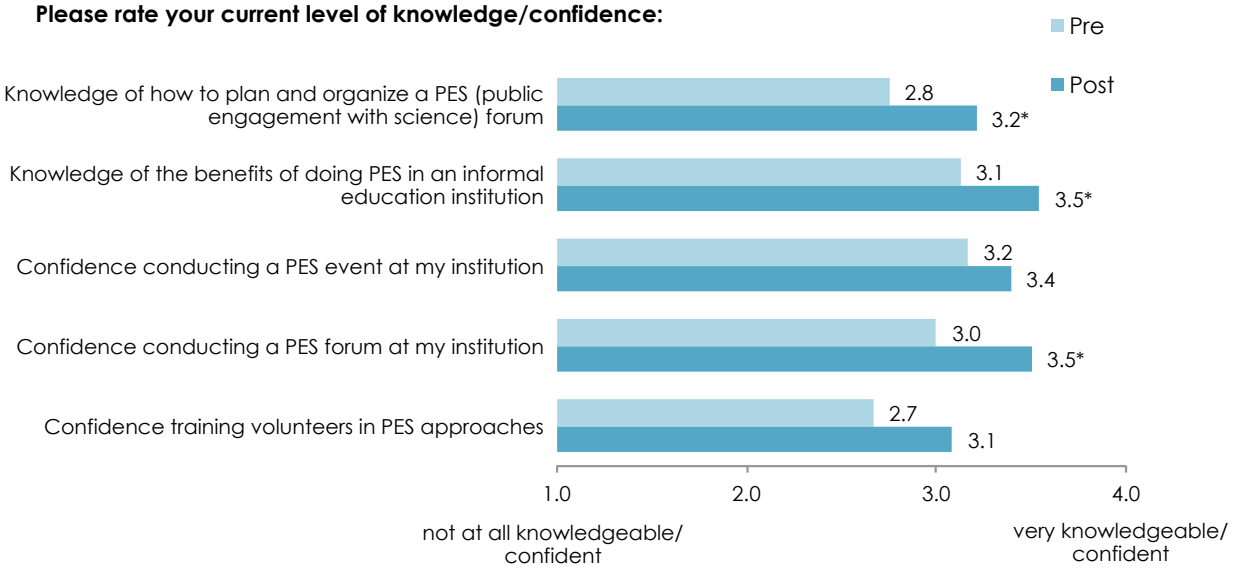
In addition to improving their understanding of PES as a concept, hosts who organized Editing Our Evolution forums also showed significant increases in knowledge and confidence related to planning and conducting PES forums and the benefits of these forums (Figure 43). Although the hosts also reported increased confidence in training volunteers in PES, the pre/post change was not significant – likely because Editing Our Evolution did not focus on volunteer training in the same way that Building with Biology did.

Still, some hosts commented in their interviews that the experience did build their confidence and also reinforced their belief that these types of PES events are valuable. One host stated:

> "I definitely feel more confident holding these kinds of events. Having that template and all of the support to go forward was really helpful and a very successful learning experience for me and so I really feel like I'm going to be able to take those skills into leading other types of programs like this."

Figure 43. Hosts' Increased Knowledge and Confidence

(Matched pre/post-survey data, n=24)



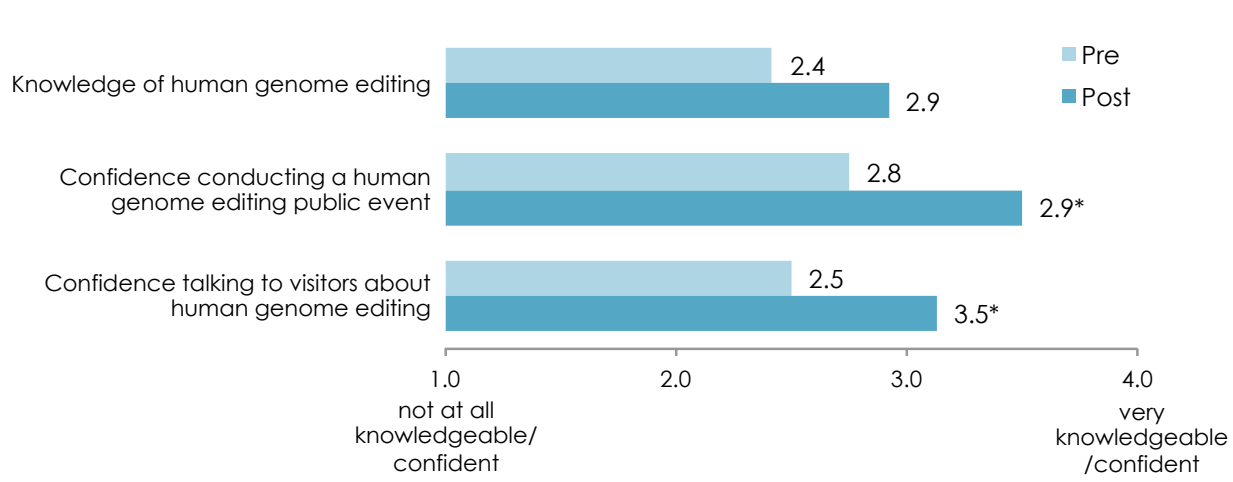
**Using paired sample t-tests, comparison of hosts' responses showed a significant increase in confidence/knowledge from pre to post on three of the five survey items above (p<.05).*

Understanding and Confidence Related to Human Genome Editing

Editing Our Evolution hosts also gained a better understanding of human genome editing through the project as well as greater confidence talking to visitors about the topic and organizing public events on it (Figure 44).

