OMSI
Everyday Encounters with Science

garibaygroup

Design Zone Professional Development Summative Report

Prepared for
Oregon Museum of Science and Industry
May 2013

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. DRL-0714634. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Photo Credits
All photos: Garibay Group
Except pages 36, 37, 39, 40, 42, and 43: OMSI

Table of Contents

Executive Summary

As part of the National Science Foundation-funded *Access Algebra* project, the Oregon Museum of Science and Industry (OMSI) developed both a 6,000 square foot traveling exhibition (*Design Zone*) and a professional development program for host-museum facilitators who would work in the exhibition. The primary goal of the project was to engage visitors in algebraic thinking, with a special focus on reaching a target audience of 10- to 14-year-olds and their families. Facilitation in *Design Zone* was intended to support and extend visitors' engagements with the exhibits and engage visitors in algebraic thinking.

Garibay Group conducted the summative evaluation using a mixed method approach design. Data were collected at three museums that hosted the *Design Zone* exhibition. This report focuses on the extent to which the professional development component met its goals and realized its projected impacts. The results were interpreted within the framework of Kirkpatrick's (1998) four-level model for evaluating professional development and training.

Key Findings

Overall, the professional development aspects of *Design Zone* were very successful, meeting eight of the ten indicators set for project impacts.

Level 1. Reaction: Did they like it?

- Professional development workshops succeeded on this level with the vast majority of participants. Over 90% of respondents in every workshop said that the workshop they attended met or exceeded their expectations.

- The large majority of respondents found the workshops useful. Ninety percent or more of Workshop I participants rated usefulness as a 4 or 5 (with 1 being low and 5 being high). Positive ratings were also solid, but slightly lower, for Workshop II with 82% of participants providing ratings in the 4–5 range. The primary reason cited for a workshop's usefulness was that the experience helped participants develop familiarity with *Design Zone* and provided them with opportunities to consider ways to engage visitors.

Level 2. Learning: Did they learn it?

- Participating in the pre-opening workshops positively affected participants' sense of being prepared to facilitate visitor experiences in *Design Zone*. Seventy-five percent of participants reported that the workshops helped them feel more confident in their abilities to facilitate visitor experiences in *Design Zone*. Participants especially appreciated being able to have training before *Design Zone* opened and to spend time becoming familiar with the exhibit. They often commented on how different this experience was to the typical one of being asked to facilitate an exhibit with little to no preparation time. The workshop successfully helped participants become more familiar with exhibition goals and the exhibits.

- The majority of respondents attending workshops (70% in Workshop I and 83% in Workshop II) "agreed" or "strongly agreed" that the workshop helped them reflect on their own approach to facilitation.

- Participants reported a range of ways in which the workshop contributed to their learning. More than a third (36%) mentioned having learned about facilitation skills. Another 24% mentioned that the workshop helped them understand how the exhibits work. Fifteen percent mentioned math as part of what they had learned. Twelve percent of respondents cited learning how to make math fun or interesting for visitors as the main thing they learned. Respondents were especially appreciative of being trained before *Design Zone* opened, which they contrasted with the usual situation where they were asked to facilitate a traveling exhibition with little or no training prior to opening.

Level 3. Transfer: Did they use it?

- More than 60% of those responding to the follow-up survey indicated that they facilitated visitor experiences at *Design Zone* at least one day a week.

- Ninety-six percent of respondents reported using at least one of the facilitator affordances. While all of the facilitator affordances received at least some use by staff, facilitators expressed feeling more comfortable with the affordances for which they had received training at an OMSI workshop.

- Over 70% of respondents indicated they used the printed *Design Zone* materials at least once, and all three host museums used parts or all of the Staff Guide to train facilitators who could not attend the workshop. Respondents were less likely to have used the *Design Zone* Professional Development portion of the website, with slightly more than 20% reporting they had visited the site at least one time.

- Facilitators interacted with visitors in *Design Zone* in many different ways. Aspects of the Cycle of Facilitation Model were applied by many of the facilitators observed, although they did not always remember the name or use all parts of the model in every interaction with visitors.

- Time spent facilitating visitor groups varied, but on average lasted between 8–12 minutes. This time was significantly longer than the dwell times recorded when visitors engaged on their own, where only 29% of groups with children in the target age range had interactions lasting 6–10 minutes and only 2% had interactions lasting 11–15 minutes.

Level 4. Impact. Did it make a difference?

- The *Design Zone* professional development component made a difference on at least three levels—affecting the visitor experience, facilitators' professional development, and organizational commitment to facilitation of math experiences on the floor. Many aspects of facilitators' interactions with visitors helped further visitors'

algebraic thinking and problem solving, and the positive effects took place across the many ways in which visitors engaged at the exhibits. The majority of visitors both appreciated and enjoyed their interactions with facilitators.

- Thinking back on their experiences in the *Design Zone* exhibition and the workshop training, 70% of respondents either agreed (50%) or strongly agreed (20%) that the training helped them obtain skills to better facilitate experiences at exhibits. Nearly a quarter agreed somewhat; these respondents noted that either some of the skills were ones they already possessed or that they still needed time and experience to hone their skills facilitating *Design Zone* exhibits.

- Seventy percent of workshop participants agreed or strongly agreed that the training workshops helped them obtain skills to better facilitate experiences at exhibits.

- The majority (66%) either agreed or agreed strongly that the workshop helped them feel more confident in their abilities to facilitate math experiences at *Design Zone.*

- Facilitators' experiences with Design Zone positively contributed to facilitators' overall comfort in facilitating math experiences in general. Some 70% of respondents indicated being comfortable (39%) or very comfortable (34%) with their abilities.

- The majority of follow-up survey respondents (92%) found the project professionally valuable to some extent.

- While surveyed staff reported obtaining important professional development from their experiences with the project, data suggested that they were less sure about the extent to which what they did and learned at *Design Zone* would translate more generally to their work at their organization. Only 23% agreed or strongly agreed that they were inspired with specific ideas for including math in their own exhibits and programs, but 51% said the workshops helped them to reflect on ways to increase their visitors' engagement with math.

Overview

Design Zone is a 6,000 square foot traveling exhibition developed by the Oregon Museum of Science and Industry (OMSI) as part of the *Access Algebra* project funded by the National Science Foundation. The primary goal of *Design Zone* is to engage visitors in algebraic thinking, with a special focus on reaching a target audience of 10- to 14-year-olds and their families.

The exhibition was organized into three thematic areas: art, music, and engineering. Each thematic area was color coded and a tower in each area presented a slide show of relevant careers. Exhibits in each area were based on real-world design challenges in which math and algebra are used.

While OMSI intended the exhibition for a public audience, *Design Zone* also had a professional development component designed to support floor staff, whose job was to facilitate visitor engagement with the exhibition and engage visitors in algebraic thinking. The professional development thread of this initiative included several components: a series of facilitator affordances that could be used at six of the exhibits, training workshops for exhibit hall staff and volunteers, written materials to support staff and volunteers, and a professional development website.

Facilitation affordances included a variety of props and software modes for supporting and extending visitor engagements with the "facilitation friendly" exhibits. These six exhibits—"Balancing Art," "Drawing in Motion," "Designing for Speed," "Sound Graph," "Laser Light Show," and "Digital Strings"—were designed especially for staff and volunteers who were facilitating. Some exhibits, for instance, had clear places for facilitators to stand and interact with visitors; others included space for families to cluster around the exhibit. All six of these exhibits had multiple entry points for facilitators to choose from, depending on the visitor's level of engagement. In addition to the challenges posed by exhibit labels, the facilitation-friendly exhibits included challenges requiring the help of a facilitator who, for instance, could use props such as a card with songs for visitors to play at "Digital Strings," a question mark shaped weight for visitors to solve for at "Balancing Art," and a wheel with adjustable weights to investigate at "Designing for Speed."

Host museum floor staff and volunteers participated in three *Design Zone* facilitation-training workshops. A few days before host museums opened the exhibits to the public, OMSI staff visited to present two types of workshops. Workshop I Module A, a basic introduction to facilitating *Design Zone,* gave participants hands-on experiences with three facilitation-friendly exhibits and their affordances: "Balancing Art," "Drawing in Motion," and "Designing for Speed." This introductory workshop, aimed at all staff and volunteers who would be facilitating *Design Zone,* was presented twice or three times depending on the needs of the host museum.

The Cycle of Facilitation is one concept presented in the 1A workshops. The idea is that facilitators should cycle through three stages during their interactions with visitors to best support their learning. Facilitators should 1) observe a visitor group before deciding whether to approach it; 2) support visitors' continuing engagement with

the exhibits using whatever combination of orientation, modeling of exploration, and additional props and challenges seem appropriate, given that observation; then 3) reflect on the effectiveness of this support before reengaging with this group or moving to another. If, during observation, it becomes clear that a visitor group is engaging well on its own, the facilitator may choose to move on without interrupting that engagement.

Workshop I Module B presented more advanced concepts and approaches to facilitating in *Design Zone* including hands-on experiences with three different facilitation-friendly exhibits and their affordances: "Sound Graph," "Laser Light Show," and "Digital Strings." This more advanced workshop, presented once, was intended for more senior facilitation staff at the host museums. As part of this workshop, host museum supervisors received a Math Toolkit to keep. The kit included a variety of tools for measuring and recording data with visitors on the floor along with suggestions on how to use those tools.

Workshop II, designed to help senior host museum staff develop math-related facilitation approaches to their existing exhibitions, was presented by one of two math researchers who were part of the *Design Zone* development team. This workshop was presented once at each of the three host museums included in this study a month or two after the *Design Zone* exhibition had opened to the public.

Printed materials to support staff and volunteer training were available as PDFs on the professional development website. In some cases, the materials were printed for use in OMSI's training workshops or by host-museum staff who developed in-house training for those who could not attend the workshops. These materials included a 57-page Staff Guide with background information, staffing tips, and strategies for facilitating *Design Zone*; four-page Facilitation Sheets with detailed information and facilitation tips for each of the six facilitation-friendly exhibits; and a Pocket Guide summarizing key strategies from the above facilitation sheets.

In addition to linking to PDFs of the printed materials, the *Design Zone* professional development site also included background information about the project and training workshops and links to online resources, including the videos shown during training workshops.

Professional Development Goals

The goal of the summative evaluation was to assess the extent to which *Design Zone* met its intended goals for professional development. The overarching professional development goals of the project were that:

- Staff will feel comfortable engaging in algebra/math activities with visitors.
- Staff will learn to facilitate mathematical exploration using strategies and facilitation affordances built into several *Design Zone* exhibits.
- Visitors and staff will have enjoyable and social experiences with algebra/math.
- Groups of visitors will feel comfortable engaging in algebra/math activities together.
- Visitors will use algebraic thinking skills and engage in mathematical exploration.

To operationalize these goals, the *Design Zone* team developed a series of impacts and indicators for the National Science Foundation. (The first four impacts, related to the exhibition, are evaluated in the exhibit summative evaluation report. Impacts five through eight refer to the professional development portion.)

Impact 5. The target audience (paid and unpaid museum floor education staff) will feel excited about and comfortable with algebra/math.

Impact 6. The target audience will recognize and support visitors' algebraic thinking at select exhibits within the exhibition.

Impact 7. The target audience will develop the skills to foster positive visitor experiences with algebra/math.

Impact 8. The target audience will develop the skills to create safe math learning environments where groups of visitors feel comfortable engaging in algebra activities together.

Evaluation Design

Garibay Group worked with the OMSI team to evaluate the exhibit and the project's professional development aspects. This report discusses summative evaluation findings for the professional development component.

Methods

Data were collected at three host sites for this study: Museum of Science and Industry (MOSI) in Tampa, the Pacific Science Center (PSC), and the Franklin Institute. We used a mixed methods approach (Green and Caracelli, 2003), collecting quantitative and qualitative data.

Workshop Surveys

Surveys were used to assess immediate outcomes from the *Design Zone* workshops and intermediate outcomes resulting from participants' involvement in the project. Paper surveys were distributed at the beginning of each workshop to collect background information on respondents, including job areas/departments, experience with facilitation, perceived confidence in facilitating math experiences, and extent to which they used math in their work. Post-workshop surveys were distributed at the end of each workshop to assess overall satisfaction, learning, and perceived usefulness of the training. For Workshop I, 173 pre-workshop surveys and 161 post-workshop surveys were completed. For Workshop II, 34 surveys were completed.

Follow-Up Surveys with Staff Facilitating in Design Zone

Near the end of their involvement in the project, facilitation staff was asked to complete an on-line survey. The survey asked about frequency of facilitation at *Design Zone* and the use of professional development materials, retrospective questions about the impact of the *Design Zone* experience on facilitators' comfort with and skills for facilitating math interactions, and perceived usefulness of the project. To ensure that as many *Design Zone* staffers as possible were involved, e-mail lists were developed based on logs from the training workshops. Supervisory staff at each host museum vetted the lists, adding names and e-mails of personnel who had facilitated in *Design Zone* but had not participated in the OMSI training workshops and removing staff and volunteers no longer at the institution and those under 18. Incentives were offered to participating staff and volunteers at host museums that met goals for participation in the survey. Survey links were mailed to 127 potential respondents. A total of 59 respondents completed the survey, a 46% response rate**.**

Observations and Intercept Interviews

Garibay Group conducted observations at *Design Zone* and followed up with intercept interviews to document and examine how facilitators applied training concepts and to understand the nature of facilitator-visitor interactions. During observations, researchers watched facilitators interact with visitor groups and systematically recorded details about these interactions, behaviors, and modes of engagement. Observations were conducted at the exhibit components (facilitators were observed interacting with visitor groups) and across exhibits, where researchers also observed facilitators roaming from exhibit to exhibit, engaging with visitors when they saw fit.

Researchers introduced themselves to staff and volunteers at the beginning of a shift and advised them that evaluators would be collecting data in the gallery of both facilitated and non-facilitated interactions, though staff was not specifically told when an observation session began. When several facilitators were on the floor during observation periods, respondents were selected using purposive sampling in order to include a mix of volunteers and paid staff of various ages and levels of experience. On the occasions where only one facilitator was at the exhibition, we used convenience sampling. (Purposive sampling, however, allowed us to still ensure a mix of respondents.)

We conducted 37 observations. When possible, researchers interviewed facilitators immediately after observing them in order to gain a deeper understanding of that respondent's experiences and perspectives. We also interviewed some facilitators who we had *not* observed working with visitors, mostly when few visitors were in the exhibition. Researchers used a semi-structured interviewing approach (Babbie, 1998), probing on a range of topics pertinent to the study (e.g., why they chose to interact with some groups but not others, what they talked about with the groups, their use of facilitator affordances, and so forth). We conducted 19 on-site interviews with facilitators.

Researchers also observed the Workshop I training sessions at MOSI and conducted short intercept interviews with select workshop participants. Observations were documented via field notes.

Phone Interviews

Once the exhibit completed its run at each site, phone interviews were conducted with staff and volunteers from all three host museums. Interviewees were selected purposively to mix administrative staff, floor supervisors, floor full-time and part-time staff facilitators, and volunteer facilitators. Interviews covered a range of issues related to facilitation philosophies and practices at the host museum, workshops and related training materials, and facilitators' experiences in *Design Zone*. The protocol was then adapted based on the responsibilities of the interview respondent. In all, 13 phone interviews were conducted with facilitators and their administrative staff.

Analysis

With quantitative data, basic summary statistics were calculated and compared, including mean and median values and distributions for each question. Statistics were calculated for the entire data set and for various subsets, including for each museum separately and for full-time and part-time staff and volunteers. These summary statistics were compared using tabular data and histograms. For open-ended questions, verbatim responses were qualitatively analyzed and coded. As categories emerged from the data, they were grouped as appropriate.

