Including Visitors who are d/Deaf or Hard of Hearing
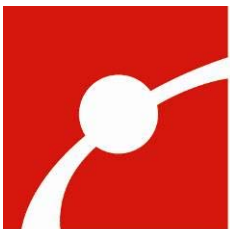## *Implications for the Museum of Science*
Research Summary Report

Report Written by Juli Goss, Stephanie Iacovelli, Elizabeth Kunz Kollmann,
& Christine Reich
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Museum of Science ®

Science Park
Boston, MA 02114-1099

NSF

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Without the help of many people, these studies and accompanying reports would not have been possible.

EXECUTIVE SUMMARY

Funded by the National Science Foundation, *The Handheld Science and Math Dictionaries for Deaf and Hard of Hearing Museum Visitors Research Project* (DRL-1008546; Signing Science) is a collaboration between the Museum of Science (MOS) and TERC, which studies how visitors who are d/Deaf or hard of hearing (DHH) integrate iPod Touch versions of the Signing Science Pictionary, Signing Science Dictionary, and Signing Math Dictionary (collectively referred to as "the App") into their museum visit. Through this project, TERC has studied the integration of the App into museum visits of both school groups and family groups. To complement this work, the MOS designed and implemented four sub-studies which investigated the Museum experience of visitors who are DHH who were *not* provided with the App during their visit.

The purpose of this report is to summarize, for the MOS, what the four sub-studies can tell us about the effectiveness of the MOS accessibility accommodations, exhibitions, and programs for visitors who are DHH and their group members. Therefore, this report compiles findings from all four sub-studies that relate to these topics. A summary of findings and potential implications include:

Accessibility Accommodations at the Museum
- The Museum should not assume that visitors who are DHH will be aware of accessibility accommodations prior to arriving that the Museum. While visitors who are DHH might have prior experience with assistive listening technologies or certain expectations of the Museum, they might or might not have looked at the website or called the Museum before visiting. Because study participants who are DHH mentioned the value of assistive listening systems or ASL interpretation for shows or live presentations in particular, it is important to provide information about the assistive listening system near the theater or stage areas. Furthermore, if ASL interpretation is offered without a visitor request, having it available for interactions with staff members, such as live presentations or for general inquiries, could be especially helpful.

Museum Exhibitions
- When navigating the Museum, visitors who are DHH were drawn to visual experiences and often made decisions based on proximity or attractive signage. However, the Museum should not shy away from hearing-related content as some also recognized learning from hearing-related components which were visually accessible and tactile. While audio phones in the Museum provide an auditory version of written text, the presence of these speakers made some visitors who are DHH feel like they were missing part of the intended content. Finally, exhibit designs that are multisensory or place the exhibit label within reach enabled communication in visitor groups comprised of individuals with a range of hearing. These designs, while useful for any group, are especially valuable for visitors who are DHH and greatly rely on being within eyesight of their group members.

Museum Programs
- Visitors, both hearing and DHH, who attended live presentations with ASL interpretation or a few interpreted terms report that these elements either did not impact or added to their experience. Furthermore, a few people who use ASL visited the Museum specifically because of the ASL-interpreted shows provided through Sign Language

Saturdays indicating that providing interpretation could be a draw for a small audience. While ASL interpretation was preferred by individuals who use ASL, several mentioned that open captioning could be a nice alternative. Finally, programs that applied the principles of universal design, such as providing physical and sensory access and multiple methods of explaining concepts, led to more positive visitor experiences than programs that did not use these principles.

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I. INTRODUCTION

Funded by the National Science Foundation, *The Handheld Science and Math Dictionaries for Deaf and Hard of Hearing Museum Visitors Research Project* (DRL-1008546; Signing Science) is a collaboration between the Museum of Science and TERC, which studies how visitors who are d/Deaf or hard of hearing (DHH[1]) integrate iPod Touch versions of the Signing Science Pictionary, Signing Science Dictionary, and Signing Math Dictionary into their museum visit.[2] Through this project, TERC has studied the integration of the App into museum visits of both school groups and family groups. To complement this work, the Museum of Science designed and implemented four sub-studies which investigated the Museum experience of visitors who are DHH who were *not* provided with the App during their visit.