Figure 44. Hosts' Increased Knowledge and Confidence

(Match pre/post survey data, n=24)

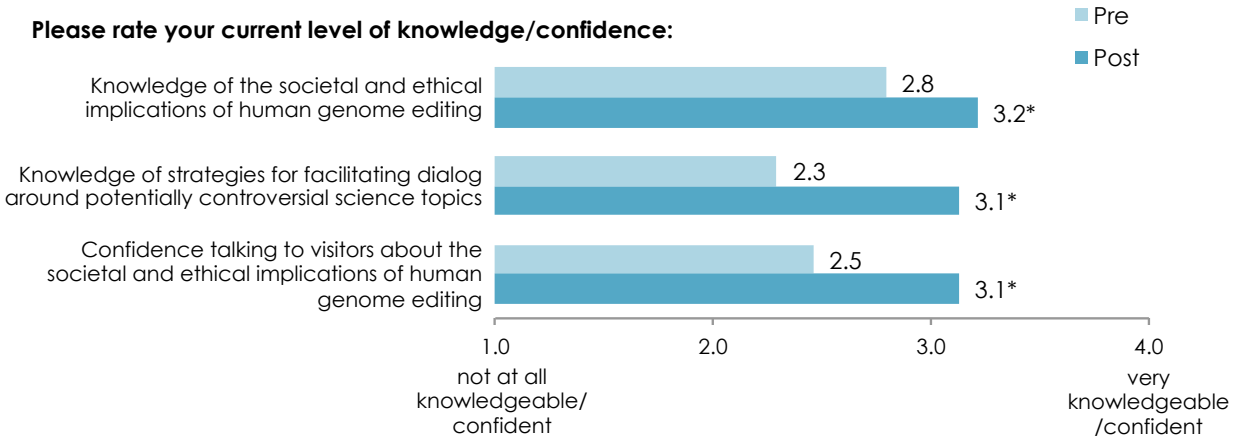


**Using paired sample t-tests, comparison of hosts' responses showed a significant increase in confidence/knowledge from pre to post on the second and third survey items above (p<.05).*

Dealing with Controversial Discussion Topics

In choosing human genome editing as a topic for forum discussions, the MSPES team knew that forum organizers and participants would have to navigate a variety of controversial issues. To understand if the project helped prepare hosts for this challenge, a number of related items were added to the pre and post-surveys to measure hosts' knowledge, confidence, and attitudes toward facilitating difficult conversations and hosting events focused on divisive or delicate topics (Figure 45 and Figure 46).

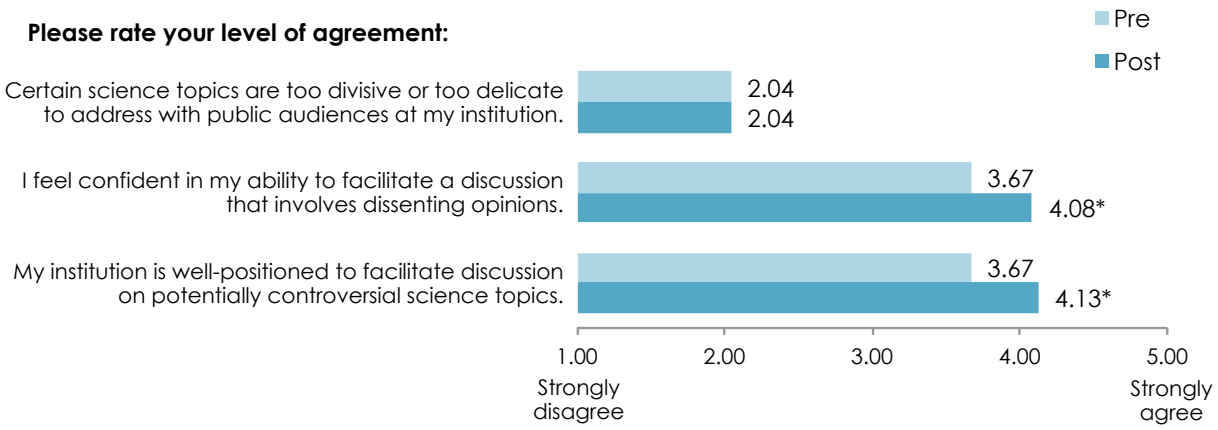
Figure 45. Hosts' Increased Knowledge and Confidence Related to Controversial Discussion Topics
(Matched pre/post survey data, n=24)



**Using paired sample t-tests, comparison of hosts' responses showed a significant increase in confidence/knowledge from pre to post on all three survey items above ($p<.05$).*

Responses show that hosts felt they had increased their knowledge of the societal and ethical implications of human genome editing, their confidence for discussing these with visitors, and their knowledge of strategies for facilitating dialog around potentially controversial science topics. They also indicated greater confidence facilitating discussions with dissenting opinions, and they were more likely to agree that their institutions were well-positioned to facilitate these difficult discussions. On average, the respondents disagreed (but did not strongly disagree) that certain science topics are too divisive/delicate to address with the public at their institutions. This sentiment did not shift between the pre and post, suggesting that although hosts are now comfortable addressing human genome editing, there are other topics which may still be too large a hurdle.