Observation and intercept interview data were coded using inductive coding (Strauss and Corbin, 1990), which allowed researchers to identify emergent patterns and themes in the data without the limitations imposed by

predetermined categories. As patterns and themes were identified, researchers used a constant comparison method to tease out the strength of patterns and themes (Miles and Huberman, 1994). In this iterative process, each unit of data was systematically compared with each previous data unit, allowing the researcher to continually identify, develop, and refine emerging categories and patterns of data. Coded data were then clustered and analyzed for interrelationships between categories.

Confidentiality and Presentation of Results

As outlined in the IRB, we assured confidentiality to all respondents. With just three host museums and a small number of respondents (some of whom had clearly defined roles within their museum), it is sometimes challenging to preserve confidentiality. We adopted the following policies in presenting results: a) we do not disclose names of respondents (any names used are fictitious), b) we do not attribute specific comments to an individual site or associate *any* quotes with specific institutions, c) data are typically shown in the aggregate. We have also left out particular quotes that could be linked to a particular respondent. While we might lose some interesting comparative findings, the loss ultimately does not negatively affect the ability to assess project outcomes.

Evaluating Professional Development Training

Kirkpatrick's (1998) widely used model for evaluating professional development and training has been adapted to various fields. The model outlines four levels of evaluation, with each successive level building on information from previous levels (Table 1). Evaluation always begins with level one and moves sequentially through the other three levels. Each successive level represents a more precise measure of professional development effectiveness but requires more rigorous and time-consuming processes. The table below summarizes the focus and key question for each level.

Guskey (2000), who adapted the Kirkpatrick model to evaluate educator professional development, argued for adding another stage between levels 2 and 3 to measure organizational support, because it is essential that organizational structures support one's professional development and practice. Yet in Garibay Group's experience evaluating professional development initiatives, organizational aspects cannot be confined to a discreet stage. Organization factors are, rather, critical contextual factors that can ultimately influence impacts.

Table 1. Kirkpatrick's model for evaluating professional development (1998)

Level	Focus	Key Question
1. Reaction	Assesses participants' initial reactions and attitudes to a workshop as well as perceived benefits from the training.	Did they like it?
2. Learning	Evaluates what participants learned, specifically examining changes in knowledge and/or skill sets acquired (based on training goals).	Did they learn it?
3. Transfer	Assesses the extent to which participants transfer knowledge, skills, and attitudes from the training context to their workplace and how they use or incorporate what they have learned into their projects.	Did they use it?
4. Impact	Evaluates the project's impact on participating individuals and organizations.	Did it make a difference?

This report is organized according to these levels. We first discuss reactions to the initial training, then learning and transfer, and finally evidence of impact.

Results

Level I: Reaction

Participant Background

The three host museums used part-time and full-time staff and volunteers on the museum floor. A slight majority of workshop attendees (44%) were paid part-time staff; more than a third (36%) were volunteers (Table 2).

Table 2. Workshop survey respondents by employment status

n = 167	MOSI	PSC	Franklin Institute	% of total respondents
Part-time paid	16	50	8	44%
Volunteer	15	11	34	36%
Full-time paid	7	14	10	19%
Intern	1	0	1	1%

Workshops typically included a mix of floor staff (both part time and full time) and senior staff. While all three host museums had well-established programs for teenage volunteers, only two host museums included them in the training workshops and only one used them in a significant way as *Design Zone* facilitators. Older volunteers, including retirees, played a larger role at some host museums than at others.

Given the range of volunteers and staff participating in the workshops, it was not surprising to find a broad range of work experience within workshop participants (Tables 3 and 4). Workshop trainers presented to audiences ranging from teens in their first few weeks of volunteer work to supervisory staff with decades of experience.

Table 3. Length of time working or volunteering at host institution

n = 168	MOSI	PSC	Franklin Institute	% of total respondents
3 months or less	13	6	2	13%
6 to 11 months	7	15	5	16%
1 to 2 years	5	23	15	26%
3 to 5 years	9	25	14	29%
6 to 10 years	1	2	8	7%
more than 10 years	3	6	9	11%

Table 4. Length of time working or volunteering in museum field

n = 165	MOSI	PSC	Franklin Institute	% of total respondents
3 months or less	11	5	2	11%
6 to 11 months	8	13	3	15%
1 to 2 years	4	21	15	24%
3 to 5 years	9	28	13	30%
6 to 10 years	1	3	8	7%
more than 10 years	3	6	12	13%

Facilitators at each museum had a wide range of responsibilities (Table 5). While some 90% of workshop participants said they spend time facilitating for visitors in exhibits, most also reported presenting demonstrations for visitors, conducting classes and workshops, or working with camp programs.

Table 5. Responsibilities of workshop survey respondents (multiple responses possible)

n = 150	MOSI	PSC	Franklin Institute	% of total respondents
Facilitate for visitors at exhibits	28	65	43	91%
Do demonstrations/shows	24	18	28	47%
Work with weekend classes/workshops	10	7	14	21%
Work with summer/holiday camps	12	7	13	21%
Give school tours	6	1	0	5%
Other	17	24	9	33%

While most workshop participants reported facilitating at their museum's exhibits, they did so with varying frequencies (Table 6). Given that some participants were part-time staff or volunteers with diverse schedules and wide ranges of responsibilities, this finding was not surprising.

Table 6. Frequency facilitating hands-on experiences at exhibits (non-school groups)

n = 166	MOSI	PSC	Franklin Institute	% of total respondents
Almost every day	17	20	13	30%
Once or twice a week	12	44	27	50%
Once or twice a month	3	7	6	10%
Once or twice a year	0	3	2	3%
Never	5	4	3	7%

The majority of workshop participants also reported incorporating math into their work with museum visitors, with more than a quarter indicating doing so once or twice a week (Table 7). Only 20% indicated that they never included math experiences in their work with visitors.

Table 7. Frequency incorporating math experience into work with visitors

n = 154	MOSI	PSC	Franklin Institute	% of total respondents
Almost every day	7	4	7	12%
Once or twice a week	10	19	16	29%
Once or twice a month	6	23	11	26%
Once or twice a year	1	14	6	14%
Never	11	13	6	20%

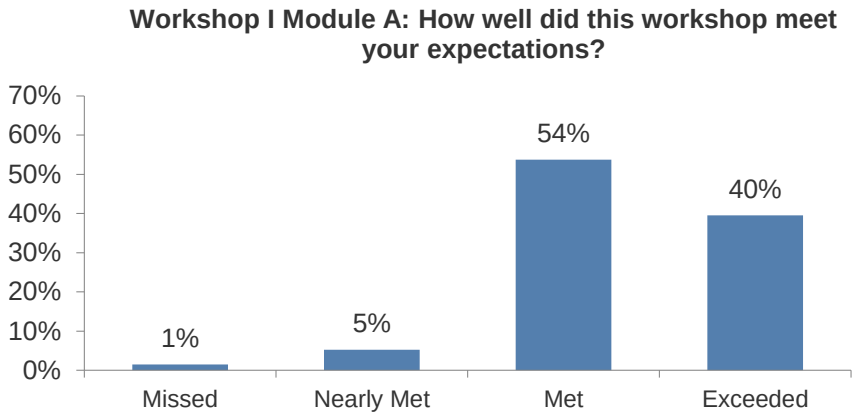
Generally, workshop participants indicated they introduced math at specific exhibits or galleries or in discussing specific topics with visitors.

> *I work in the planetarium and the majority of the math I incorporate into the show is in regards to calculating the approximate mileage a star is from Earth based on the age of the light molecules when it reaches Earth.*
>
> *Measurement conversions and scalar comparisons relating to the field of astronomy.*
>
> *I talk about the voltages for Tesla Coil [and the] Van de Graaff generator and compare [the] amount to [the] power [of] the Sun.*
>
> *The bed of nails allows me to explain the formula for surface area.*
>
> *When you give statistics about hurricanes, tornadoes, etc. Giving averages of the amount of times lightning strikes in the U.S. and things of that sort.*

Expectations

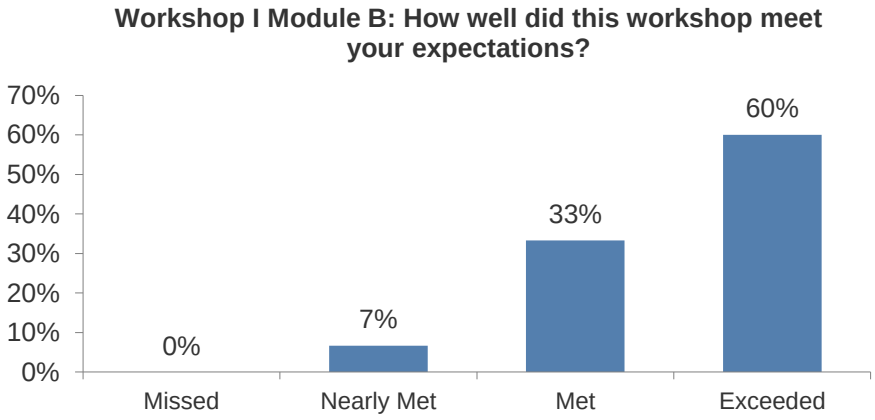
Respondents generally reacted positively to the *Design Zone* professional development workshops. More than 90% of respondents said that the workshop they attended met or exceeded their expectations (Figure 1). Participants in both modules of Workshop I reported “met” or “exceeded” expectations ratings in the 90% range (Figures 1 and 2). Workshop II received somewhat lower ratings with 83% providing “met” or “exceeded” responses (Figure 3).

Figure 1. Expectations met: Workshop I Module A



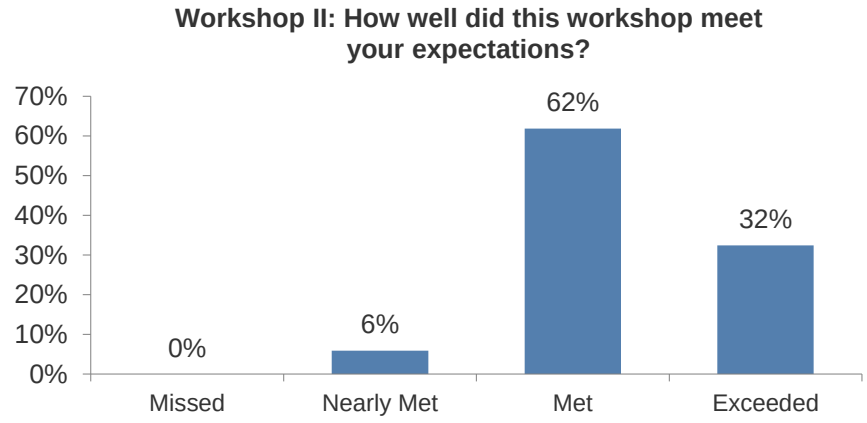
n = 134

Figure 2. Expectations met: Workshop I Module B



n = 30

Figure 3. Expectations met: Workshop II

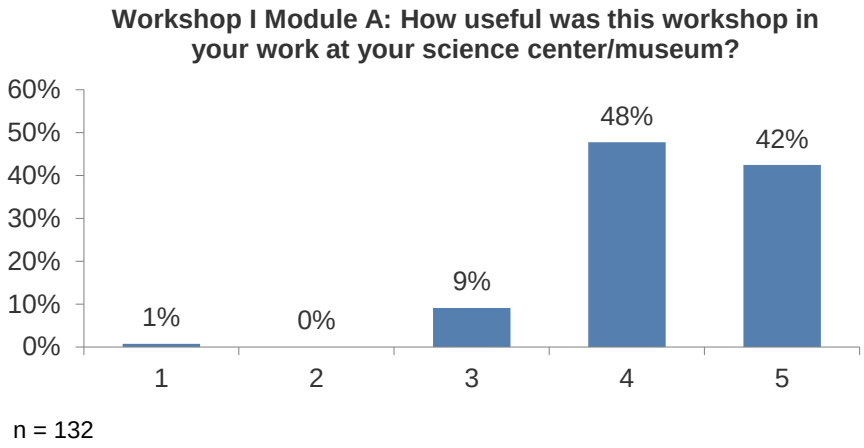


n = 34

Usefulness

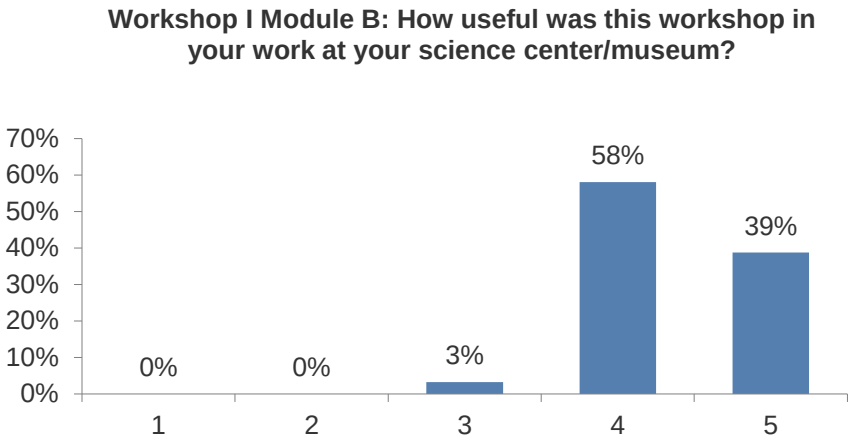
The large majority of respondents also found the workshops useful. Ninety percent or more of Workshop I participants rated usefulness as a 4 or 5 (with 1 being low and 5 being high) (Figures 4 and 5). Positive ratings were also solid, but slightly lower for Workshop II (Figure 6), with 82% of participants providing ratings in the 4–5 range.

Figure 4. Usefulness of Workshop I Module A



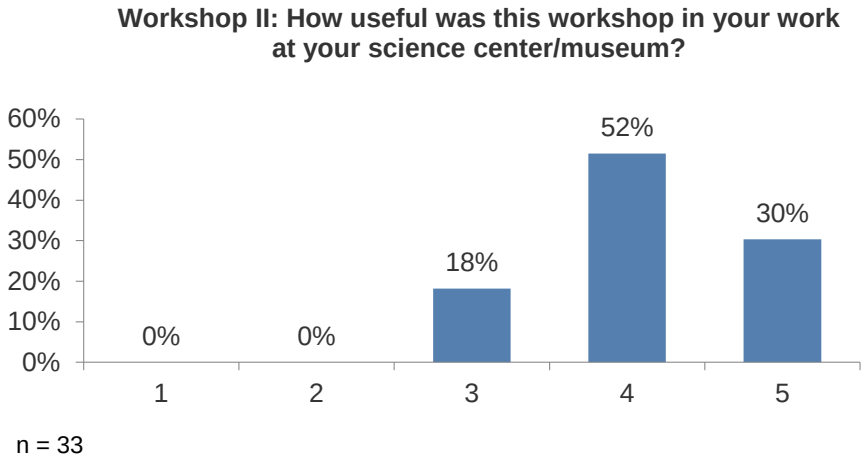
n = 132

Figure 5. Usefulness of Workshop I Module B



n = 31

Figure 6. Usefulness of Workshop II



The primary usefulness for a workshop was, according to respondents, that the experience helped them develop familiarity with *Design Zone* and provided them with knowledge of how to better engage visitors.