The Museum of Science (MOS) sub-studies were guided by the following three questions:

1. What are the goals and motivations of visitors who are DHH for visiting the Museum of Science, and how might the App be used to facilitate accomplishment of these goals?
2. Without the presence of the App, how do visitors who are DHH interact with and learn from the Museum of Science exhibitions?
3. What are the potential uses and considerations for integrating the App into DHH visitors' experiences with Museum of Science live presentations?

The first of the four sub-studies, the Goals & Learning Study, aimed to answer questions one and two listed above. This study provided insight into how visitors who are DHH experience the Museum and utilize existing Museum of Science resources or design elements during their visit. This study examined the full Museum visit for groups who had at least one member who is DHH. The second study, Programs Online, aimed to help answer question three about DHH visitors' experiences with live presentations. This study used captioned videos of live presentations found on the Museum of Science YouTube channel. Visitor feedback was provided about the videos as well as about the content of the presentations. The third study, Sign Language Saturdays, also helped to answer question three about DHH visitors' experiences with live presentations and focused on programs which included American Sign Language (ASL) interpretation. This study solicited responses from all groups who viewed the programs, including those who identified as DHH, as well as those who did not. The last study, "Super-Cold Science" Team-Based Inquiry, also sought to answer research question three. During these shows, an animated sign language interpreter (avatar) was incorporated into some of the presentation slides and the audience was encouraged to try signing a term in ASL. Table 1 provides an overview of the alignment between research questions and Museum of Science sub-studies.

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[1] "Deaf" is used to refer to individuals who identify as a member of Deaf culture whereas the lower case "deaf" is used to describe the physical loss of hearing. "d/Deaf" is used to mean those who identify as deaf or Deaf. Unless referring to individual research participants who have described their hearing in detail, this report will use the abbreviation "DHH" to include those who identify as deaf, Deaf, or hard of hearing.

[2] Throughout this report the Signing Science Dictionary, Signing Math Dictionary, and Signing Science Pictionary will collectively be referred to as "the App."

TABLE 1. Alignment of Research Questions and Sub-Studies

Research Questions	Sub-Study Name	Focus	Methods Overview
1. What are the goals and motivations of visitors who are DHH for visiting the Museum of Science, and how might the App be used to facilitate accomplishment of these goals? 2. Without the presence of the App, how do visitors who are DHH interact with and learn from the Museum of Science exhibitions?	Goals & Learning Study	• Groups that include at least one person who is DHH • Whole museum visit	• Observations and interviews throughout visit • Videotaping in one exhibition
3. What are the potential uses and considerations for integrating the App into DHH visitors' experiences with Museum of Science live presentations?	Programs Online Study	• Individuals who are DHH • Videos of live presentations with captioning	• Online survey with embedded videos
	Sign Language Saturdays Study	• Individuals who are hearing or DHH • Live presentations in the museum with ASL interpretation	• One survey collected from each group attending the show
	"Super-Cold Science" Team-Based Inquiry Study	• Individuals who are hearing or DHH • "Super-Cold Science" live presentation that included two terms in ASL and encouraged visitors to try them.	• Observations of all visitors watching the live presentation • One survey collected from a portion of groups attending the show

The purpose of this report is to summarize, for the Museum of Science, what the four sub-studies can tell us about the effectiveness of the design of MOS exhibits, programs, and experiences for visitors who are DHH and their group members. Therefore, this report compiles findings from all four sub-studies that relate to these topics. However, it should be noted that a majority of the report focuses on findings from the Goals & Learning Study since this study followed people who are DHH and their groups throughout their entire MOS visit. Therefore, this study allowed the Research and Evaluation Department to understand how visitors who are DHH plan for their visits, navigate the Museum, use exhibits, and utilize programs. Additional data is provided from other studies. In particular, findings from the Programs Online, Sign Language Saturdays, and "Super-Cold Science" Team-Based Inquiry studies are used to illustrate how people who are DHH use programs and demonstrate how programs can be improved for individuals who are DHH.