Figure 46. Hosts' Opinions on Tackling Difficult Topics
(Matched pre/post survey data, n=24)



**Using paired sample t-tests, comparison of hosts' responses showed a significant increase in agreement from pre to post on the second and third survey items above (p<.05).*

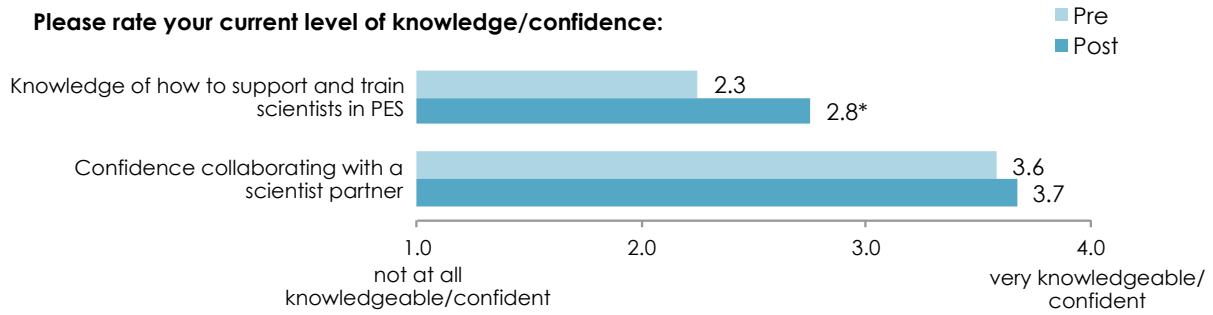
Despite the spectrum of strong opinions that could potentially arise from the forum discussion prompts, interviewees indicated that the discussions were remarkably civil. In some cases, hosts were surprised that the forum scenarios didn't elicit stronger reactions from the participants. At one forum, for example, the host noted that the participants seemed fairly receptive to the idea of gene editing. They moved quickly through the first two scenarios and were in agreement on most issues. Dissenting opinions didn't arise until the third scenario. Another host said they had hoped for more opportunities to discuss dissenting opinions, but that the discussion had remained somewhat mild. In general, however, most seemed pleased about the variety of opinions that were shared during the discussions.

Collaborating with Scientists

Editing Our Evolution required some collaboration with scientists in order to secure speakers for the opening presentations of the forums, but it did not require the same depth of collaboration as Building with Biology, which required hosts to provide their scientist facilitators with training in PES. Editing Our Evolution hosts gave their knowledge of supporting and training scientists in PES only moderate scores. Nonetheless, hosts' knowledge of supporting and training scientists in PES showed a significant increase from pre to post (Figure 47). Their confidence for collaborating with scientist partners was also high, with not much room for improvement from pre to post.

Figure 47. Hosts' Responses on Collaborating with Scientists

(Matched pre/post surveys, n=24)



**Using paired sample t-tests, comparison of hosts' responses showed a significant increase in agreement from pre to post on the first survey item above (p<.05).*

Outcomes Compared to Building with Biology

As noted above in the discussion of hosts' understanding of PES, Editing Our Evolution hosts self-reported a better understanding of PES on their pre-survey than Building with Biology hosts, likely because many of them had previous training through their involvement in Building with Biology. The project team hoped that their experience in Editing Our Evolution would help hosts advance even further in their understanding of PES and their knowledge of how to organize PES events. Their surveys, however, did not show significant differences from those completed by Building with Biology hosts, with a single exception where Building with Biology hosts scored higher.[3] Since Building with Biology hosts gave themselves high confidence and knowledge scores on their post-surveys, there was little room for improvement when these individuals moved on to organize Editing Our Evolution forums. Although the surveys did not signal significant improvements for Editing Our Evolution hosts, those who participated in phone interviews did talk about how this additional experience helped expand their confidence, knowledge, and skills:

> "I definitely feel more confident holding these kinds of events. Having that template and all of the support to go forward was really helpful and a very successful learning experience for me, and so I really feel like I'm going to be able to take those skills into leading other types of programs like this."

> "Every time I do one I feel more and more confident. I'm excited about doing more."

Their responses suggest that their increased confidence for holding forums has also increased the likelihood that they will host additional forums in the future.

[3] BwB hosts scored significantly better than EOE hosts when asked to rate their knowledge of supporting and training scientists in PES. This is understandable, since training scientists in PES was not a responsibility for EOE hosts.