> *[Workshop leaders] were very clear and explained all of the exhibits in detail.*
>
> *It showed me the [Design Zone] exhibits and the math/science behind it.*
>
> *It will be really helpful in interactions not only in Design Zone but other exhibits.*
>
> *It allowed me to become comfortable with the [Design Zone] exhibits & gave me great ideas to use with guests (a little less talking would be good).*
>
> *It taught me some new strategies to interact with guests.*

The less positive comments came mostly from respondents who felt that the workshops either covered material they already knew or were too similar to previous experiences. Specifically, some felt that the workshop spent too much time on facilitation; they seemed a bit put off by the suggestion that they needed training in this area.

> *Less instruction on how to do our jobs [facilitation] (we've been doing for years!).*
>
> *Some things we already learned.*
>
> *I know most of what was talked about.*

Suggestions for Improvements

The top three suggestions for how Workshop I could be improved (Table 8) included: a) spending more time in the exhibition (23%), b) providing more examples of effective facilitation (17%), and c) allowing more time for role-playing (11%). Other suggestions included lengthening the workshop, having the workshop cover more exhibits, and how to improve the overall workshop format.

Table 8. Suggestions for improvement to Workshop I by category

	% of suggestions
Allow more time in exhibition	23%
Give more examples/modeling of effective facilitation	17%
Allow more time for role-playing/more direction during role-playing	11%
Lengthen the workshop	9%
Cover more exhibit units	8%
Spend less time reading slides	7%
Allow more time for questions/discussions	4%
Spend less time on facilitation skills	2%
Use shorter or better videos (Workshop I Module B only)	2%
Other	18%

I think more time is needed to explore and learn the individual parts of the exhibit. Possibly two sessions?

Show video examples at each exhibit of interest to show the strategies being used.

Have brief explanations about the math and/more physics behind each station explained at universal age levels.

I liked how the examples of facilitation were given, although I think a lot of things about the way to facilitate this exhibit were repeated a lot.

Suggestions about Workshop II were more disparate than those for the first workshop and did not cluster into clear categories. The most common improvements mentioned included incorporating more activities into the workshop, allowing more time for discussion about facilitating math learning at exhibitions, and providing more ideas for implementing small changes.

More guided discussion about where/when/how/who will implement changes to incorporate more math.

Add discussion on how facilitating math learning regardless of exhibit shortcomings and signage.

Could use more info or more types of math and what to look for to see if that type of math is present. Focus on data collection, would like a general info on different types of math and their characteristics.

More activities to implement. Possibly provided in packet if not enough time.

Sprinkle a few more very small change ideas—changes in spoken vocabulary, things that can be printed and used, stuff that needs very little development or buy-in.

Didn't feel that we discussed [what visitors' math exploration or talk might look like]. It felt too much on how science center staff view exhibits, not visitors.

Recommend Workshop to Others

As a second way to measure perceived value of the professional development training, we also asked participants whether they would recommend the workshop to colleagues. The vast majority of respondents in Workshop I (98%) and Workshop II (100%) indicated that they would recommend the workshop.

Because I think it is important to remember that math and science are so related. As we move further we should have a closer tie to math in our exhibit planning and floor interaction.

Engaging workshop that shows how easy it is to include math in science instruction and exhibiting. Great way to meet STEM emphasis.

It is helpful for those facilitating and for those developing activities to think about how to maximize the experience people have with us.

Math is a difficult subject to learn for some people, and are turned off to it as a result. Facilitating in a museum setting can help them get more out of their learning.

It already has me more invested in how I approach our own exhibits and not just Design Zone.

It was very helpful and made me think about how I would interact at the exhibits to make sure the guests get the most out of the interaction.

Very well organized workshop—good balance of theory and practical work.

The fact that you need to participate in vs. dominate interactions make effective use of props and challenge visitors with questions are applicable to all fields of interpretation (even if not directly related to this activity).

I think it's easy to lose sight of the goals of interacting with visitors when you do it often, and a refresher like this helps remind one to be conscious of what he's doing.

It got our brains working to process ideas for facilitation. I assume or hope it would do the same for the rest.

Because it helps with ideas for not "spieling" at visitors, but rather letting them lead discussions about math with us.

Only three respondents (all in Workshop I Module A) indicated they would not recommend a workshop. Two respondents provided reasons; one respondent admitted not liking math and the second said that only the time spent exploring the exhibits was useful.

Level II: Learning

Takeaways

Following the training, Workshop I participants were asked the most important thing they learned from the workshop. More than a third (36%) mentioned learning about facilitation skills.

> *Don't "over-facilitate."*
>
> *Facilitation is important. You don't need to be a fact machine to interpret well.*
>
> *Letting the visitor guide the interaction.*
>
> *As an interpreter, sometimes you can be the most effective by just standing by and encouraging.*
>
> *Reinforcing the idea this isn't a lecture hall. It's a chance for visitor's exploration. If we can relate it back to math... Awesome!*
>
> *Being reminded that it's not about being right or smart, it's all about how much we can help the guests.*
>
> *Don't show up and throw up! Stand back and let them figure stuff out, while asking questions to facilitate instead of leading the interaction.*
>
> *The facilitator cycle.*
>
> *Questioning and how to guide people through the exploration.*
>
> *The importance of letting visitors answer their own questions and use teamwork.*

Another 24% mentioned that the workshop helped them understand how the exhibits work. Some responses in this category mentioned very specific exhibits based on what had been covered in the workshop; others mentioned the facilitation affordances included.

> *How the exhibits actually work.*
>
> *How to use the exhibits.*
>
> *I learned it doesn't matter how many pieces or weight you place on one side, it's the location of the piece(s) that counts.*
>
> *I'd rather say the most helpful thing was learning about how the wheels in motion worked when given the example of the ice skater bringing their arms in to gain speed or momentum.*
>
> *How the laser machine works—I GET it now.*
>
> *An introduction to the exhibit and how its extra components work.*
>
> *The secret tools + moving whiteboard.*
>
> *All the extra tools we can use to customize the experience.*
>
> *The hidden "challenges."*

Another 15% of respondents mentioned math as part of what they had learned, most noting they had learned that math was the *main* focus of the exhibit even if it wasn't apparent at first. Others mentioned gaining some insights about math (e.g., "math is everywhere").

> *That we can and should focus on math in this exhibit. It isn't as visibly noticeable in a lot of places, but with some discussion, it can be accessible.*
>
> *What math is in the exhibit—it was not always immediately apparent.*
>
> *It involved math! Algebra!*
>
> *I learned that you can do a lot of math without thinking of it as math.*
>
> *I learned some of the different extents to which math can be applied to different parts of the exhibit.*
>
> *You can teach a math/science concept without using the math/science language.*
>
> *Math of some sort is used in our everyday activities.*

Twelve percent of respondents said that the main thing they learned was how to make math fun or interesting for visitors.

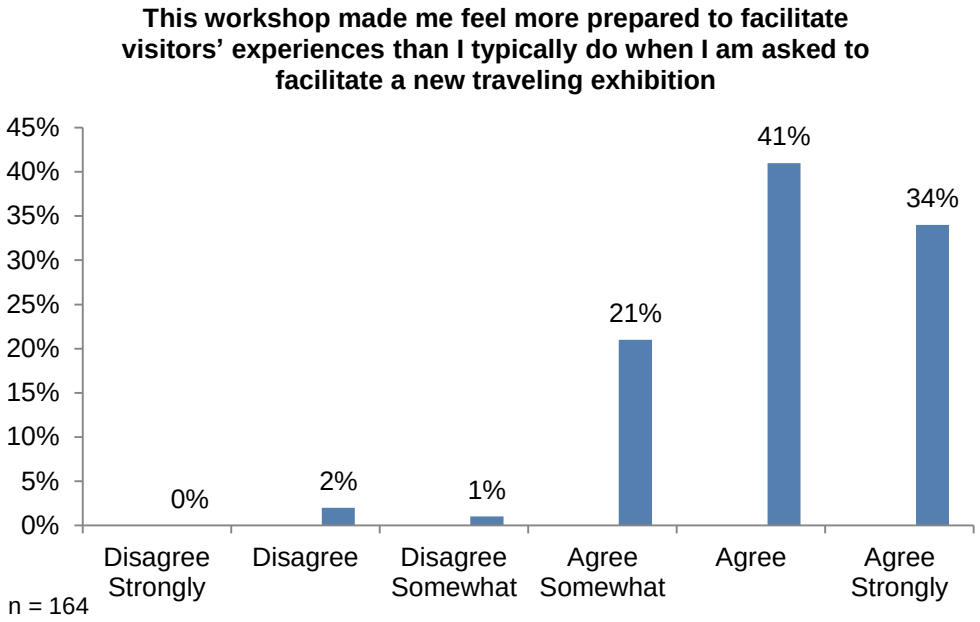
> *How to re-imagine a subject that most accept as unchangeable and boring.*
>
> *Facilitation of math.*
>
> *I think the most important thing is ways to make math and mathematical concepts fun!*
>
> *Strategies to get visitors to re-use math can be easy and fun and is something we use all the time.*
>
> *How to make math less intimidating and more approachable.*
>
> *How to talk about math.*
>
> *Making math concepts more fun.*
>
> *How to allude to but not mention the algebra.*
>
> *Math doesn't completely suck.*
>
> *How to make math concepts more interesting to kids.*
>
> *Math learning doesn't always need math vocabulary.*

Preparedness

Workshop I also positively affected participants' sense of being prepared to facilitate *Design Zone*'s visitor experiences. Compared with other traveling exhibitions, they felt more prepared to facilitate *Design Zone*.

Averaging ratings for Modules A and B, 75% of participants provided "agree" or "agree strongly" ratings to the question of increased confidence (Figure 7).

Figure 7. Preparedness in facilitating visitor experiences: Workshop I Modules A and B respondents



Participants especially appreciated being trained *before Design Zone* opened and being able to spend time becoming familiar with the exhibit. They often commented on how different this experience was compared to the usual (being asked to facilitate an exhibit with little to no preparation time). The workshop successfully helped participants become more familiar with exhibition goals and the exhibits.

> *Normally when there is a new traveling exhibition, our training is being thrown to the proverbial "wolves" on the opening night*.
>
> *Because this is a traveling exhibit, I always find it beneficial to have some type of workshop or training program to go through instead of just being thrown in. Whereas if you're just thrown in, you have to read each exhibit and find out challenges and overall things to say and do for that just to have a conversation starter with a visitor or guest.*
>
> *Traveling exhibits rarely come with adequate training, let alone as thorough as this.*
>
> *We are used to little or no prep/support for new exhibits.*
>
> *We're never trained like this for other traveling exhibits.*
>
> *I learned about the exhibits.*
>
> *Oh man, 3 hours of dedicated training for a traveling exhibit, AND have that BEFORE the exhibit opens? HEAVEN! (and necessary)*

Confidence

We also found that workshops positively affected participants' sense of confidence about facilitating math experiences for visitors at *Design Zone*. The majority of respondents in both modules of Workshop I agreed that the workshop helped them feel more confident in facilitating math experiences for visitors at the *Design Zone* exhibits (Figures 8 and 9). (Only two respondents to the Workshop I Module A survey disagreed somewhat.)

Figure 8. Confidence facilitating math: Workshop I Module A respondents

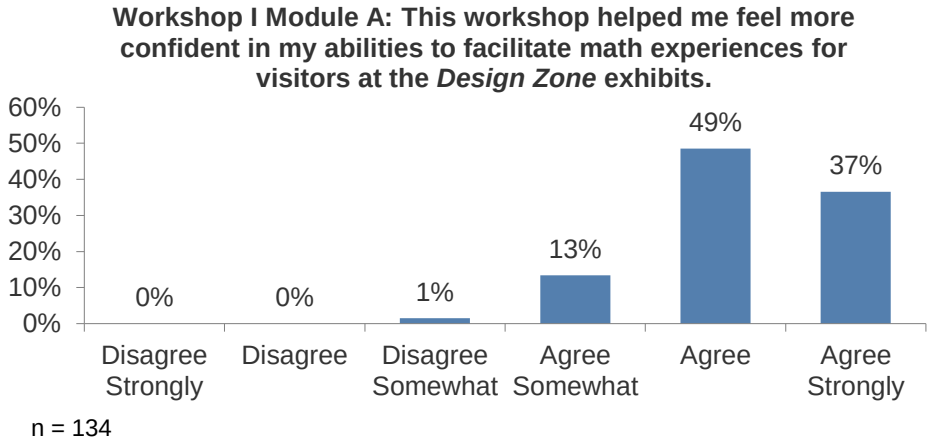
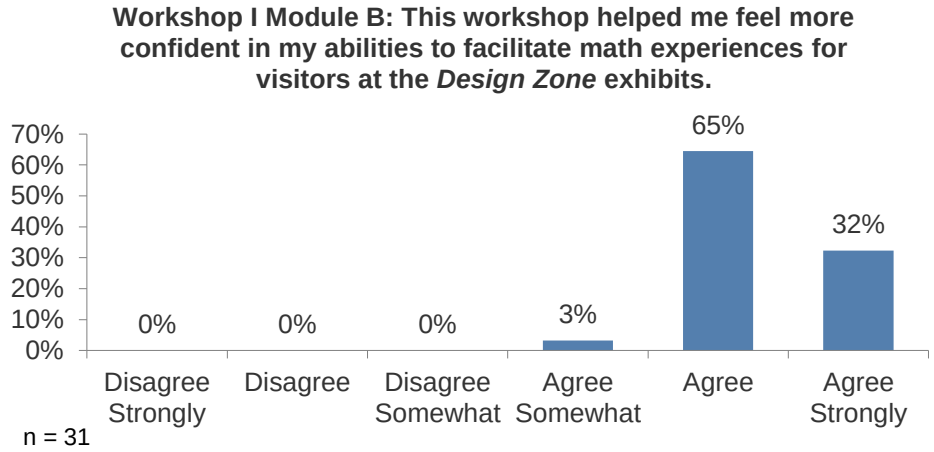
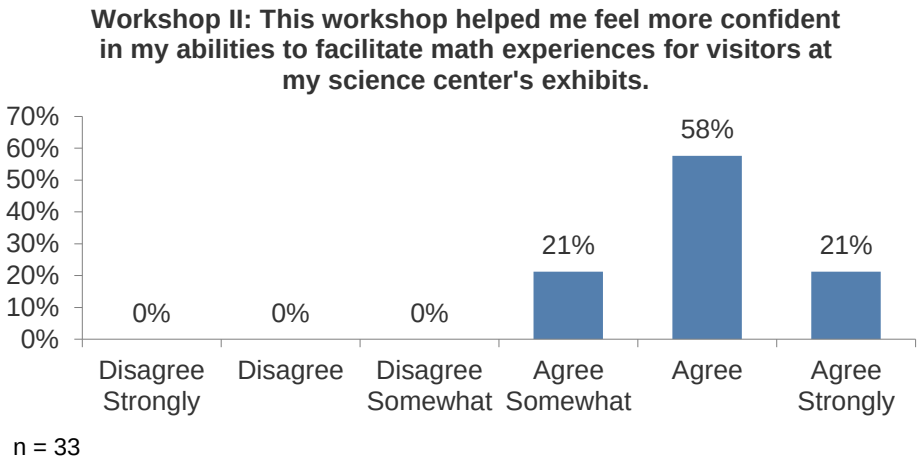


Figure 9. Confidence facilitating math: Workshop I Module B respondents



Respondents in Workshop II—which focused on math facilitation in exhibits outside *Design Zone*—provided slightly lower overall "agree" and "agree strongly" ratings (71%) regarding their confidence to facilitate math experiences at their science centers (Figure 10).