It should be noted that data from these studies have also been presented in other reports, including a memo focusing on visitor feedback about potential use of the Signing Science Apps, a team-based inquiry report focusing on that individual sub-study, and a journal article (Goss, Kollmann, Reich, & Iacovelli, in press) analyzing the Goals & Learning Study data through the lens of multilingual museum engagement. Therefore, more can be learned about these studies through their individual reports.

As a part of the studies, a great deal was learned about the variation among individuals who are d/Deaf or hard of hearing. This information may be of great interest to staff members at the MOS who design and implement Museum experiences. However, as this information was explored in great detail as a part of the journal article, it is not included in this report. For further information about the variation among museum visitors who are d/Deaf or hard of hearing and a discussion of how the museum field can better support these audiences, please see this article (Goss, Kollmann, Reich, and Iacovelli, in press).

II. METHODS

This section describes the methods used for each of the four sub-studies, including information about the data collection instruments and protocol, as well as sample demographic information. Data analysis procedures are also summarized at the end of this section.

GOALS & LEARNING STUDY

The Goals & Learning Study took place from November 2013 to April 2014. During this study, participant groups with at least one group member who is DHH were observed throughout their Museum of Science visit. Each group was also observed in a "focus exhibition," which was either *Science in the Park* or *Take a Closer Look*. This investigation was grounded in the work of Fougeyrollas et al. (1998) and their development of the Disability Creation Process (DCP) model, which looks at the interaction between personal and environmental factors and the extent to which social participation is achieved. For the purposes of this study, environmental factors, such as exhibit design or science content, interact with personal factors, such as interest in the content or ability, to interact with the exhibit. Further information about the theoretical framework driving the Goals & Learning Study can be found in Appendix A.

Because this was an in-depth study investigating the full Museum visit, and because it sought to answer multiple questions about the Museum experience of visitors who are DHH, it was necessary to use multiple methods of data collection. The following instruments were created for the Goals & Learning Study:

1) Pre-visit questionnaire
2) Observation sheet for ethnographic notes
3) Interview after the focus exhibition
4) Interview after the full visit (which could include additional exhibitions and programs as determined by the visitor)

Participant groups who consented were also videotaped in the "focus exhibition" so that videotaped behaviors and conversations could be used for analysis in conjunction with researcher observation notes. The questionnaire and interview questions are attached as Appendix B.

A total of 15 groups with 40 individuals (at least one who is DHH per group) participated in this study. Groups were recruited for this study using the Research and Evaluation Department contact list and by advertising the study on listservs subscribed to by people who are DHH. Each group was provided with free Museum admission and parking on the day of their participation, as well as free passes to visit the Museum of Science exhibit halls on another day. Tables 2 and 3 summarize demographic information about the focus individuals and other group members that participated in the Goals & Learning Study.

TABLE 2. Goals & Learning Study Group Demographics (N=15)

Group Number	Description of Subject(s) who are DHH[3]		Description of Group Overall	Any Primary ASL Users?	Last MOS Visit
1	M, 8	Hard of Hearing *Normal hearing in left ear; almost no hearing in right ear*	Family group Includes mother and siblings (all hearing)		Within the past 3 months
2	F, 11	deaf *oral deaf; wears hearing aids and FM every day*	Family group Includes mother, sister, and friend (all hearing)		1-2 years ago
3	M, 30 F, 32	Deaf *Profoundly Deaf since birth* Hard of Hearing *Severe-profound, both ears*	Adult-only group Includes friend (hearing)	Yes	3-6 months ago
4	M, 12	deaf *deaf since birth with cochlear implant*	Family group Includes mother (hearing)		3-6 months ago
5	F, 36 F, 50 M, 49	Deaf Deaf Deaf	Adult-only group	Yes	1-2 years ago More than 10 years ago More than 10 years ago
6	F, 47	Hard of Hearing *Severe to profound sensorineural hearing loss*	Adult-only group Includes husband (hearing)		1-2 years ago
7	M, 10	deaf *profound (90db) hearing loss with cochlear implant*	Family group Includes mother and another parent and child friend (all hearing)	Yes	2-5 years ago
8	F, 8 F, 8	deaf *deaf with cochlear implant* Hard of Hearing *Wears cochlear implant*	Family group Includes mothers of both focus subjects and one sibling (all hearing).		1-2 years ago 6 months to within the last year
9	F, 18	deaf *Lost hearing post-speech; Legally deaf; Bilateral hearing loss; Hearing aid/cochlear implant*	Adult-only group Includes friend (hearing)		More than 10 years ago
10	F, 55	deaf *deaf but hearing with cochlear implants*	Adult-only group		3-6 months ago
11	F, 80	Hard of Hearing *Moderate/severe. Worn hearing aids for 30 years*	Adult-only group		Within the past 3 months
12	F, 24	Deaf *Profound-Deaf*	Adult-only group Includes friend (hearing)	Yes	6 months to within the last year
13	F, 33	Deaf *Profound/severe deafness*	Adult-only group	Yes	Never
14	F, 36	Deaf	Family group Includes fiancé and two children (hearing)	Yes	5-10 years ago
15	F, 69	deaf *deaf without technology*	Adult-only group Includes husband (hearing)		2-5 years ago