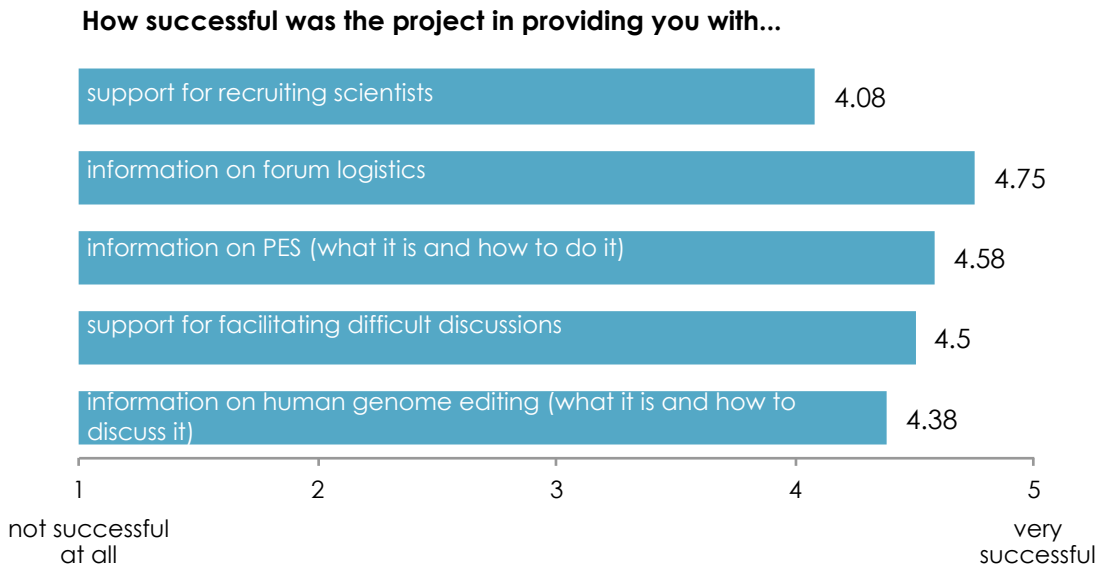
Support from Project Team

Hosts' post-survey responses indicate they felt well-supported by the project team to carry out their responsibilities in hosting forums (Figure 48). In particular, hosts reported that the project did an excellent job providing guidance on the logistics of hosting forums. On open-ended survey questions and through the interviews, several participants also stressed that attending the forum in Boston was very helpful for helping them plan their own events:

> "Being able to have someone from our team participate in a forum at Boston was extremely valuable. We learned things through the first-hand experience we never could have known just on paper. For instance, the type of catering we needed and that we wanted to have more opportunities for sharing out from the table discussions."

Hosts also talked about the forum "kits" being extremely thorough and helpful. They talked about making minor tweaks to the marketing materials and the slide presentation, but overall felt like they were well-prepared for their events. A few hosts requested more support in the form of additional marketing materials as well as post-engagement materials. One person noted that the public didn't seem to know what to expect at the forum despite their best efforts to make it clear in their marketing efforts, and another said the same of the scientists they had invited. Two others said that it would be nice to have a way to engage with participants afterward or perhaps have materials to send home with the participants, especially since the discussion notes were supposed to be left behind for the project research.

Figure 48. Hosts' Feedback on Project Support
(Post-survey, n=24)



A few hosts reported difficulty recruiting scientists, but this was not generally seen as a project fault. Instead, most hosts who had a hard time finding scientist participants owed it to the timing of the forums. Since many hosts were recruiting university faculty and students who were on

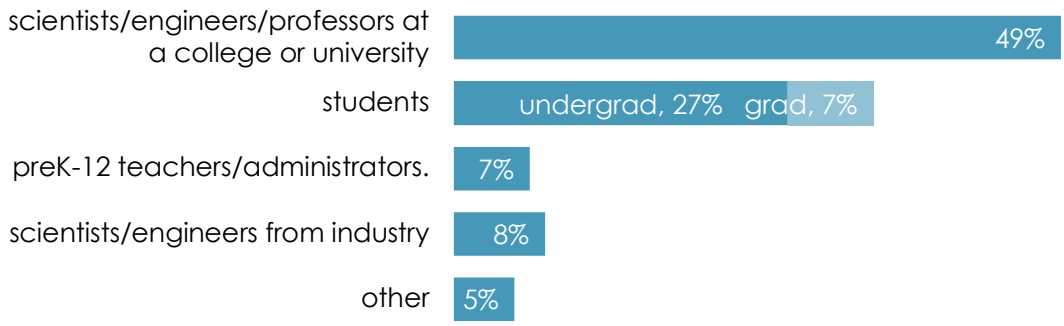
summer break at the time the forums were being held, getting in touch with scientists was sometimes difficult. Some hosts also found or suggested innovative methods for recruiting scientists. One site had one of their presenters give their address via Skype. Another indicated that while it is not difficult to find expert scientists, it can be difficult to find expert scientists who are also effective communicators. She commented that it might be helpful to use a directory of vetted speakers, similar to the one used by the American Chemical Society.

Outcomes for Scientists

Scientist Participants Profile and Prior Science Engagement Experience

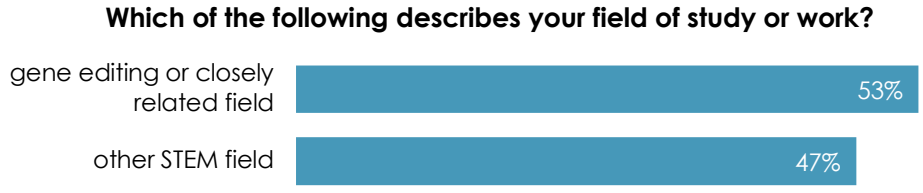
Eighty-one participants completed the scientist post-survey, representing all but one of the host sites and roughly half of the participants for whom contact information was available. Almost half of these participants indicated they were scientists, engineers, or professors at a college or university (Figure 49). Approximately one third were either undergraduate or graduate students from science fields. Building with Biology facilitators, for comparison, were comprised mostly of students (55%), while university scientists, engineers, or professors made up only 18%. Scientists or engineers from industry (including medical fields) made up 7% of Editing Our Evolution scientists, educators accounted for 7%, and the remaining 5% included museum professionals, retired scientists, and a few individuals who do not work directly in STEM fields, including a journalist and a professor who specializes in the philosophy of science. Those who do not work directly in STEM fields or study a STEM field (five individuals) are excluded from the analysis that follows.