Figure 10. Confidence facilitating math: Workshop II respondents

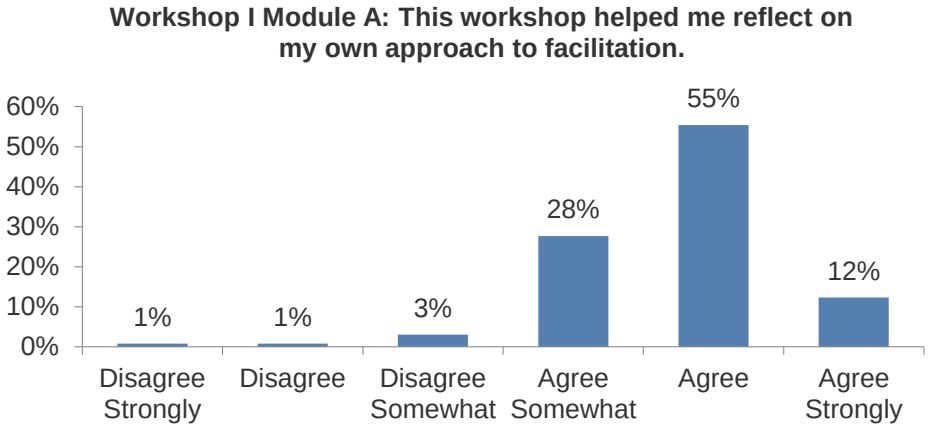


n = 33

Approach to Facilitation

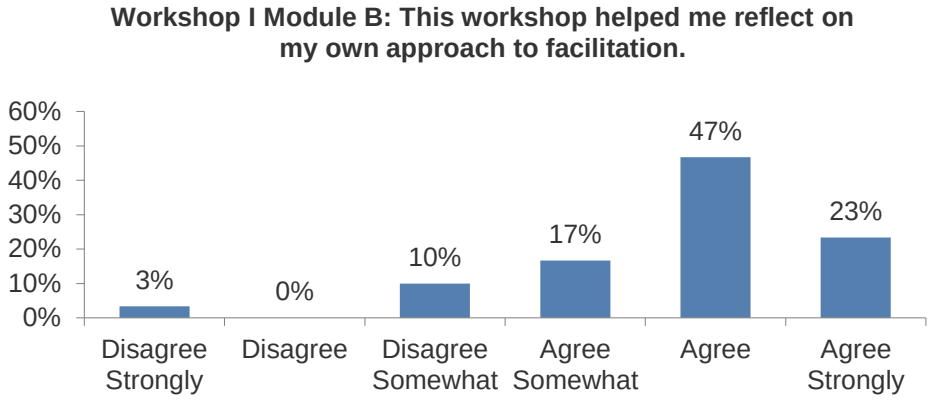
The majority of respondents in Workshop I Module A (67%) and Module B (70%) and those in Workshop II (83%) "agreed" or "strongly agreed" that the workshop helped them reflect on their own approach to facilitation (Figures 11–13).

Figure 11. Extent to which Workshop I Module A helped respondents reflect on their approach to facilitation



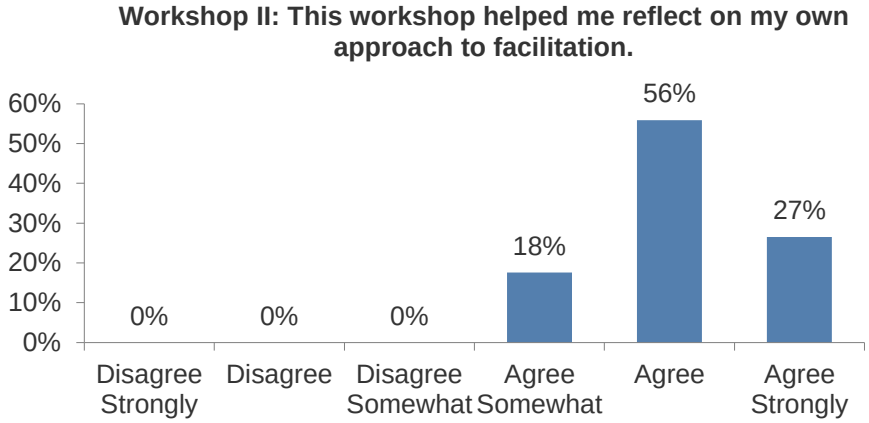
n = 130

Figure 12. Extent to which Workshop I Module B helped respondents reflect on their approach to facilitation



n = 30

Figure 13. Extent to which Workshop II helped respondents reflect on their approach to facilitation



n = 30

It helped me think about how it is often appropriate to stand to the side.

Made me take a look at how I interact with guests. Telling them info vs. facilitating.

I realized I talk too much!

I have never thought about observation.

I wouldn't say I learned new strategies, but it was great practice.

I always apologize for math, but never for science, and both are "scary" for some people. I can do for math what I do for science.

Most exhibit trainings are not as in depth as this one was.

The workshop gave me a huge amount of information that will help me in the future.

Best workshop on traveling exhibit—very in depth.

Normally when there is a new traveling exhibition, our training is being thrown to the proverbial "wolves" on the opening night.

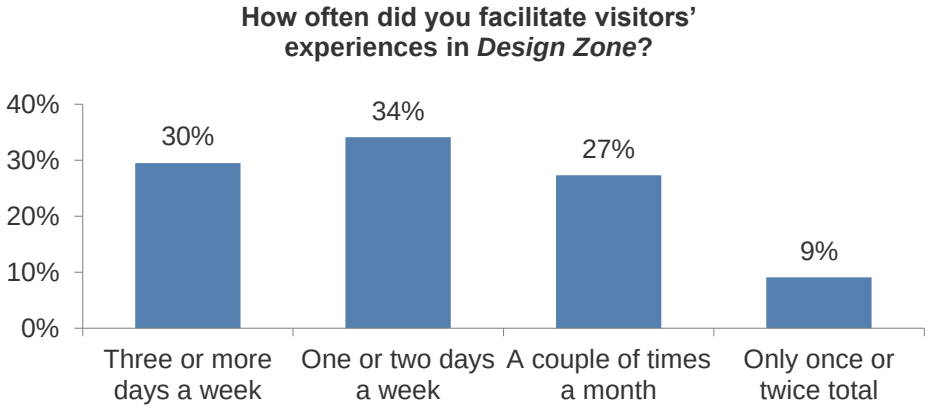
The few respondents disagreeing with this statement tended to be experienced facilitators. An example of a comment from one such facilitator was, "[*Reflection] is something I already do and do every day*."

Level III: Transfer

Frequency of Facilitation

More than 60% of those responding to the follow-up survey indicated that they facilitated visitor experiences at *Design Zone* at least one day a week (Figure 13). Only 4 of 44 individuals indicated facilitating only once or twice during the entire run of the exhibition.

Figure 13. Frequency of facilitation



n = 44

Use of Facilitation Affordances

Overall, 96% of the total respondents in the sample reported using at least one affordance. (Only three individuals indicated never using one.) While some differences existed between institutions in terms of frequency of use, the adjustable wheels at "Designing for Speed" and the question mark weights at "Balancing Art" were the most widely used across sites, while the software override controls at "Sound Graph" and "Laser Light Show" were used the least (Table 9).

Table 9. Use of facilitation affordances (Frequency)

Never=1, Rarely=2, Occasionally=3, Almost every time=4, Every time=5	Rating Average			
	Franklin Institute (N=17)	MOSI (N=3)	Pacific Science Center (N=24)	All
Adjustable wheels at “Designing for Speed”	2.8	3.7	3.7	3.3
Question mark weights at “Balancing Art”	2.9	3.7	3.3	3.2
Software override controls for “Designing for Speed”	1.7	1.7	3.0	2.4
Challenge cards for “Drawing in Motion”	1.7	2.7	2.6	2.3
Challenge cards with “Digital Strings”	1.7	3.3	2.1	2.0
Software override controls for “Drawing in Motion”	1.6	2.0	2.2	2.0
Challenge cards for “Laser Light Show”	1.5	3.0	1.8	2.0
Musical instruments at “Sound Graph”	2.1	2.3	1.9	2.0
Software override controls at “Sound Graph”	1.5	2.3	1.8	1.7
Software override controls for “Laser Light Show”	1.5	1.7	1.5	1.5

Each facilitator affordance received at least some use by host museum facilitators, but several factors seemed to influence how often specific affordances were used.

Facilitators expressed feeling more comfortable with the affordances they were trained on at an OMSI workshop. Since most facilitators had learned the affordances for “Designing for Speed,” “Balancing Art,” and “Drawing in Motion” at Module A, they were more apt to feel comfortable using them with visitors. Those facilitators attending Module B were relatively more comfortable with the affordances for “Digital Strings,” “Sound Graph,” and “Laser Light Show” than those only receiving on-the-job training.

Access to storage areas housing the affordances became an issue at some host museums. At times, facilitators did not use the affordances because a key to the storage room was unavailable. For example, not long after opening the exhibit, one host museum had only one key available, which facilitators had to access from an office or from on-the-floor supervisory staff, creating a barrier to its use. But even two or three copies of a key were often not enough on busy days when three or four facilitators were working.

Facilitators tended to more often use the affordances (at least the ones they found most useful) with visitors already engaged with the exhibit concepts. At those facilitation-friendly exhibits that were perceived to either work well on their own or where the affordance did not seem to add much to the interaction, the props and software override controls were used less often. For example, the question mark weights at “Balancing Art” added a whole new dimension to this exhibit because facilitators could set up equations for visitors to try to solve. The adjustable

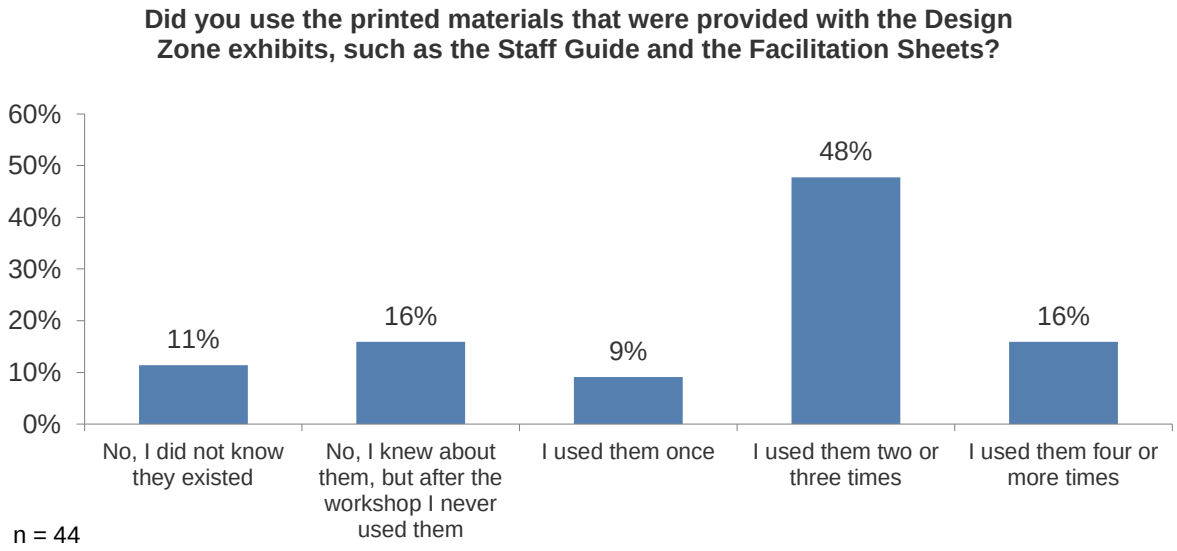
weight wheels at “Designing for Speed” allowed groups to set up experiments. In contrast, some facilitators perceived that the challenge cards for certain exhibits (like “Drawing in Motion”) were simply “more of the same” rather than providing something new or different than what visitors could do on their own.

Of course, use of affordances also largely depended on visitors’ level of engagement. If visitors really enjoyed what they were doing, facilitators were more apt to introduce affordances to prolong the engagement. (This is partially because floor staff introduced affordances only when a group had first spent time engaging with the exhibit “as is” without extension activities.) The facilitation props gave visitors something else to do and often brought new visitors to the exhibit to see what was happening.

Use of Other Design Zone *Resources*

More than 70% of respondents indicated having used the printed *Design Zone* materials at least once (Figure 15).

Figure 15. Use of printed materials



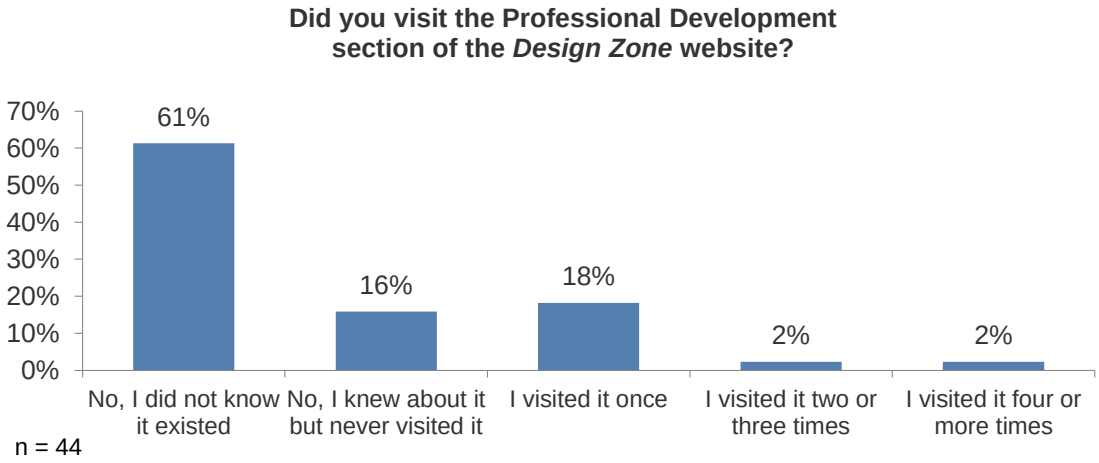
At all three host museums, however, the Staff Guide was used to train facilitators who could not attend the workshop. As one supervisor explained, “That was great from a training standpoint. Every time somebody new came in that didn’t attend a workshop, there was that one page [Facilitation Sheet] that they could easily refer to of how to interpret it. So that was great.” Another supervisor printed the Pocket Guide that was part of the larger Staff Guide and gave one to everyone who received the training. Another supervisor altered the Staff Guide to make training materials for staff who had not attended the workshop, outlining major points using simple bullets. One host museum laminated pages from the Pocket Guide then taped them inside the facilitator storage areas at several exhibits.

While the survey did not ask specifically about frequency of Math Toolkit use, interviews illuminated some use patterns. Toolkit use varied significantly across sites, although in general, kits were used far less frequently than affordances. Access to the Toolkits seemed to pose a challenge. Some facilitators noted being disappointed to learn that the Math Toolkit was stored in a supervisor's office, where they could not access it. Other front-line staff noted having access to the toolkits but were so busy with other responsibilities that they never found time to use them. (Even at one host site where toolkit supplies sat in the exhibit's mobile white board, the kits were still not used frequently.)

Nonetheless, when toolkits made it to the exhibition, facilitators used them in a variety of ways. The Etch A Sketch was among the toolkit items most used at *Design Zone*. At one museum, staff conducted informal in-the-office math exercises, using a stopwatch to time the speeches that volunteers gave at the entrance to an exhibition then plotted the times on a graph with stickers. At some host museums, materials from the kits were used in school, homeschool, and after-school programs.

The *Design Zone* website featured a section specifically for museum staff. Respondents were less likely to have used the *Design Zone* Professional Development portion of the website than the printed materials, however, with only 22% reporting visiting the site at least once (Figure 16). More than half of the respondents (61%) indicated they did not know about these resources.