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[3] Includes sex, age, and description of hearing. Italicized text is additional description provided by the subject him or herself.

TABLE 3. Goals & Learning Study Participants' Reasons for Typically Visiting the Museum of Science (N=19)

When you Visit the Museum of Science, Why Do you Decide to Visit?	Number of Responses
To spend time together as a group/family	11
Educational experience for group members/children	10
For fun/entertainment for group members/children	7
To bring out of town friends/family	6
To see a specific exhibit, program, or show	5
Educational experience for myself	3
For fun/entertainment for myself	3
Had a coupon/free pass	3
Something to do while visiting Boston	1
Something to do in poor weather	1

Note. This table includes responses from 19 individuals (one survey per adult who is DHH and one survey per parent of a minor who is DHH). Individuals were asked to select up to two reasons and many selected more than two.

PROGRAMS ONLINE STUDY

The Programs Online Study asked people who are DHH to provide feedback on captioned videos of Museum of Science live presentations. For this study, educators on the Museum of Science Current Science & Technology team recorded four of their shows: "Genetically Modified Foods," "Lightning!," "Live Animal: Porcupine," and "Hurricanes." The videos of these shows were then captioned and added to the Museum of Science YouTube channel.[4]

For the Programs Online Study, the Research and Evaluation team created four online surveys, one for each live presentation topic. The captioned YouTube videos were embedded into each of the online surveys so that participants could watch the presentation and take the online survey remotely. The survey asked participants demographic questions, as well as questions about the video they watched.

The survey instrument for the Programs Online Study can be found in Appendix C.

Participants for this study were selected through solicitations on listservs subscribed to by people who are DHH and by using the Research and Evaluation contact list. Participants were offered free passes to visit the Museum of Science exhibit halls as an incentive to participate. In May 2014, the survey link was sent to 12 people who are DHH who agreed to take part in the study. Three groups received a link to the "Genetically Modified Foods" presentation, three to the "Lightning!" show, three to the "Live Animal: Porcupine" show, and three to "Hurricanes." A total of seven[5] people who are DHH of the 12 invited completed the online survey.

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[4] At the time of this report, these videos were not public, but now can be accessed through the following links: "Genetically Modified Foods" (http://youtu.be/ZUflfYr7hWQ), "Lightning!" (http://youtu.be/OoKbd4mN1yI), "Porcupine" (http://youtu.be/fHEZHwwrFlA), and "Hurricanes" (http://youtu.be/PBXA7R9vEe8)

[5] One participant who is DHH was a minor, and completed the survey with her mother. Therefore, the sample actually included eight people.

Demographic information gathered from the individuals who filled out the online survey is as follows:

- Respondent 1 was a group that consisted of a female under 8 years old who described her hearing level as "mod-severe hearing bilateral loss" and her mother, who was hearing. Neither of them uses ASL. They had last visited the Museum of Science 1-2 years ago.
- Respondent 2 was a 71-year-old male who described his hearing as "CI [cochlear implant] right ear, hearing aid left ear." He does not use ASL.
- Respondent 3 was a 37-year-old female who is "deaf" and is an intermediate ASL user. It had been more than 10 years since she last visited the Museum of Science.
- Respondent 4 was a 28-year-old male who is "profoundly deaf, wear[s] cochlear implant" and is a novice ASL user. He had last visited the Museum of Science 1-2 years ago.
- Respondent 5 was a 40-year-old male who was "profound deaf" and considered himself to be an advanced ASL user. He last visited the Museum of Science 5-10 years ago.
- Respondent 6 was a 56-year-old female who described her hearing as "moderate loss, wear two hearing aids." She does not know ASL, and she had visited the Museum recently, 3-6 months before taking the survey.
- Respondent 7 was a 57-year-old female who describes herself as having "severe/profound loss with aid in R ear, very new (<1 week) cochlear implant user L ear." She does not know ASL, and she had last visited the Museum within the past three months.