Figure 49. Professions of Scientist Participants
(Post-survey data, n=76, participants could select more than one answer)



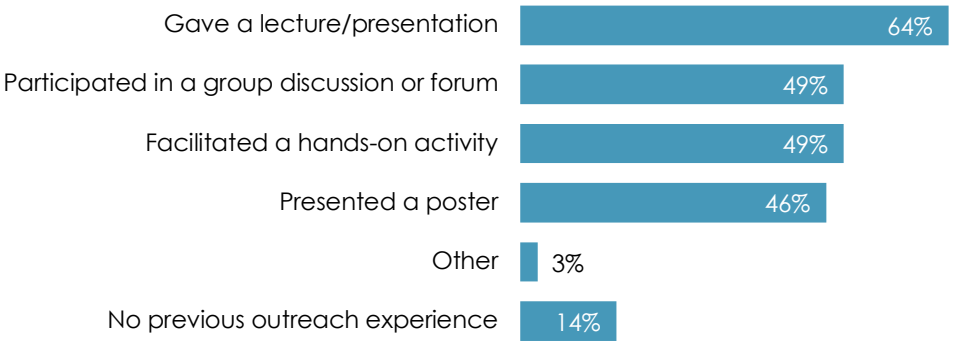
Over half of the scientists (53%) indicated they either study or work in human genome editing or a closely related field (Figure 50). The remaining 47% said they work in a different STEM field.

Figure 50. Scientists' Area of Study/Work
(Post-survey data, n=76)



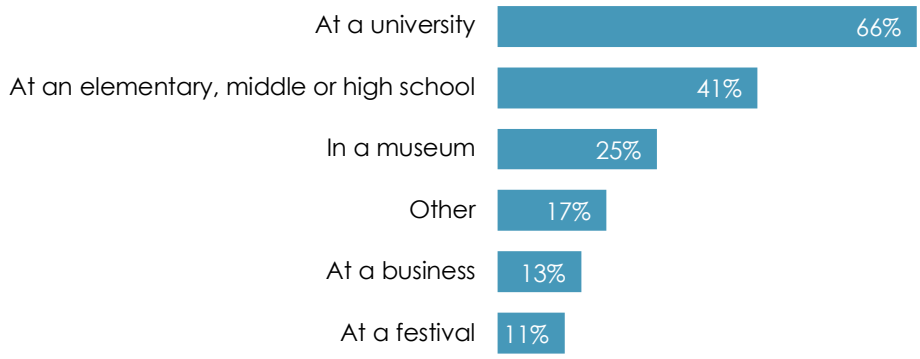
Most of the scientists (86%) had previous experience in some form of public outreach prior to participating in the Editing Our Evolution Forum (Figure 51), and in this regard they were quite similar to the facilitators who took part in Building with Biology. Nearly two thirds of the Editing Our Evolution participants had given a lecture or presentation in the past, and roughly half had participated in a forum in the past or facilitated a hands-on activity. Fourteen percent, however, said they had not participated in any science outreach before.

Figure 51. Scientists' Previous Outreach Experience
(Post-survey data, n=76)



For the most part, the scientists' prior outreach experience took place at universities (66%) or schools (41%) (Figure 52). A smaller percentage of scientists had done outreach in museums, at business, at festivals, or other venues.

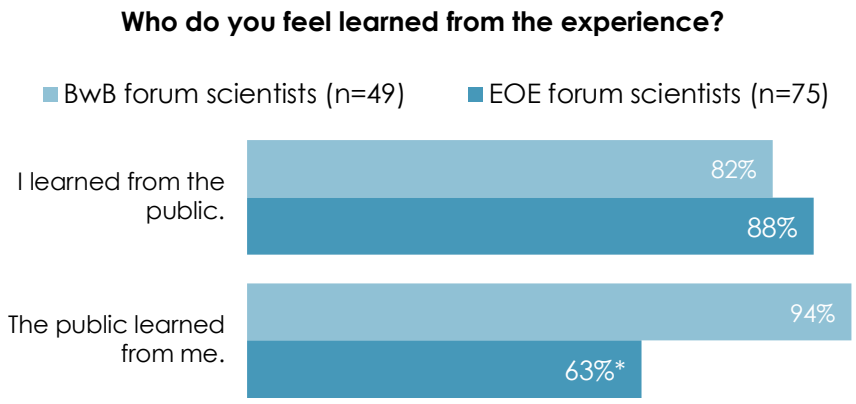
Figure 52. Where Scientists' Previous Outreach Experience Took Place
(Post-survey data, n=76)



Learning from Scientists, Learning from the Public

Like those scientists who participated in Building with Biology forums, most scientists who participated in Editing Our Evolution forums felt they had learned from the public, fulfilling a goal of the MSPES project (Figure 53).

Figure 53. Mutual Learning in MSPES Forums
(BwB and EOE scientist post-survey data)

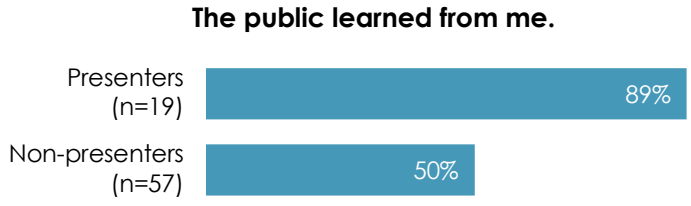


**A Chi-Squared test showed a significant difference between BwB and EOE forum scientists' responses to the statement "The public learned from me." (p<.05).*

The few scientists who did not say they learned from the public gave a range of reasons. In some cases, their responses suggested that they did not have much of an opportunity to hear public opinions. One scientist, for example, did not sit at the discussion tables but rather circulated during the forum in a more administrative role. Another scientist stated, "Most discussion topics caused different group members to enthusiastically ask me questions based on my scientific background." It's possible that this individual and perhaps some of the others heard viewpoints from the public but didn't view this as learning on their part.