Figure 16. Use of the *Design Zone* website's Professional Development section



Ways Facilitators Interacted with Visitors: The Cycle of Facilitation

Facilitators interacted with *Design Zone* visitors in different ways. Many of the facilitators we observed applied aspects of the Cycle of Facilitation Model, although they did not always remember its name or use all four parts of the model in every interaction. Some host museum facilitators consciously emulated the Cycle of Facilitation approach by observing a visitor group at an exhibition, stepping in for a relatively short interaction where they

supported visitors' engagements with the exhibit, then stepping back to reflect on what they had accomplished and observe some more.

Facilitators following this model sometimes chose to step back in and provide more support. For instance, as a group finished a challenge, a facilitator might use props to extend the engagement by posing another challenge. At other times, a facilitator was satisfied with the group's engagement and moved on to observe another group. Some facilitators observed groups at an exhibit, felt satisfied that things were going well, and moved to another exhibit, repeating the observations until finding a group they felt needed support.

Other facilitators settled in at a single exhibit and waited for visitors to come to them. Once a group arrived, the facilitator might help orient the group to the exhibit and/or guide their engagement with questions, challenges, inquiries, and, if questioned by visitors, short explanations. Some facilitators used to engaging with visitors at carts told us they were more comfortable with this type of interaction, since they did not have to approach and interrupt anyone. Facilitators with other backgrounds also used this approach at times. For instance, one facilitator stood by "Hit the Target" and gave some visitors who clearly needed the help detailed instructions about how to use the mechanism. When props were available, facilitators sometimes held them in reserve, to (for example) pose visitors a more sophisticated second or third challenge.

In the most extended engagement we observed, a facilitator stayed with a single family group for nearly an hour, moving through a series of exhibits where the group stayed for 10 to 15 minutes each. She conversed almost continually with both children and adults, sometimes guiding the engagements and other times following the visitors' leads. At "Sound Graph," she pointed a younger child toward various small challenges, shapes the group could match, or sounds the group could make to keep the child engaged. She then took a small cloth bag from storage, said "Tuning forks are great!" and demonstrated the tuning fork shapes to the child (and some newly arrived teens). The facilitator also had an in-depth conversation about the rest of the exhibition with the parents.

Most interactions with visitors did not last as long. Some facilitators spent a lot of time "roaming" or "patrolling" and having very short interactions with visitors, such as showing them how to hit with the drumsticks at "Slide-a-Phone" and asking "Why don't you try this?" and "What did you notice?" at various exhibits. Some of these engagements only took a few seconds while others evolved into slightly longer interactions lasting, on average, between 8–12 minutes. (This is significantly longer than the dwell times recorded when visitors engaged on their own, where only 29% of groups with children in the target age range had interactions lasting 6–10 minutes and only 2% had interactions lasting 11–15 minutes.)

It is also important to note that although some exhibits had been designed as "facilitation friendly" ("Balancing Art," "Drawing in Motion," "Designing for Speed," "Sound Graph," "Laser Light Show," and "Digital Strings"), each facilitator we spoke to had developed his or her own preferences for the exhibits they liked to facilitate. They rated the exhibits designed to be "facilitator friendly" most highly and noted that a few exhibits worked well without

facilitation. For example, one facilitator described “Fast Tracks” as fun for visitors, but noted that it was difficult to “get in there” and facilitate. The facilitator also quickly noted, however, that visitors at the exhibit were making their own predictions and did not necessarily need facilitation. In addition, in general, exhibits where visitors sat down were harder to facilitate than ones where visitors stood. Some other exhibits regarded as harder to facilitate included:

- The music exhibits with headphones. Facilitators did not find using headphones conducive to engaging visitors in conversation.
- “Design a Skateboard” and “Design a Roller Coaster” were two computer-based exhibits where facilitators seemed a bit at a loss as to how to facilitate visitor experiences.
- Facilitators also found it more difficult to engage younger children at the “Laser Light Show” exhibit.

Note that of the above exhibits, only “Laser Light Show” was specifically designed to be “facilitator friendly.”

Some Case Examples

In this section of the report, we provide a deeper look at facilitator-visitor interactions through detailed descriptions of interactions observed. These interactions were selected to provide a range of typical engagements across all three sites.

Interaction 1: “Balancing Art”

“Balancing Art” is essentially a giant scale (Figure 17). A balancing beam is suspended from above at a center pivot point. The challenge for visitors is to make the beam balance horizontally, as indicated by a balance meter on either side of the beam. Free-form pieces, numbered according to their relative weights, could be hung on hooks at numbered points along the beam. Visitors are, of course, free to approach the balancing problem in any way they see fit. A challenge label just below the beam suggests three challenges that could be attempted by visitors, showing a balanced beam with weights at various positions along the beam (but without indicating numbered points). A panel located off to the side explains the algebraic concept (balancing an equation) modeled by this exhibit.

As one of the more facilitation-friendly exhibits, “Balancing Art” includes some special props—several question mark shaped weights—in a locked storage space. Because the weights were not labeled, facilitators could use them as unknowns when setting up special challenges for visitors. These challenges were physical manifestations of equations that visitors could solve for the weight of the question mark.

Figure 17. "Balancing Art" exhibit

One experienced full-time staff facilitator, George, had taken out the question mark weights at "Balancing Art." Standing behind the exhibit and facing visitors, he could look at them and point to aspects of the exhibit he wanted to discuss. In many ways, it was as if he was standing at one of the science carts elsewhere in the museum.

As visitors approached the exhibit, George would greet them almost immediately, talking with them about how to use the exhibit and suggesting activities. As usual for this exhibit, children stood in the front, handling the weights, hanging them, and adding and shifting weight positions until a balance was achieved (or the problem with the unknown weight had been solved). Parents mostly stepped back behind their children, allowing George to take over the teacher-like role that some of them otherwise would have assumed. Compared with non-facilitated experiences, the children still were in charge of engaging with the exhibits, but the parents were more like observers but sometimes making suggestions, giving encouragement, and doing behavior control, as in "Hey, pay attention!"

George asked many questions and visitors responded to them with words, actions, and sometimes their own questions. George generally guided the engagement from the beginning through the time the visitors decided to leave. He oriented most groups to the exhibit's math components faster than most non-facilitated groups could do on their own, and he helped visitors see the exhibit differently, including those aspects of math and algebra that many usually missed. The use of the question mark weights was an important aspect of the experience for many of the older children and adults, because the weights helped them link solving equations on the beam with the algebra they had done in school.

Most visitors seemed receptive to George's approach, if perhaps a bit intimidated by some of his questions. Visitors usually attended to what George said (nodding and smiling at times and responding to his suggestions). It was clear that many adults and older children engaged in and understood the sorts of algebraic thinking that

George had in mind. Comparing his interactions with the non-facilitated engagements seen at this museum, indications are that many visitor groups perhaps thought about and solved problems more quickly than they would have on their own. Typically, we found less discovery and fewer creative responses by children and generally more instruction than many parents would have provided. Most parents played a minor role in the experience; in some groups, this was not how they would have approached the exhibit on their own.

Interaction 2: "Balancing Art" and "Drawing in Motion"

"Drawing in Motion" is like a giant Etch A Sketch. At this exhibit visitors draw pictures on a coordinate grid shown on a large video screen (Figure 18). Two sliders, X and Y, move along tracks numbered from 0 to 10. Visitors have to work collaboratively to move a point on the screen, with the visitor using the slider on the right to move the point in the horizontal (or X) direction and the visitor using the slider on the left to move the point in the vertical (or Y) direction. Visitors first push buttons to select among four exhibit challenges, which direct them to connect a series of on-screen dots (coordinate points), then watch their coordinated movements as the commands produce a real-time drawing. The connected dots form a key part of a picture that is then completed and colored by the exhibit's program, resulting in an animated sequence that rewards visitors' efforts. Visitors can also either "scribble" or complete their own challenges in Free Draw mode and may erase the screen at any time by pushing a red button.

As one of the more facilitation-friendly exhibits, the locked prop cabinet in "Drawing in Motion" gives facilitators access to control switches that deactivate the automatic timeout feature on the screen and/or deactivate the challenge buttons on the central label panel. Facilitators can also use special challenge cards to extend visitor engagement with the exhibit.

Figure 18. "Drawing in Motion" exhibit

Helen, a 17-year-old member of a youth program at a host museum, was assigned to the Art section of *Design Zone* for the first hour of the day. The Art section included two facilitator-friendly exhibits, "Balancing Art" and

"Drawing in Motion." Helen was free to roam among the 10 exhibit units in the section, deciding for herself where and when to interact with visitor groups. The exhibition was not very crowded, with only two families walking through Helen's assigned area. First she watched a small family group with children begin to engage with "Balancing Art." As the children grabbed their first weights, Helen stood a bit back and to the side. For half a minute she observed the children hang weights, trying to balance the mobile with their parents' supervision. Deciding her assistance was not needed, Helen moved to "Drawing in Motion," where a mother and her 10-year-old daughter had stopped to examine the exhibit with slightly puzzled expressions. Helen stepped in immediately. She coached them about how to use the sliders and helped them discover what the sliders did on the screen when moved separately or together. Helen recommended they select one of four challenge buttons, but cringed a bit when they selected Challenge 4—the hardest one—which had them draw several diagonal lines to complete the picture on the screen. (This was not obvious to the visitor group.) The mother and her daughter carefully followed the instructions on the screen as Helen watched, holding back as they worked through each step. They succeeded, drawing jagged lines but connecting all the dots. As the reward animation played for them, the girl jumped up and down, and Helen clapped in celebration. The child hit the Free Draw button, so Helen opened the facilitator storage door. She offered to help the family complete a free-draw challenge that used a grid to help them orient the points on the screen. The mother declined, and the family moved to another exhibit. Helen walked back to "Balancing Art" to watch and see if a newly arrived family needed her help.

Interaction 3: "Designing for Speed"

At "Designing for Speed," visitors roll four wheels of equal weight (but different weight distributions and colors) down two parallel tracks (Figure 19). Visitors set each wheel at a gate then press a button to release the wheel and start a timer. The wheels roll downhill until hitting a sensor at the bottom of the track. A table of LED readouts shows the elapsed time for each wheel. The positions of the weights on these wheels are visible but cannot be moved. A nearby scale allows visitors to confirm that the wheels all weigh the same.

As in another of the facilitation-friendly exhibits, Designing for Speed includes a small door at the top of the track that gives facilitators access to special white wheels with adjustable weights as well as software override switches. The adjustable weights allow visitors to see and feel the key relationship between weight distribution and rotation rate. The weights can be adjusted by hand to move them closer to or farther from the hub or center of the wheel. (The farther the weights are from the hub, the slower the wheels roll.) The switches override the external controls for each side; the red button starts a special timer for the adjustable wheels.

Figure 19. "Designing for Speed" exhibit

Mary, a 20-year-old volunteer, was assigned to roam the Action section of *Design Zone*. She had approached a father and his six-year-old daughter at "Designing for Speed," watching the girl roll the colored wheels down the track one by one, letting the wheels roll on their own rather than pushing them as some children did. Her father seemed to be at a bit of a loss about what to say to her about what she was doing, so Mary opened the facilitator storage door and took out the two white wheels with adjustable weights. She showed the father and daughter the weights on the white wheels and pointed out similar weights embedded in the four colored wheels. She then showed them how to adjust the weights on the white wheels, which the father did as Mary helped the girl. As they started rolling the white wheels down the track, the girl's seven-year-old brother joined them to see what was happening. He was soon joined by another 10-year-old brother. The brothers watched the white wheels roll and get their weights adjusted once or twice before claiming their own turns. The father smiled and seemed to enjoy his turn at the wheel, but soon yielded his spot to the older son. The father talked with his son about what they had been doing and tried to explain why things worked the way they did, as Mary helped the younger children adjust the weights on the wheel they shared.

Now that the kids had control of the wheels, they began a series of races, using many combinations of wheels. Mary kept asking them questions: "Which wheel is fastest?" "Which is fastest, and why?" "I'd like to hear…what do *you* think?" Her questions were sometimes answered with words and sometimes with gestures or other actions. She tried to get the family to think of the races as a way to test their guesses about the fastest wheel and why it was so fast. The father seemed to understand this, but the boys mostly wanted to race.

They raced an adjustable wheel against the blue wheel two times; the blue wheel won both times. Then they raced the two adjustable white wheels against each other and set the slower wheel aside. When they raced yellow against red, yellow cruised to victory, as it did against blue and green. Although their father pointed to the times being recorded on the chart at the end of the track, the children persisted in hitting the reset button after every run, so they never built up a record of race times to compare. Since the children seemed to remember which wheel won each race, Mary did not intervene. Although yellow was emerging as a consistent winner, the

kids still had not noticed a pattern. The father took out his camera and took photos of their efforts, and talked with the older boy about it. The boys then adjusted the weights as close to the center of a white wheel as possible and ran more trials, but could not defeat the yellow wheel. The boys and their father knew yellow was a winner because of the permanent position of its weights, but were a bit disappointed that they had not been able to design a wheel to beat it.

The two boys quarreled for a bit as the older one took control of the yellow wheel. Although their sister had moved on to "Roller Coaster Hills," her brothers ran a few more races, which the older one, of course, won every time. The younger boy lost interest and wandered off, followed by his brother. As another family walked up and claimed the wheels, Mary began talking with them.

Interaction 4: "Fast Tracks"

"Fast Tracks," a giant magnet wall, allows visitors to create and test their own roller coaster courses (Figure 20). The challenge presented in the label is to construct a course that sends a ball through a series of gates at specific speeds. Visitors can discover and experiment with the relationship between hill height and ball speed. This exhibit is not one of the six designated as facilitation-friendly, yet facilitators often worked here with visitors (especially children too short to reach the top of the magnet wall).

Figure 20. "Fast Tracks" exhibit

Charlie, an experienced facilitator, began his interaction by watching two boys about 12 or 13 years old. He did nothing until one of the boys turned around. At that point, Charlie asked him to put the ball at the top of an extra-tall track piece. Charlie heard the boy say the number readouts on the speed gates aloud ("7.1"). The boy compared that number with his friend's, who registered an 8.1. He then made a few adjustments to his track and tried again. This time he got a 7.5. Charlie saw an opening and chimed in, "That 7.5 is very nice." Then the boy made some more adjustments, and Charlie asked, "What do you think it's going to be?" The boy answered by releasing the ball and getting only 7.3. Charlie stepped in and he and the boy worked together to make a really long track. The boy did another run and got a 7.7, and Charlie asked, "Was that the speed you were trying for?"

The boy made a few more adjustments, and Charlie said, “I’ve never seen anybody do that. It’s a great idea!” At this point Charlie stepped back and just watched for a while, saying, “Just let me know when you need my help.”

When the boy’s interest seemed to flag, Charlie stepped up and said, “One of these days I’m going to try making a super slow track.” The boy started flattening out his track until the ball is barely moving along some sections of track. Charlie said, “I had my ideas, but your idea was even better. When I make my super slow one, I’m going to use your idea.” But slow speed wouldn’t do for long, and the boy started building steeper tracks. Henry kept trying to encourage predictions, asking things like, “If we do this, will it go faster here or slower?” Eventually they set a record high score for this boy. Charlie celebrated with him, saying, “7.8! Five, please!”

At this point, the boys noticed that one speed gate was not recording. Charlie tested it himself and said, “I’m going to call someone.” The exhibit repair guy came some five minutes later and did a reset. He explained to Charlie and the boys that a static charge builds up because of the rolling ball and throws the speed gate off. The reboot fixed the problem.

The first boy got two of his friends, about the same age, and bought them over and they began to build a new track. Charlie stepped back and watched as the boy he had been helping explained and demonstrated for his friends. The boy’s mother came over and said to the boys, “Five minutes, guys.” Charlie then spoke with her and said, “I was very impressed by his creative use of materials.” Some 20 minutes after Charlie first walked up to “Fast Tracks,” the mom finally dragged the boys away.