SIGN LANGUAGE SATURDAYS STUDY

The Sign Language Saturdays events took place on five sequential Saturdays in May and June 2014. During these days, four shows at the Museum of Science were interpreted in ASL: 1) a "Live Animal Story Time" show for preschoolers, 2) a "Live Animal" or "Super-Cold Science" show, 3) a "Lightning!" show, and 4) a Current Science & Technology presentation. These events were advertised on DHH listservs and the Museum of Science Facebook page. Additionally, a flier was sent out to Museum of Science Research and Evaluation Department contacts who are DHH. Attendees of these events were not provided any free admission or parking passes; however, the shows interpreted in ASL were included free of charge with the purchase of general exhibit halls admission.

Data were collected at all four ASL-interpreted shows on all five Saturdays. One survey was given to a single adult member of every group who entered the theater areas prior to the ASL interpreted shows (regardless of the visitors' hearing levels). The survey included questions about visitor demographics, including if anyone in the group identified as being DHH or using ASL, as well as questions about whether the presentation was easy to understand, interesting, and what they learned from it. These surveys also asked visitors if and how they were impacted by the ASL interpretation of the show they watched and whether they visited the Museum because the shows would be interpreted. Over the five Saturdays, surveys were collected from a total of 315 groups, 13 of which included a group member who identified as being DHH.

The Sign Language Saturdays Study survey can be found in Appendix D.

The Sign Language Saturdays Study data indicated that most visitors who filled out the survey were 35-44 years old (34%), although there were also many respondents who were 30-34 years of age (19%), and 44-54 years of age (16%). Many of the survey respondents reported that they had visited the Museum of Science within the past 3 months (23%) or had never visited before (25%). Most groups were comprised of adults and children (77%), although adult-only groups (20%) and lone visitors (3%) also responded to the survey. These data are summarized in Table 4.

TABLE 4. Sign Language Saturdays Study Respondent Demographics (N=315)

	Number of Survey Respondents	Percentage of Survey Respondents
Age		
18-24	34	11%
25-29	20	6%
30-34	59	19%
35-44	107	34%
45-54	50	16%
55-64	29	9%
65+	6	2%
No response	9	3%
Sex		
Male	148	47%
Female	162	51%
No response	5	2%
Last visit to MOS		
Within the last three months	72	23%
3-6 months ago	34	11%
6 months to within a year ago	15	5%
1-2 years ago	28	9%
2-5 years ago	27	8%
5-10 years ago	26	8%
More than 10 years ago	25	8%
Never	79	25%
No response	9	3%
Group Type		
Adult and children	239	77%
Adults only	64	20%
Visiting alone	10	3%

The Sign Language Saturdays Study surveys also asked visitors whether anyone in their group is DHH and if they use ASL. About 4% of groups (13 of 315) included an individual who identified as being DHH and 4% (14 of 315) also said that an individual in the group use ASL (Table 5). Although it may appear as though all of the respondents who are DHH use ASL because the percentages are the same, in actuality, only nine of the 13 groups who had an individual who is DHH included someone who uses ASL. Five of the 14 groups who included ASL users did not include anyone who identified as being DHH. Although the survey did not ask visitors why they use ASL, one of these five hearing visitors wrote in the comments that she is an ASL interpreter. It is possible that some of the other groups with hearing visitors who use

ASL were also interpreters, or that they use ASL to communicate with a friend or family member who did not come to the Museum with them.