Interestingly, far fewer scientists who participated in Editing Our Evolution forums agreed with the statement, "The public learned from me" than scientists who had participated in Building with Biology forums. This difference is driven by those Editing Our Evolution scientists who did not serve as presenters during the forum, who were less likely to say that the public learned from them (Figure 54). Those who served in a presenter role likely had a similar experience to many Building with Biology scientists, who often served as facilitators either in their forums or in presenting the hands-on activities during BwB events. These individuals had more opportunities to present their knowledge to the public than Editing Our Evolution scientists who served as discussants but not presenters.

Figure 54. Presenters v. Non-Presenters at EOE Forums
(Post-survey data)



Those who did not feel the public learned from them gave a range of responses. Some of them said they had purposefully kept quiet during the discussions so as not to sway people's opinions with their own point of view:

> "I am not very well versed in genome research and tried to stay mostly quiet and let the presenters lay the groundwork. I did not want to quash discussion, which might have happened if I presented my (in their eyes expert) opinions."

The forum guide provided to hosts instructed them to inform scientists that "they will participate on the same footing as members of the public" and "are not here to lead the discussion or teach the topic." Some scientists' survey responses suggest that they interpreted this direction as instruction to not voice their own opinions.

In other cases, scientists had offered their point of view but felt that they hadn't been heard. One survey respondent stated, "My group was pretty opinionated, so it was hard to be heard at times." Another scientist who took part in a phone interview talked about how his viewpoint was sometimes disregarded in the conversation due his being young and not having children. Others simply felt they learned more from the public than the public may have learned from them. One stated, "Several participants brought up ideas that I hadn't thought about before," while another said, "I don't think I contributed as much as I learned from them."

Scientists talked frequently about hearing viewpoints they hadn't considered before. One participant described it as "eye-opening." Many said it was interesting to hear people weigh different factors into their decisions than those a scientist might consider. Some, for example, talked about religion influencing their decisions. Another scientist talked about how anecdotal data and personal experiences factored heavily into people's responses to the discussion prompts. One survey respondent stated:

> "It was kind of a reality check that highly religious people still exist. Also, it reminded me that delivering medicine to people is more than a scientific pursuit. It is heavily influenced by business and law, which I still know very little about."

In some cases, public participants did not object to various gene editing treatments, and when this occurred scientists expressed surprise similar to the hosts. Several scientists commented on how younger people seemed to be very much in favor of gene editing in the scenarios described – even in the case where it was to be used for muscle enhancement for non-medical reasons. One survey respondent noted that the public didn't dwell as much on ethical issues that concern some scientists:

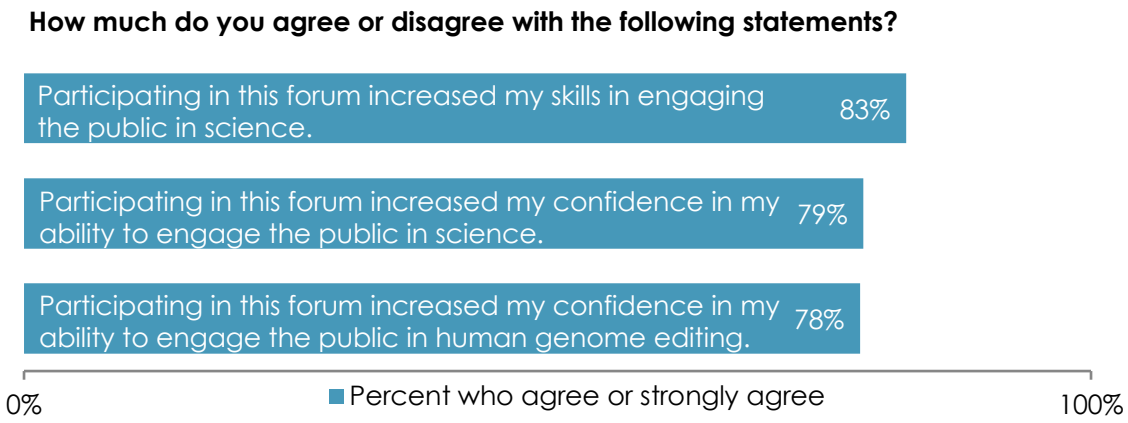
> "There are some issues that we as genetics professionals really focus on that were not issues even really worthy of attention by participants. For example, many people in my group didn't understand why you wouldn't allow your child to be treated. Also, people didn't draw any distinction between using the technology on children or adults."

In other cases, however, scientists engaged in discussions with people who were strongly opposed to the use of gene editing therapy. Scientists' take-away impressions of the public's opinions therefore seem to be highly varied depending on the individuals with whom they interacted.

Communicating with the Public

Whether scientists interacted with individuals who were receptive to the idea of gene editing or opposed to the idea, many seemed to take away a better understanding of how to communicate with the public simply by understanding the range of opinions that exist. One survey respondent stated, "I am a professor, and my hope was to learn how students and community members think about science. I did learn a great deal about that and it will help me communicate better in the future." The majority of scientists also said they had improved their skills and confidence for engaging the public on topics related to science and human genome editing (
Figure 55).