Interaction 5: “Laser Light Show”

“Laser Light Show” consists of a real laser controlled by two oscillating mirrors (Figure 21). Knobs allow visitors to control the oscillation frequency of each mirror in order to produce different projections on a screen (called Lissajous patterns). The pattern is projected on a screen in front of the visitors, and its shape varies with the ratio between oscillation frequencies of the two mirrors. A computer monitor guides visitors through a series of challenges, and large LED displays show the oscillation frequencies.

Figure 21. "Laser Light Show" exhibit

Gail, a full-time staff member, was facilitating at "Laser Light Show" for a group of three: a boy, about 14, and two adults. She had initially observed that the group seemed a bit puzzled about what to do and had stepped in to help. She pointed out how to work the controls and helped them make one of the examples, emphasizing the role of ratios in finding a setting or settings to produce a given shape. As a way of helping them understand the concept, she opened the facilitator storage cabinet and used the controls to slow down the laser. She then explained how the laser and mirrors generated the shapes projected on the screen.

Gail had started the group on a new challenge to generate a shape that had five loops. She was called away from the exhibit by her supervisor, however, before the visitor group could complete the challenge. Nonetheless, the 14-year-old continued to experiment with various ratios, such as 55:11 and 60:10, trying to get the figure to stabilize. He finally got a stable five-loop shape with the dials set at 60:12 which, with an adult's help, he recognized as a 5-to-1 ratio. He was excited to have conquered the challenge.

Interaction 6: "Hit the Target" and "Designing for Speed"

"Hit the Target" is essentially a catapult that allows visitors to adjust its release angle (Figure 22). The exhibit uses flashing lights to guide visitors as they tried to hit a series of designated targets laid out in a straight line. The targets are labeled with their distance from the catapult, and a graph shows how the release angle (x-axis) relates to the distance traveled (y-axis). By using this graph to choose release angles, visitors can increase their chances of getting the ball into their chosen target. Although "Hit the Target" is not one of the six facilitation-friendly exhibits, facilitators often helped visitors learn to use the mechanism and sometimes pointed out how the graph could improve their chances.

Figure 22. "Hit the Target" exhibit

Henry was an experienced facilitator—older than most of his coworkers—who spent much of his time doing science theater presentations for visitors. Early one morning he was one of two facilitators in *Design Zone*, free to facilitate in whatever section of the exhibition he chose. Henry decided it was a good time to practice some of the facilitation techniques he had learned in the OMSI workshops, including the rather radical idea that sometimes the best facilitation is no facilitation at all.

Once visitors started to arrive in *Design Zone*, Henry roamed around the gallery, stopping and standing about 5 to 10 feet back from exhibits where visitors had gathered. Sometimes Henry would watch at an exhibit for 20 or 30 seconds then step in and talk to visitors. Coming upon a father and young son at "Hit the Target," Henry watched for a while then stepped in to help them learn to operate the catapult mechanism. The group was having trouble getting the arm to ratchet down all the way and lock into place (a frequent problem at this otherwise fun exhibit). The father and son were grateful to learn how to do it. When the boy got a score, Henry clapped and congratulated him.

Many times, however, Henry would walk away without saying or doing anything. For instance, he watched a mother and her children at "Designing for Speed," but did not step in. He said she was doing as well as anyone could do and did not want to "mess with it." Later he came back and introduced the adjustable wheels to the group. He thought about how this related back to the OMSI training and the advice he remembered was "not to overdo it" on the interpretation. "I keep running into situations where I'm not going to add anything to the interaction. It's interesting, but it's hard to quantify when I should step in."

Later that afternoon Henry was back on duty in *Design Zone*, and he stopped to talk with a lone adult male at "Designing for Speed." After a brief conversation Henry opened the facilitator storage door and took out one of the white wheels (with adjustable weights). Soon the visitor was adjusting the wheel's weights himself. After asking a few guiding questions, running the adjustable wheel a few times, and discussing the results, Henry stepped away

and watched. Satisfied that things were going well, he walked to the nearby “Fast Tracks” to watch a young boy engage with his friend. When he finally turned back toward “Designing for Speed” some 20 minutes later, the visitor was still experimenting with the adjustable wheel.

Level IV: Impact

Impact on Visitors

Engaging Visitors in Algebraic Thinking

A major goal of *Design Zone* was for staff to learn to facilitate visitors’ math explorations by using strategies taught in the OMSI-led workshops and using the facilitation affordances accompanying six *Design Zone* exhibits. Now that we have looked closely at how staff applied those strategies and using affordances with visitors, we can begin to understand how those actions contributed to visitors’ explorations and uses of algebraic thinking.

The project defined algebraic thinking as:

- Finding and exploring mathematical patterns and relationships between quantities (functional relationships)
- Representing mathematical relationships in a variety of ways, including images, words, models, tables, graphs, and symbols
- Using mathematical relationships to describe, analyze, predict, and create

Though our analysis of how visitors thought and discussed functional relationships in the exhibits, we identified general patterns that describe the ways visitors engaged with these concepts.

One possible scenario: Visitors might start by observing a phenomenon at the exhibit. Once visitors discovered a challenge or set a goal, their efforts became more focused. They started applying strategies to solve whatever problems they encountered. The simplest strategy was trial and error: try something, whatever comes to mind, and see whether it works. Thinking about the results of their informal experiments led some visitors to discover a key relationship—the thing they had to change and the way they had to change it to achieve their goal. When this relationship was expressed through visitors’ actions and words, we termed it *finding a relationship*.

If visitors discovered that they could apply numbers—measurements and counts—to describe a functional relationship, they were applying numbers to a relationship. Visitors moved *to generalizing the relationship* when they started to approach the challenge using the more abstract ways of thinking generally associated with school algebra. This mode of engagement often involved using graphs, data tables, and equations expressing the key relationship in ways that allowed visitors to meet a range of challenges that the exhibit presented.

What we call “generalizing the relationship” overlaps considerably with what might traditionally be considered doing algebra (sometimes defined as “abstract arithmetic”). We do not, however, restrict the term “algebraic thinking” to this mode of engagement. As defined for this study, algebraic thinking begins as soon as visitors

recognize a relationship between two things at the exhibit that change (i.e., two variables)**.** In other words, algebraic thinking begins at finding a qualitative relationship. In informal settings like *Design Zone*, therefore, even children too young to know the word "algebra" can, at a basic level, practice algebraic thinking. As visitors shift to other modes, their thinking might become quantified, then generalized, so that their understanding of a relationship applies to a range of challenges.

The scenario above presents a generalized and rather linear description of visitor engagement. In a video study carried out for the exhibition summative, however, we found that visitors' engagement with math in the exhibition was complex and did not follow one prescribed path. Engagement was fluid, with visitors moving across modes as they approached the challenges.

The summative exhibition evaluation (Garibay Group, 2013) found that 90% of children in the target age range at the exhibits (and 88% of children in the entire sample) engaged in algebraic thinking. More than 40% engaged quantitatively and another 17% engaged in abstract thinking (generalizing).

Given these results, what can facilitators contribute to visitors' algebraic thinking? As it turns out, quite a lot. Many aspects of facilitator interactions helped further visitors' thinking and problem solving, and these positive effects took place across the modes of engagement. Table 10, below, describes ways facilitators supported visitors' engagement.

Table 10. Ways facilitators supported visitors' algebraic thinking by mode of engagement

Visitors' Mode of Engagement	Ways Facilitators Supported Engagement
Observe Phenomena	Facilitators helped visitors find ways to engage with the exhibits, often by pointing out the exhibit challenges. Once visitors had accepted a challenge or set a goal, they were typically able to move into deeper exploration of the exhibit concepts.
Explore through Trial and Error	Facilitators used questions, suggestions, demonstrations, brief explanations, and sometimes special props to help visitors discover the key variables at the exhibits and the relationship between them.
Find a Relationship (Qualitative)	Facilitators helped visitors discover and apply numbers to one or both variables in a relationship—weights, distances, speeds, times, frequencies—depending on the exhibit.
Notice Numbers	Facilitators helped visitors find and apply the exhibits' math tools—graphs, data tables, and equations—pointing out the tools available to all in the exhibits and bringing out special props.
Apply Numbers to a Relationship (Quantitative)	
Generalize the Relationship	Once visitors moved into generalizing relationships, facilitators sometimes helped them connect what they had done with other applications of algebraic thinking, either in everyday life or with the algebra they had learned in school.
Generalize the Relationship and Articulate It	

The summative evaluation of the exhibition found that about one-third of parents remained unengaged as their children engaged with the exhibits (Garibay Group, 2013). Sometimes the mere presence of a facilitator motivated adults to take part in the engagement (listening to and talking with the facilitators, for instance, as their children engaged). In those cases, facilitators likely contributed significantly to groups' engagements with algebraic thinking.

When visitors began engaging through observation, facilitators helped them find ways to use the exhibits, often pointing out the exhibit challenges or by using the special facilitator challenge cards (e.g., the name-that-song challenge cards at "Digital Strings"). Groups with children in the target age range nearly always found or developed a challenge on their own (Garibay Group, 2013); facilitators, however, often inspired these groups to accept new challenges. Observations also revealed that facilitators were important in successfully engaging children younger than six or seven, who often needed assistance to move beyond observation. In our observations, facilitators were almost always successful at moving these young children into further exploration.

Facilitators used questions, suggestions, demonstrations, brief explanations, and sometimes props to help visitors discover and explore the relationship between key variables at the exhibits, assisting visitors in extending their engagement beyond trial and error. One popular prop among facilitators was the adjustable wheel at "Designing for Speed." From our observations, facilitators working with visitors engaging by trial and error almost always successfully helped them focus on key variables and the relationships between them.

To support algebraic thinking, the *Design Zone* exhibits provided ways ("math tools" or "quantitative tools") for visitors to apply numbers to one or both variables in a relationship: weights, distances, speeds, times, or frequencies, depending on the exhibit. These tools included quantitative labels indicating weight or distance, quantitative representations of functional relationships such as images, graphs, tables, or equations provided on graphic panels (challenge panels and parent panels) and screens (in computer-based interactives), and representations of relationships and data, such as graphs and tables created by visitors through their interactions with a component. During the exhibition summative study, however, nearly half of children and a third of adults did not use the information in parent panels and representations of data as they engaged with an exhibit (averaged across all exhibits, Garibay Group, 2013). In general, facilitators called visitors' attention to the quantitative tools; this was a major contribution toward supporting visitors' algebraic thinking in *Design Zone.*

Some quantitative tools, including graphs, data tables, and equations, directly represented functional relationships and could help visitors discover or apply general approaches to using numbers to meet their challenges. Some visitors discovered and used these tools on their own, but many did not. Facilitators helped visitors find and apply these quantitative tools in many ways, pointing out the tools available to all in the exhibits and also bringing out special props (e.g., the question mark weights at "Balancing Art") and special software modes (e.g., the specialized table for recording data on the adjustable wheels at "Designing for Speed"). This was another area where facilitators, on the whole, excelled, especially at the exhibits with facilitator affordances. On average, only about 10% of visitors in the target age range began to generalize relationships on their own at an exhibit (Garibay Group, 2013). At more than 50% of facilitator-visitor observations, however, facilitators successfully aided visitors already thinking quantitatively to engage in more abstract modes of problem solving, applying graphs, data tables, or equations to various challenges. For visitors thinking qualitatively, however, it would have been inappropriate for facilitators move immediately to quantitative generalization. Facilitators following the Cycle of Facilitation could note this during their initial observations of a visitor group then approach their interaction with that group in an appropriate way.

Once visitors were thinking more abstractly, facilitators often continued to engage with them. For instance, they sometimes helped visitors connect what they had done with other applications of algebraic thinking in everyday life or with the algebra they had learned in school.

Overall, there was significant evidence that facilitators played an important and, for some groups, indispensable role in helping visitors engage in algebraic thinking.

Visitor Responses

Observations also revealed that the majority of visitors both appreciated and enjoyed their interactions with facilitators. Visitor comments collected during exit interviews for the exhibition's summative evaluation pointed to the range of ways in which facilitators supported visitors' interactions, which included everything from keeping exhibits functioning to helping visitors better understand the exhibit to providing additional ways of engaging that made the experience fun.

> *Having staff around is great and essential for explaining some exhibits and to help keep order.*
>
> *We had a lot of fun and the staff was helpful.*
>
> *We started at "Balancing Art" and an explainer showed us how to use the math for it. That basically got the ball rolling for us.*
>
> *[The] explainers were helpful.*
>
> *[There were] lots of explainers to help.*
>
> *[I liked] the friendly people. Everyone was very helpful.*

On the other hand, when large crowds were present or not many facilitators were available, some visitors specifically mentioned wishing for help from staff.

> *We needed more assistance, [more] people to show how to use the exhibits.*
>
> *[It] would be better with more staff to help kids.*
>
> *If someone would explain, that would be great.*
>
> *It would be nice to have more volunteers and staff around.*
>
> *There should be staff around to pay attention and to help out.*

Visitor Group Dynamics

Another intended impact of *Design Zone* professional development was for facilitators to develop the skills to create safe math learning environments where groups of visitors feel comfortable engaging in algebra activities. The focus for this impact was on supporting group (rather than individual) engagement and including all group members in facilitated interactions regardless of their comfort level with math and algebra. Some suggestions and encouragements about this were mentioned in the workshops and Staff Guide, but overall, many experienced facilitators brought this skill with them rather than learning it from *Design Zone* workshops.

The exhibit design helped convey this impact; many exhibits (especially the facilitator-friendly ones) allowed for a small group to gather around and, together, engage with the exhibit. Exhibits designed to be used cooperatively by two visitors (such as “Drawing in Motion” and “Slide-a-Phone”) and exhibits supporting competition (such as “Bike Race,” “Testing Gears,” and “Designing for Speed”) also supported *Design Zone’*s intended impact. We did find, however, that group use was to some extent undermined by having so many attractive interactives in the same room. Groups with multiple children often split up and went to nearby exhibits as they became available so that each child got to control his or her own exhibit experience, rather than share it. Thus, facilitators worked with some tendencies in visitor use of the exhibits and against some other tendencies.

Summative evaluation of the exhibition produced mixed results regarding how visitors engaged as groups (Garibay Group, 2013). For instance, 78% of children in the target age range (and 70% of adults) spoke with others in their group. At individual exhibits, some 40% of parents took on teacher-like roles. Adults, however, were also much more likely than children to stand back and watch rather than take an active role. On average, some one-third of adults stepped in and got their hands on the exhibit, but another third remained disengaged (Garibay Group, 2013). Thus, many visitor groups engaged successfully at the exhibits on their own, but a fair number did not necessarily engage as a group. In addition, during the course of their time in *Design Zone*, groups often gathered at an exhibit, split up to explore other components, then came back together. In other words, a fluidity to interactions existed that make it impossible to categorize groups as falling discreetly into exploring “together” or “apart.”

As pointed out earlier, some parents felt comfortable enough—and confident enough in their children—to step back from the exhibits and either watch from a distance or engage with other activities. Thus, we observed many interactions between facilitators and children whose parents were elsewhere. Sometimes the presence of a facilitator was enough to cause the group to reassemble, at which point facilitators would typically step back and allow members of the group to engage. The group dynamics in these situations could be complex. For instance, at one 15-minute facilitated interaction at “Sound Graph,” a group including a mother, grandmother, two teens, and several young children assembled and split up several times. At one point the grandmother and facilitator walked off to talk about a different exhibit while the rest of the group stayed to complete a challenge begun by the facilitator. At other times, the facilitator took on the role that an adult might otherwise have filled. This role was especially important at exhibits designed as cooperative experiences (such as “Slide-a-Phone” and “Drawing in Motion”). Many children exploring on their own got help from roaming facilitators who stepped in to give a hint or a challenge then stepped back.