TABLE 5. Sign Language Saturdays Study Respondent Hearing Level and ASL Use (N=315)

		Number of Survey Respondents	Percentage of Survey Respondents
Group Members' Hearing Level	Nobody in the group is d/Deaf/hard of hearing	301	96%
	Somebody in the group is d/Deaf/hard of hearing	13	4%
	No response	1	<1%
Group Members' ASL Use	Nobody in the group uses ASL	300	96%
	Somebody in the group uses ASL	14	4%

"SUPER-COLD SCIENCE" TEAM-BASED INQUIRY STUDY

A Team-Based Inquiry (TBI) study was performed after adding ASL terms to a "Super-Cold Science" live presentation. TBI is a method for teams to conduct small-scale, manageable, and flexible evaluation with the help of an evaluator and is intended to help teams systematically gather data and use that data to improve their own practice (Pattison, Cohn, & Kollmann, 2014).

For this TBI study, two members of the live presentations team modified the "Super-Cold Science" show to include a selection of vocabulary terms provided by an animated ASL interpreter (avatar) on one of the presentation's slides. Terms were selected based on the vocabulary often used in the "Super-Cold Science" show, existing animations of terms that were available in the App, and terms that were easy-to-learn pictograms (rather than more complex finger spellings). Team members also chose signs that represented the science term in a visually correct manner. The ASL terms added to these shows were "molecule," "expand," and "contract." Along with being signed by an animation on the slide, these terms were verbalized by the educator, spelled out in text on the slide, and accompanied with other visuals.

Data were collected for this study from December 2013 to April 2014. Data collection included both observations of visitors watching the show and surveys. Visitors were chosen at random and asked if they would be willing to fill out a survey that would help improve Museum programming. The survey included demographic questions, as well as questions about how visitors felt about the show and the presence of the ASL animation. A total of 56 responses were collected from visitors with and without disabilities.

For observations, visitor reactions to the show were tallied in an observation worksheet that identified the percentage of student and adult audience members that carried out certain behaviors, such as raising a hand, watching the ASL animation, and practicing the sign. Additionally, an excitement/enthusiasm rating was given for each sub-segment of the show.

The survey and observation instruments can be found in Appendix E.

Of the 56 groups who took a survey after the "Super-Cold Science" show, 33 (59%) groups were family groups, 14 (25%) were adult-only groups, and six (11%) were visiting with school groups (Table 6). Visitors who completed a survey ranged from under 18 years old to over 55 years old. Visitors were most commonly 30-39 years old (18 visitors; 32%), 18-29 years old (11 visitors; 20%); and over 55 years old (11 visitors; 20%). See Table 6 for a complete summary of participant ages.

TABLE 6. Super-Cold Science Survey Respondent Demographics (N=56)

	Number of Survey Respondents	Percentage of Survey Respondents
Age		
Under 18	4	7%
18-29	11	20%
30-39	18	32%
40-49	7	13%
50-54	3	5%
55+	11	20%
No response	2	4%
Group Type		
Adult and children	33	59%
Adults only	14	25%
School group	6	11%
No response	3	5%

Five people (9%) who took a survey identified as having a temporary or permanent disability. These visitors were also asked to describe their disability. Four identified as having a mobility disability, one reported that s/he has a learning disability, and one said s/he has a visual disability.[6]

DATA ANALYSIS

Data collected through these studies were both qualitative and quantitative in nature. The quantitative data collected were analyzed using descriptive statistics such as counts, and percentages when the sample was greater than 40 groups or individuals.

Qualitative data were analyzed using both inductive and deductive coding methods. Inductive coding analysis involves "immersion in the details and specifics of data to discover important patterns, themes, and interrelationships" (Patton, 2002) and was used to analyze open-ended questions on the Programs Online, Sign Language Saturdays, and "Super-Cold Science" TBI studies surveys, as well as a portion of the Goals & Learning Study data analyzed for this report. Deductive coding wherein themes are derived from the theoretical framework (Crabtree &

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[6] Visitors could check off all boxes that applied. Therefore, totals do not add up to 5.

Miller, 1999) was also used for the Goals & Learning Study data. This allowed researchers to investigate personal factors, environmental factors, and evidence of social participation. The majority of the Goals & Learning Study data were analyzed using NVivo, software designed to aid qualitative analysis.