Figure 55. Effect of Forum on Scientists' Communication Skills & Confidence
(Post-survey data, n=73-76)



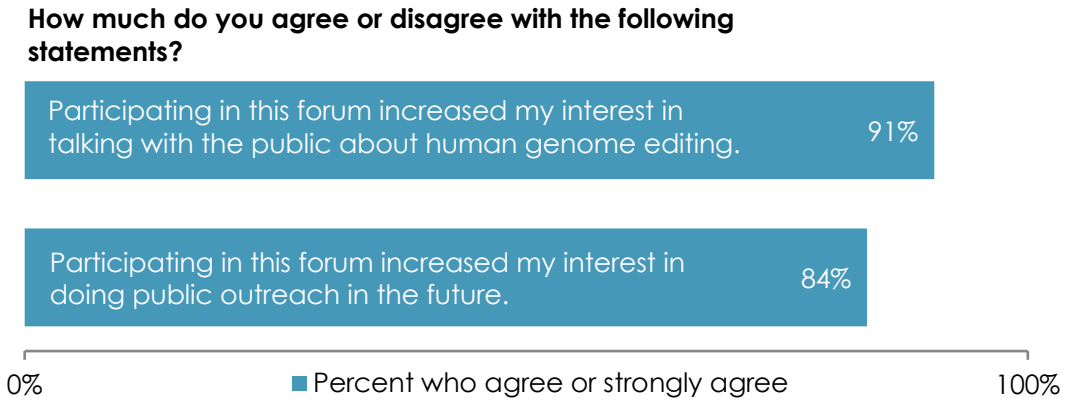
Some scientists mentioned specific strategies they had learned for communicating better with the public. One said, "listening is the best policy" while another noted, "Some people are shy until you ask them a specific question that they could relate to." Another said simply, "The words you use matter." An interviewee noted that the experience provided training in a different kind of science communication than most scientists are used to:

> "I felt I learned how to better communicate with the public. I think that's not something I've ever received any sort of formal training on or done a lot. And the only way to gain experience is to do it. Maybe I know how to make the argument for the use a specific technology in an academic setting or in a paper that's going to be graded by somebody with a PhD, but maybe I lack the ability to communicate those ideas to somebody who doesn't have a PhD. So it was really beneficial for me and the other scientists there."

One scientist said he gained more respect for the public's ability to understanding scientific concepts, stating, "At this forum, I learned that when communicating with the public around science they will pretty much be able to grasp a lot of the general concepts--ideas do not have to be dumbed down or heavily simplified." This sentiment was echoed by other survey responses and the fact that 93% of the scientists agreed or strongly agreed that the experience "had a positive influence on the way I think about the public's ability to understand or engage in thinking about scientific research."

The experience also had a positive influence on most scientists' interest in having further interactions with the public. Ninety-one percent said the forum increased their interest in talking with the public about human genome editing, and 84% said it increased their interest in doing public outreach in the future (Figure 56).

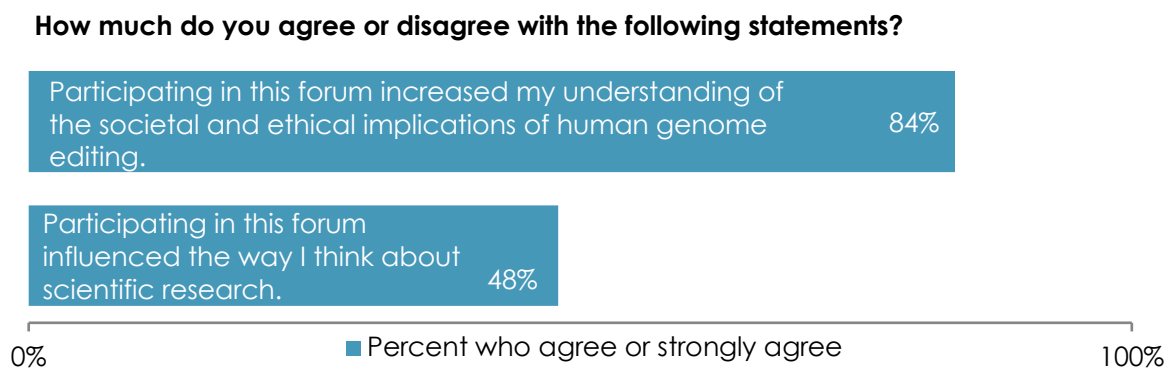
Figure 56. Effect of Forum on Scientists' Interest in Public Interactions
(Post-survey data, n=68, 63)



New Outlooks on Gene Editing and Scientific Research

As an extension of exchanging point of views with the public, another goal of the Editing Our Evolution forums was to help scientists consider gene editing and their own work in a new light. Although a few respondents described the public as being ill-informed, anti-science, or inflexible in their opinions, most indicated more respect for the public's opinions, and some even said these opinions had a new influence on their way of thinking. One scientist said, "I think that I have started thinking more deeply about it [gene editing]." They said that a particular comment from another participant had stuck in their mind. This person had noted that by selecting our mates, we are already engaging in a form of gene editing – a point that this young scientist had not considered before.