Two remaining types of cases must be considered: 1) cases in which families or other groups engaged together at an exhibit, and facilitators, perhaps after a short observation, decided to approach and offer support; and 2) cases where the facilitators at an exhibit were approached by a group.

In the large majority of Case 1 interactions, facilitators tended to consciously use part of the Cycle of Facilitation, first observing visitors, deciding what support (if any) they could provide, stepping in and interacting, then stepping back. (Note that some facilitators used a similar approach, but did not specifically cite the Cycle of Facilitation, stating that their museum had already taught and practiced that sort of approach.)

Case 2 interactions were familiar to facilitators with experience working with carts. We saw this sort of interaction at exhibits where facilitators could bring out props to attract and intrigue visitors, such as the adjustable wheels at "Designing for Speed" and the question mark weights at "Balancing Art." Perhaps because these facilitators were more used to facilitator-focused approaches to interpretation, they often became the center of visitor attention—perhaps drawing parents and children together, but with the facilitator as more of an instructor and less a support resource.

We also noted that when facilitators used to cart-based interpretation approached a family already functioning as a group (Case 1), they tended to *disrupt* the functioning of that group. Often the parent, who had been actively participating, stepped back and allowed the facilitator to take over; parents often seemed to be displaced by this facilitation approach. Children were still in charge of engaging with the exhibits, but the parent was now more an observer only responsible for behavior control ("Hey, pay attention!"). (It should be noted, of course, that some parents seemed grateful to be temporarily relieved from "teacher" duty.) The facilitator would ask questions, mostly to move the group step-by-step through the exhibit as its designers intended. The facilitators also would explain how to use the exhibit although the kids would usually "do the doing." In this sort of facilitation, the staffer tended to move the group through its initial orientation to the exhibit more quickly than it would have moved otherwise. Therefore, some groups probably spent more time completing exhibit challenges and engaging with more quantitative and abstract algebraic thinking than if left to their own devices. In addition, children engaged in less discovery and received more instruction than many parents would have provided. Concerning the project's intended impacts, one positive result of this type of facilitator interaction is that visitor groups engaged with exhibits in more quantitative ways than they might have on their own. This approach, however, did not achieve the intended impact of having facilitators support the existing group dynamics.

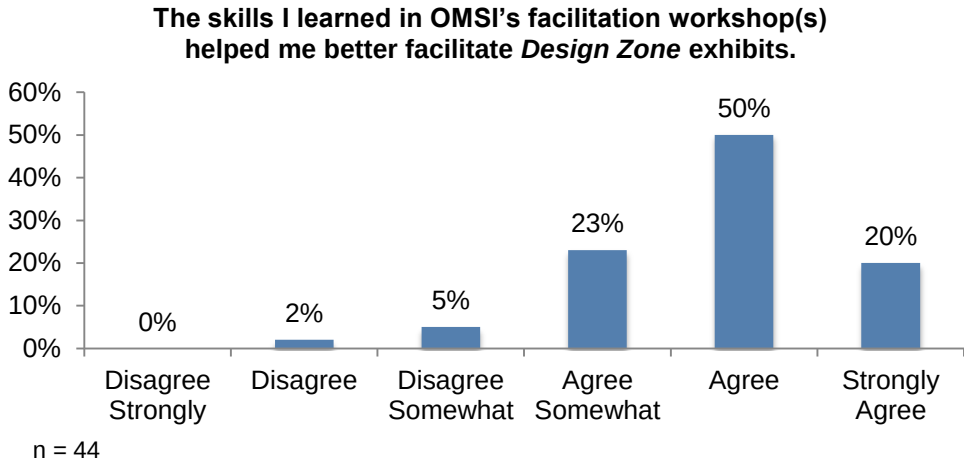
Impact on Facilitators

This section examines the impact of *Design Zone* on facilitators. Data are primarily drawn from follow-up surveys and interviews.

Skills

Thinking back on their experiences in the *Design Zone* exhibition and the workshop training, 70% of respondents agreed (50%) or strongly agreed (20%) that the training helped them obtain skills to better facilitate experiences at exhibits (Figure 23). Nearly a quarter agreed somewhat; these respondents noted either that they already possessed some of the skills or that they still needed time and experience to hone their skills facilitating *Design Zone* exhibits.

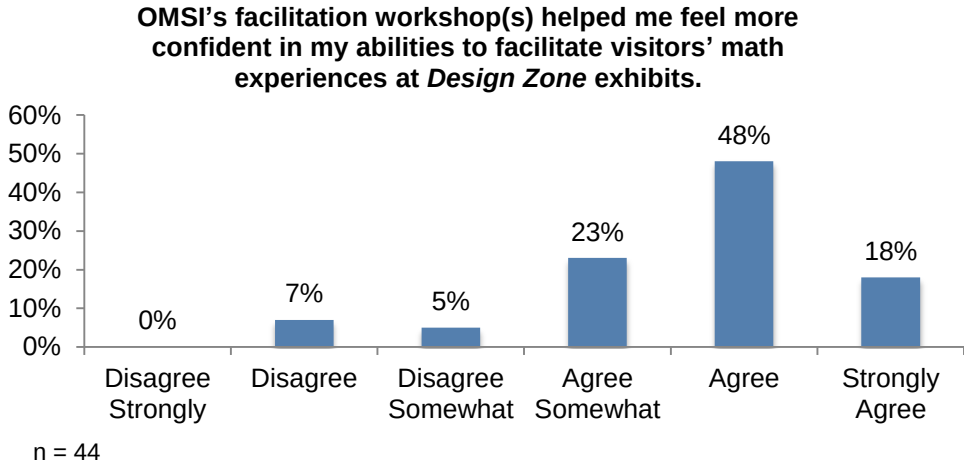
Figure 23. Impact of workshops on facilitation ability: Skills



Confidence

Retrospective questions about the extent to which the workshop contributed to facilitators' confidence in facilitating math experiences also suggested that *Design Zone* training was successful. The majority (66%) either agreed or agreed strongly that the workshop helped them feel more confident in facilitating math experiences at *Design Zone* (Figure 24).

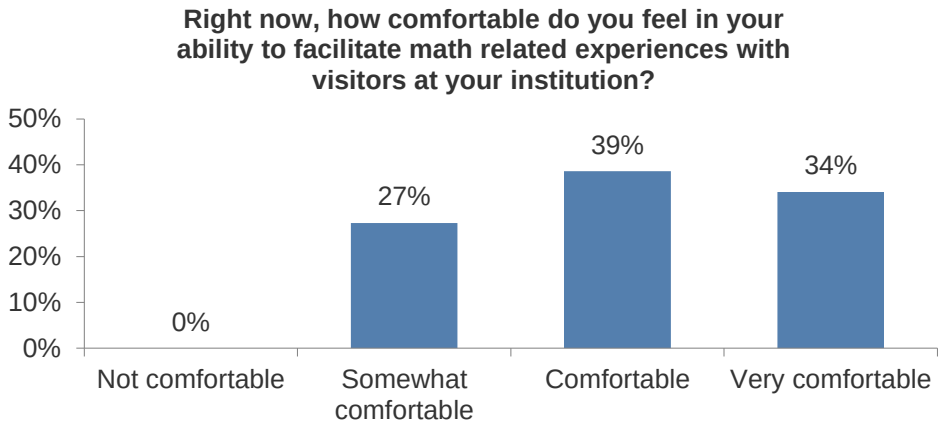
Figure 24. Impact of workshops: Confidence



Comfort

Data also indicated that the experiences positively contributed to facilitators' overall comfort in facilitating math experiences in general (Figure 25). Some 70% of respondents indicated being comfortable (39%) or very comfortable (34%) with their abilities.

Figure 25. Comfort facilitating math experiences

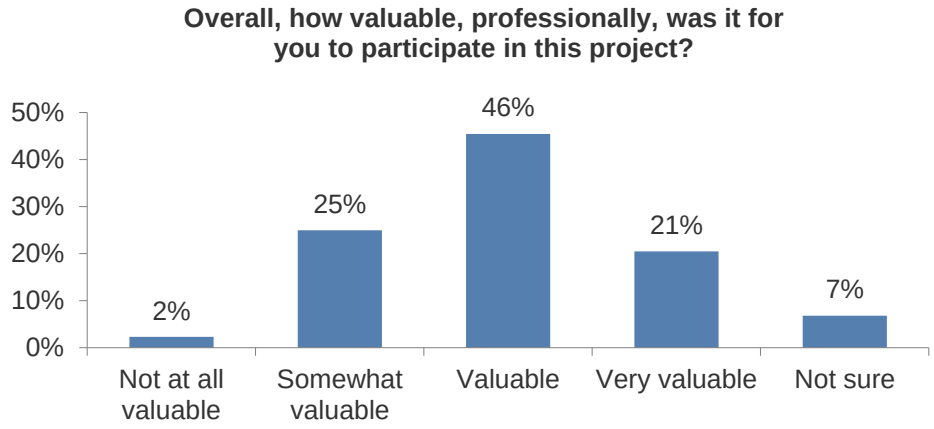


n = 44

Perceived Value

The majority of follow-up survey respondents (92%) found the project professionally valuable to some extent (Figure 26).

Figure 26. Value of participating in the *Design Zone* project



n = 44

Impact on the Organization

While surveyed staff reported obtaining important professional development from their experiences with the project, data suggested that they were less sure of how what they did and learned at *Design Zone* would translate more generally to their work at their organization. Nonetheless, more than half the respondents either agreed or agreed somewhat that the experience would have some impact on their future work. Most respondents said they continued to discuss the workshops with their colleagues (Figure 27). Most said they were inspired with specific ideas for including math in their own exhibits and programs (Figure 28). Most respondents noted being inspired to reflect on ways to increase their visitors' engagement with math (Figure 29).

Figure 27. Extent to which respondents continued to discuss workshop ideas

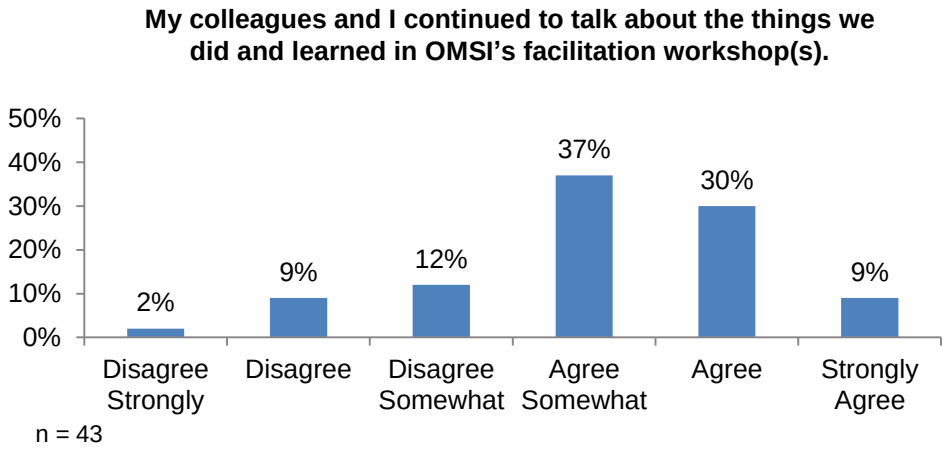


Figure 28. Extent to which workshops inspired ideas for math activities in exhibits and programs

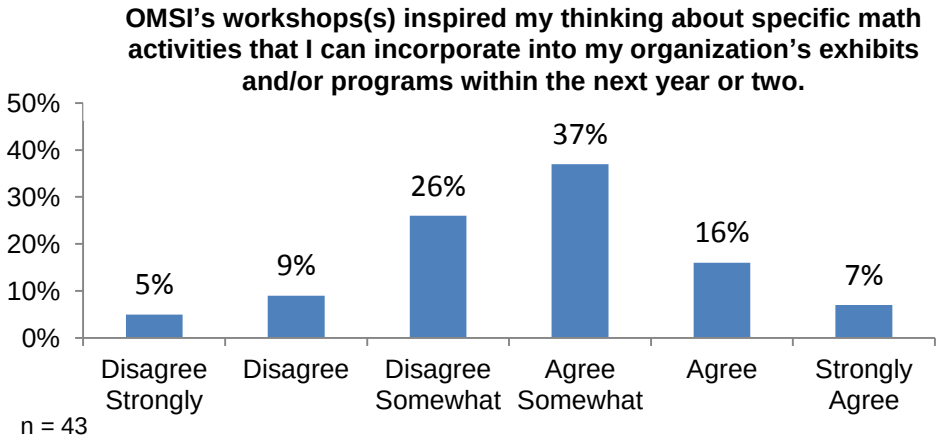
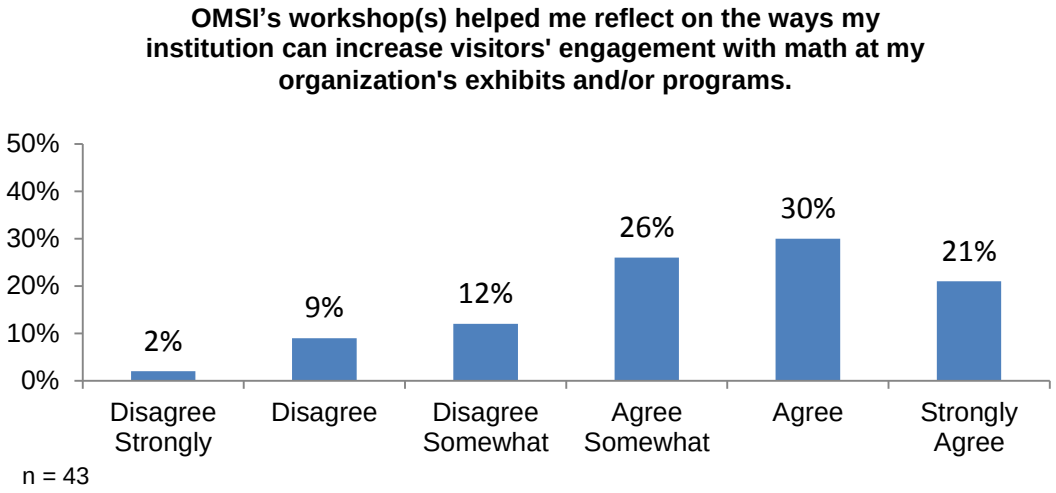


Figure 29. Extent to which workshops inspired reflection on how organization could increase visitors' engagement with math



In examining the organizational impact of *Design Zone* training, it is important to consider any given institution's trajectory in incorporating math as part of its organizational focus.

One host museum, for example, was already moving ahead with some of the ideas that it had developed during the workshop.

> *We're definitely going to be following up on a lot of the things we talked about. In fact, a lot of staff will have annual goals that sort of correspond to some of the ideas we talked about. We're definitely going to be putting together some exhibit guides that sort of follow the exhibit guide that was given out for* Design Zone*. We're also going to put together some more challenge cards for a couple of the exhibit components, sort of like the Digital Strings—an added challenge for the guest that the facilitator can use with them.*

At another larger institution, one supervisor noted that making larger changes takes a long time.

> *[Workshop II] was a good workshop. I liked the ideas a lot, and there was really good stuff presented. Where I think it didn't end up holding up was in connecting it to actionable things that we can do now. And partially it's not because anything was wrong with the workshop, just because it's hard to do actionable things on a scale that's really going to make a difference. Whether that's modifying exhibits, or bringing interpretation into other activities that we currently do, where we're bringing in math interpretation—all really good things, and things I would like to do, but they're things that have to be done long term. Just because it means that activities need to be created, things need to be adjusted, and then we have to train a couple hundred people…It has to be long term for us, on the scale we're operating on.*

At each museum, some ideas developed during Workshop II involved changing the exhibits themselves; programming staff pointed out that such changes would take longer to implement.

> *There are some other ideas that we came up with that are really the responsibility of our Exhibits Department. That's not my division to oversee that. So that's going to require a little more collaboration with that division, and some of those things may have to wait until it's that exhibits turn to be refurbished. All the exhibits are on a 10-year refurbishment plan, so for [some exhibits] that's not going to be for a while.*

At one host museum, *Design Zone* coincided with the beginning of a much larger effort to increase the amount of math facilitated by museum interpreters. Specific ideas developed during Workshop II might not be implemented, but the overall impact of math-related programming for visitors was still likely to increase.

> *I don't know that any of the specific ideas from the workshop are being implemented. But we definitely are moving in a math direction as an institution. [A math organization in] partnership is going to bring out more of the math content that already exists in our carts and deliver it to offsite audiences. And I think that will also strengthen math components of our current activities and of the interpreters that are presenting them. And that's a partnership that's just getting started.*

Impacts Summary

Evaluation showed that the project was successful in meeting its impacts. In terms of indicators, eight were met and two were nearly met (Tables 11–14).

Table 11. Impact 5: The target audience (paid and unpaid museum floor education staff) will feel excited about and comfortable with algebra/math.

Indicator	Evidence of Indicator
75% of participants will report confidence in their abilities to facilitate math/algebra learning after the professional development.	80% of follow-up survey respondents who attended a workshop and facilitated in *Design Zone* agreed with the statement: "My *Design Zone*-related experiences helped me feel more confident in my abilities to facilitate math experiences for visitors at my institution's exhibits."
75% of participants will report comfort in their abilities to facilitate math/algebra learning after the professional development.	100% of follow-up survey respondents who attended a workshop and facilitated in *Design Zone* reported feeling "somewhat comfortable," "comfortable," or "very comfortable" in their ability to facilitate math-related experiences with visitors at their institution.
75% of participants will report an eagerness to attempt math/algebra facilitation after participating in the professional development.	87% of follow-up survey respondents who attended a workshop and facilitated in *Design Zone* agreed with the statement: "As a result of attending OMSI's workshop(s), I was eager to facilitate math experiences with visitors."
75% of participants will report their conception of the relevance of algebra and math has deepened as a result of participating in the professional development.	77% of follow-up survey respondents who attended a workshop and facilitated in *Design Zone* agreed with the statement: "OMSI's workshop(s) helped me reflect on the ways my institution can increase visitors' engagement with math at my organization's exhibits and/or programs."

Table 12. Impact 6: The target audience will recognize and support visitors' algebraic thinking at select exhibits within the exhibition.

Indicator	Evidence of Indicator
70% of facilitated interactions in the exhibit will appropriately support algebraic thinking for the visitors (measured through observation and follow-up interviews).	75% of the interactions observed supported algebraic thinking (as defined in the project and in the modes of engagement framework). Facilitators often helped visitors engage more deeply.
70% of facilitated interactions in the exhibit will demonstrate good algebraic thinking and math-talk skills (measured through observation).	75% of the interactions observed demonstrated both a good understanding of the mathematical principles embedded in the exhibit AND appropriate communication of those principles, given the mathematical sophistication displayed by the particular visitor group.

Table 13. Impact 7: The target audience will develop the skills to foster positive visitor experiences with algebra/math.

Indicator	Evidence of Indicator
80% of professional development training participants will report that they understand exhibit facilitation after the professional development training.	93% of follow-up survey respondents who attended a workshop and facilitated in *Design Zone* agreed with the statement: "The skills I learned in OMSI's facilitation workshop(s) helped me become a better facilitator of the *Design Zone* exhibits." 82% of these respondents agreed with the statement: "My *Design Zone*-related experiences helped me reflect on my own approach to facilitation."
80% of facilitated interactions in the exhibit will result in positive visitor experiences with math and algebra.	75% of interactions observed resulted in positive visitor experiences with math and algebra. Facilitators often either 1) helped visitors overcome their frustrations when they had trouble figuring out what to do at an exhibit, 2) turned relatively mindless play or exploration into an attempt to meet math-related challenges, or 3) helped visitors discover how quantitative tools (e.g., graphs) could help them meet the challenges they had set for themselves at that exhibit.

Table 14. Impact 8: The target audience will develop the skills to create safe math learning environments where groups of visitors feel comfortable engaging in algebra activities together.

Indicator	Evidence of Indicator
50% of facilitated interactions in the exhibit will be supporting group engagement (rather than individuals).	In 74% of the interactions observed with more than one visitor, the facilitator supported engagement by the group. Facilitators who used aspects of the Cycle of Facilitation in their work almost always supported group engagement—for instance, involving both parents and children in the engagement with the exhibit. Facilitators who used other less visitor-centered approaches in their work wound up replacing absent parents in about a third of their interactions, often displacing parents' leadership roles when parents had been interacting with their children.
80% of staff will demonstrate ability to be inclusive of all group members in facilitated interactions in the exhibit regardless of visitor comfort level with math and algebra.	In 75% of the interactions observed where some visitors seemed uncomfortable with aspects of math or algebra, intervention by a facilitator helped even the less comfortable visitors have an enjoyable and productive time at the exhibit. This happened even when facilitators approached their work in a more traditional, less visitor-centered approach (in part because uncomfortable parents were happy that someone else was helping their children with the exhibit).

Conclusions

Conclusions

There are several ways to judge the overall effectiveness of the *Design Zone* professional development efforts. One way is to examine the previous section of the report, which looked at NSF impacts and indicators based on the project's goals.

Simply measuring outcomes—the training met 8 of 10 indicators—leads to the conclusion that the professional development aspects of *Design Zone* were very successful. The OMSI-led workshops left paid and volunteer staff comfortable and confident with their abilities to facilitate math and algebra learning in the exhibition and eager to start facilitating for visitors. Observations at the exhibition found that host-museum facilitators demonstrated good algebraic thinking and supported visitors' development of such skills. In addition, the workshops helped most host-museum staff reflect on and improve their own facilitation philosophies and skills, resulting in positive experiences for most visitors they interacted with. Furthermore, in the majority of interactions we observed, facilitators supported group engagement and included group members of various levels of math comfort. In this last case, those staff and volunteers who adapted aspects of the Cycle of Facilitation were even more successful.

Another way to assess the overall effectiveness of the project's professional development efforts is to review the findings relative to the Kirkpatrick Model of Professional Development, which was used as an organizing principle for much of the report.

Level 1. Reaction: Did they like it?

Findings suggest that for the vast majority of participants, the workshops succeeded on this level. The majority of participants reported that the workshops met or exceeded their expectations and were useful to their work at the science centers. Nearly all respondents indicated that they would recommend that colleagues attend the workshops. When asked how to improve the pre-opening Workshops I, the top suggestions asked for *more.* Respondents wanted the workshops to devote more time to exploring in the *Design Zone* exhibition, provide more examples of effective facilitation, allow more time for role playing as facilitators in the exhibition, cover more exhibits, and allow more time for discussion.

Level 2. Learning: Did they learn it?

Participating in the pre-opening workshops positively affected participants feeling prepared to facilitate visitor experiences in *Design Zone* and their sense of confidence about facilitating math experiences for visitors. Participants were especially appreciative of being trained before *Design Zone* opened, noting that they felt more prepared than for other traveling exhibitions. The majority of workshop participants mentioned specific things they learned from the workshops, listing ideas about facilitation skills, math and how to make it fun and interesting for visitors, or specific things about the *Design Zone* exhibits and the facilitation affordances included with six of them.

Level 3. Transfer: Did they use it?

One hallmark of the *Design Zone* facilitation workshops was that most participants got to put what they learned into practice almost immediately. Most respondents to the follow-up survey indicated facilitating visitor experiences at *Design Zone* at least once a week, the vast majority reporting using at least one of the affordances. Facilitators felt more comfortable with the affordances when an OMSI workshop had supplied specific training on them. Many facilitators we observed applied aspects of the Cycle of Facilitation Model presented at the workshops; some facilitators at the host museums consciously emulated the Cycle of Facilitation approach in *Design Zone.*

Level 4. Impact: Did it make a difference?

The *Design Zone* professional development efforts made a difference on at least three levels, affecting the visitor experience, facilitators' professional development, and organizational commitment to facilitation of math experiences on the floor.

Although facilitators could not interact with all visitors to *Design Zone*, those times when facilitators and visitors worked together saw visitors' engagements with the exhibits positively affected in many different ways. Visitors could better understand how the exhibit worked and facilitators showed them additional ways to engage that made their stay at the exhibits more fun. Many aspects of facilitators' interactions with visitors helped deepen visitors' algebraic thinking and problem solving, and the positive effects took place through all modes of visitor engagements developed for this study. Observations and visitor comments revealed that the majority of visitors appreciated and enjoyed their interactions with facilitators. On the other hand, during periods of large crowds or when few facilitators were available, some visitors specifically mentioned that that they would have welcomed some help.

Most workshop participants agreed that the training helped them obtain skills to better facilitate experiences in *Design Zone* and beyond, although some more experienced staff and volunteers noted that they already possessed some of these skills and were less positive about that aspect of the workshop. Surveyed after *Design Zone* moved on, most facilitators said they felt that the workshops contributed to their confidence in facilitating math experiences in *Design Zone*. The vast majority of follow-up survey respondents found their participation in *Design Zone* professionally valuable, at least to some extent. While surveyed staff reported obtaining important professional development from their experiences with the project, data suggested that they were less sure about how (or how much) the ideas learned and their experiences at *Design Zone* would translate to their future work. Nonetheless, more than half of respondents either agreed or agreed somewhat that the experience would have some future impact on their work.

The impact of the *Design Zone* experience on any host museum must be considered in terms of the museum's own trajectory in incorporating math as part of its organizational focus. Because all three host museums deployed trained facilitators to work with visitors in *Design Zone*, the short-term impact of the workshops was—of course—

considerable. In the longer term, once *Design Zone* had moved on to its next stop, its lasting impact seemed to vary among the three host museums. One of the host museums with a smaller core staff was already moving ahead with some of the facilitation ideas it developed during Workshops I and II. At one larger institution, one supervisor noted that making larger changes to facilitation practices would take a long time. At one host museum, *Design Zone* coincided with the beginning of a much larger effort to increase the math done by museum interpreters, so specific ideas developed during Workshop II might not be implemented, but the overall impact of math-related programming on visitors was still likely to increase. At each museum, some of the ideas developed during Workshop II involved changes to the exhibits themselves, something that programming staff pointed out would take longer to implement.

The existing professional development efforts for the *Design Zone* project did not completely meet all of its challenges in training veteran floor staff and volunteers. Aspects of Workshop I harnessed some of their skills and energy for facilitating math experiences for visitors, but did not always succeed in convincing staff and volunteers that the OMSI approach to facilitation was the best way to work with visitors on the floor. Also, some facilitation affordances were used much less than others, in part because the train-the-trainer model used to pass on information about the Workshop II facilitation-friendly exhibits did not function effectively at all host museums. The professional development aspects of the *Design Zone* website were underutilized, especially the online forum developed to share experiences among floor facilitators, and at some host museums, the Math Toolkit was sequestered in a supervisor's office rather than being available. Finally, the existing professional development approach may be ineffective in inspiring longer-term impacts at some of the larger host museums.

That said, whether looking at the NSF Impacts or Indicators or the Kirkpatrick Model of Professional Development, *Design Zone* professional development training and support systems clearly had a large short-term impact on both host museum facilitators and on the visitors they interacted with on the floor. In addition, the training will have longer-term impacts on some individual staff and volunteers and on at least one of the host museum's overall floor programs.

References

References

Babbie, E. (1998). *The practice of social research*. Albany, NY: Wadsworth Publishing Company.

Garibay Group (2013). *Oregon Museum of Science and Industry's Design Zone exhibition summative report.* Unpublished manuscript, Oregon Museum of Science and Industry, Portland, OR.

Greene, J. C. & Caracelli, V. J. (2003). Making paradigmatic sense of mixed methods practice. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research*, (pp. 91–110). Thousand Oaks, CA: Sage Publications.

Guskey, T. R. (2000). *Evaluating professional development*. Thousand Oaks, CA: Corwin Press.

Kirkpatrick, D. L. (1998). *Evaluating training programs: The four levels.* San Francisco, CA: Berrett-Koehler Publishers, Inc.

Miles, M. B. & Huberman, A. M. (1994). *Qualitative data analysis* (2nd ed.). London: Sage Publications.

Strauss, A. & Corbin, J. (1990). *Basics of qualitative research*. Newbury Park: Sage Publications.

Appendices

Appendix A: *Design Zone* Professional Development Workshop Goals

General goals for facilitators in the exhibit:

- Encourage a deeper level of engagement with the exhibit activities
- Promote and model mathematical exploration
- Help visitors to find personal relevance and construct their own meaning

Goals for workshop participants for the three workshops:

Workshop I Module A

1. Recognize mathematical and algebraic exploration in the context of the exhibits
   a. help visitors to recognize and engage in challenges
2. Have basic familiarization with three exhibits
   a. discover and understand math in each of three exhibits
   b. experience applying several facilitation support strategies
   c. greater comfort with one exhibit (more in-depth knowledge/expertise)
   d. knowledge of all support resources available to them as a facilitator
3. Recognize importance of the roles of facilitators and visitors in the cycle of facilitation
4. Feel excitement about facilitating math learning as an important and valued part of a non-formal learning experience

Workshop I Module B

1. More deeply explore ideas from Module A related to mathematical exploration and the cycle of facilitation
2. Apply ideas (with attention to building expertise on one or two exhibits) through:
   a. discussion and role playing in small groups
   b. individual observation (of video and real interactions) and reflection (of others in the role of facilitator and their own experience as facilitator when role playing)

Workshop II (first three sites only)

1. Recognize the math of measurement and data in everyday experiences
2. Recognize examples of measurement and data in the context of their own museum's exhibits
3. Learn facilitation and questioning strategies to help visitors recognize measurement and data in exhibits

.

Appendix B: *Design Zone* Professional Development Workshop Dates

Table 15. Dates of workshops by host museum and type of workshop

Host Museum	Workshop I Module A	Workshop I Module B	Workshop II
MOSI	1 on June 28, 2011	1 on June 29, 2011	1 on July 28, 2011
Pacific Science Center	1 on September 27, 2011 2 on September 28, 2011 (second for Youth Volunteers)	1 on September 27, 2011	1 on November 29, 2011
Franklin Institute	1 on January 21, 2012 1 on January 26, 2012	1 on January 26, 2012	1 on March 21, 2012

Appendix C: Surveys by Host Museums

Table 16. Surveys by host museum

Host Museum	Pre-Workshop	Post-Workshop	Online Follow-Up
MOSI	53	39	6
Pacific Science Center	81	64	33
Franklin Institute	39	58	20
Total	173	161	59

Table 17. Online survey respondents' employment status. (N = 61)

Employment Status	% of Respondents
Full-time paid	33%
Part-time paid	36%
Volunteer	31%

Appendix D: Observations and Interviews

Table 18. Observations and interviews by host museum

Host Museum	# Observations	# Interviews	# Phone Interviews	# Total Interviews
MOSI	6	1	3	4
Pacific Science Center	17	9	7	16
Franklin Institute	14	9	3	12
Total	37	19	13	32