Figure 57. Effect of Forum on Scientists' Thinking
(Post-survey data, n=75)

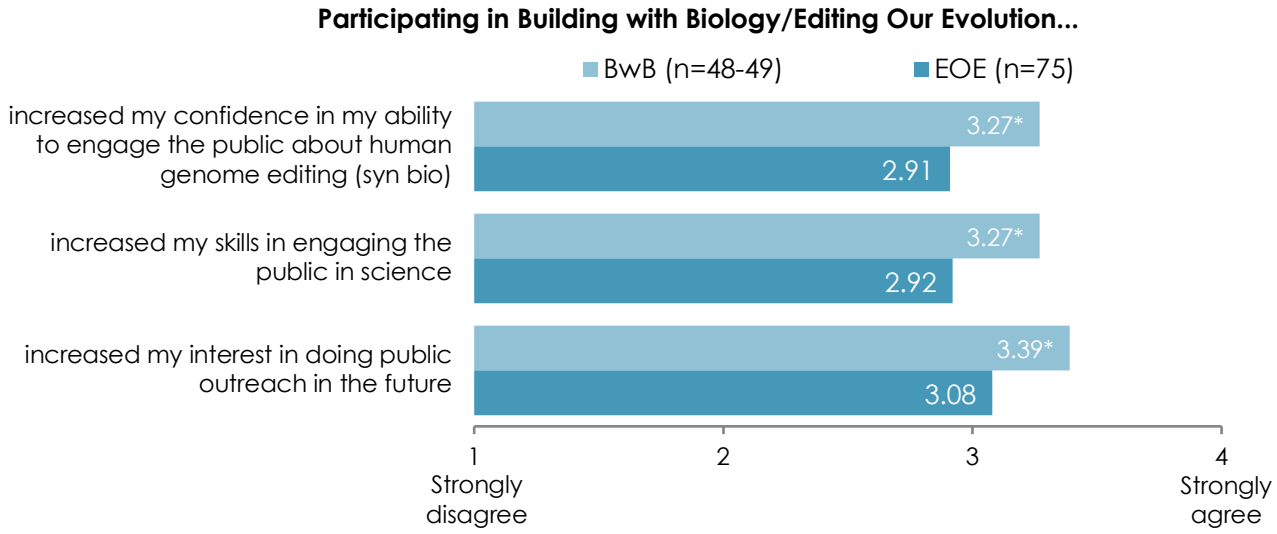


Another scientist commented in their survey, "The discussion left me much to think about due to the variety of ideas and opinions expressed. Overall, this has led me to somewhat modify my opinions regarding gene editing."

Outcomes Compared to Building with Biology

The Editing Our Evolution scientists' surveys were also compared to those submitted by Building with Biology scientists who had participated in forums. When looking at the responses from these two groups, most outcomes were comparable. In a few areas, however, Building with Biology scientists had significantly higher scores than Editing Our Evolution scientists (Figure 58). These responses indicate that Building with Biology did a better job increasing scientists' confidence engaging the public around the topic area, increasing scientists' public engagement skills, and increasing their interest in doing public outreach in the future.

Figure 58. Significant Differences between Impacts on BwB and EOE Scientists
(BwB and EOE scientist post-survey data)



**Using paired sample t-tests, comparison of scientists' responses showed significant differences between BwB and EOE participants on the three survey items above (p<.05).*

As noted above, most scientists who participated in Building with Biology received PES training, unlike the requirement for scientists who participated in Editing Our Evolution forums. Many Building with Biology scientists also participated in events where they served in a facilitator role, interacting with the public around hands-on activities. The differences in outcomes for these two groups might therefore be owed to the more intense level of engagement many Building with Biology scientists experienced, in terms of both training and interactions with the public.

Benefits for All

Both scientists and hosts expressed a clear belief in the importance of these types of forums and noted the many benefits they bring for different kinds of participants. Scientists see great value in helping dispel some of the myths surrounding science or just providing more information about a topic that the public might not consider very often or very deeply:

> "I think in general there are a lot of misconceptions about medicine or even just about my job. A lot of people hear 'genetic counselor' and think, 'Oh! You make designer babies.' And no, that actually has nothing to do with what I do. Especially those who don't have a science background, just kind of giving them a better understanding - even if they can't fully grasp everything – of the medicine and what's happening and where we are, how close we are to actually implementing this technology… I think there's a huge benefit to trying to increase the medical literacy in the general public."

Scientists also see the value for themselves, in hearing what the public has to say. One scientist noted that through the forum:

> "We [scientists] get to understand what our community specifically is thinking and feeling and hoping to learn. The benefit to the public is that they get to sort of gain a new lens on something that they may have had a very staunch opinion about… I think that's very important, this element of developing a trust with local people who you think won't steer you wrong, right? And you certainly hope that to be true, and that's our job as scientists – to steer people correctly and share real things."

Hosts described the value for the general public, for scientist participants, and for their own institutions. There was a consensus that providing opportunities for open discussions and room for varying opinions around science topics is important and that forums can meet this need. One host spoke passionately about the forum format and its benefit:

> "The overall value is public engagement with science and how to do it effectively. I've drunk the koolaid. If you want to engage with the public, it needs to be a conversation, not a lecture or a planned talk. It needs to be a dialog back and forth. The public needs to be able to have a voice. You have to be careful about not having too much of one voice. But as long as we're open minded and willing

> to listen it goes so much farther than just telling people, 'This is how it works and how it should be.'"

Another host commented, "There's a lot you can learn from just talking with people and that's really what I appreciate about these forums." Only one host expressed doubts about the forum format, and this was due to the limited number of people it has the potential to reach as compared to other kinds of museum events (such as festivals, for example). Although they saw the benefit for those who attended, this host noted that their institution would have to weigh that value against the sheer numbers that can be reached through other offerings.

The vast majority of both hosts and scientists, however, talked about their eagerness to do additional forums in the future. Hosts talked about either reusing the Editing Our Evolution forum materials or exploring new topics. One host said, "I'm sending people to the website already saying, 'Hey go access these materials. You can do these forums yourself.'" Like Building with Biology, it appears that the goals of MSPES will live on through additional forums supported by the materials the project has produced, as well as through the enthusiasm the project has engendered for Public Engagement with Science among a wide audience.