III. FINDINGS

Data from all four Signing Science sub-studies are compiled below to illustrate findings related to different aspects of the Museum of Science experience. The section is organized as follows:

1. Findings related to accessibility accommodations at the Museum;
2. Findings related to the design of Museum exhibits; and
3. Findings related to the development of Museum programs.

1. FINDINGS RELATED TO ACCESSIBILITY ACCOMMODATIONS AT THE MUSEUM

The Museum of Science currently provides two kinds of accessibility accommodations that are most applicable to visitors who are DHH: An assistive listening system and American Sign Language (ASL) interpretation.

An assistive listening system that "amplifies the presentations at all of the Museum's stages and theaters" has been available at the Museum of Science for some time but was updated and expanded to additional locations in the exhibit halls in Summer 2014 (www.mos.org/accessibility). Data collection for the Signing Science sub-studies took place prior to this installation. However, data were collected regarding how visitors find out about the assistive listening system both before their visit and once they arrive at the Museum. Insights gained from these visitors are shared here as they might be helpful to the implementation of the new system.

Providing ASL interpretation is something the Museum of Science offers in order to support visitors who use ASL and because providing effective communication to visitors is legally required for museums that receive federal funding under Section 504 of the Rehabilitation Act. The Museum of Science offers ASL interpretation when it is requested at least two weeks in advance of a visit. As a part the Signing Science sub-studies, ASL was provided for groups who requested an interpreter for the Goals & Learning Study, as well as during live presentations that were a part of Sign Language Saturdays. Insights gained from these studies about how and when visitors request ASL are discussed below.

Data in this section are intended to provide insight about how visitors who are DHH prepare for their visits to the Museum. This includes whether and how visitors who are DHH seek out information on hearing-related accommodations. Data from the Goals & Learning Study suggest the following findings:

1.1   Visitors who are DHH are not always aware of accessibility accommodations prior to arriving at the Museum.
1.2   Visitors who are DHH often have prior experience with assistive listening technologies and report that they would look for information about any system at the theater or stage areas.

1.3 Visitors who are DHH and use ASL report that ASL interpreters are most helpful during interactions with Museum staff members or while attending a live presentation.

1.1 Visitors who are DHH are not always aware of accessibility accommodations prior to arriving at the Museum.

In order to understand how the Museum of Science supports visitors who are DHH and their goals for a successful visit, 14 groups who participated in the Goals & Learning Study were asked how they plan for a typical visit to the Museum of Science or visits to museums in general. This section examines these responses and finds that visitors who are DHH represent a range in their amount of prior planning and might not always be aware of the accessibility accommodations available prior to visiting.

Seven groups mentioned researching both the Museum's educational offerings and hearing-related accommodations. Conversely, three groups said they usually did not plan anything before arriving at the Museum and four groups mentioned planning only related to their interests. These seven groups included visitors who might be interested in ASL interpretation and/or assistive listening devices, but would not be aware of them prior to visiting. This is summarized in Table 7, along with participant quotes provided below.

TABLE 7. Study Group Planning Practices and Awareness of Accessibility Accommodations

Typical Planning Prior to Museum Visits	Number of Study Groups	Awareness of Accessibility Accommodations Prior to Museum Visits
Plan based on interests AND hearing-related accommodations	7	Potentially aware of accessibility accommodations before visiting (n=7)
Plan based on interests and schedule only	4	Not likely aware of accessibility accommodations before visiting (n=7)
Group does not plan before a museum visit	3	

Of the seven groups who would not be aware of accessibility accommodations prior to visiting, three reported that they do not do any prior planning before visiting museums. One visitor who had recently moved to the area and had never been to the Museum of Science said,

> *I've found that different museums—art museums or science museums, you know, I usually don't look at the site, you know, with the aquarium I might look up a little about that and see what kind of animals they have but for this type of museum it's really hard to, you know, look at different exhibits on the internet and decide what you want to go to beforehand I kinda just wanted to be surprised as I came in and just look around.*
> [Female, 33, Deaf]

Four groups mentioned planning for a typical museum visit based on their interests and schedule. For example, one 47-year-old woman who is hard of hearing said, "I think a lot of times we'll

plan our visit around an OMNI movie. So we'll look and see what's playing and what the schedule is." When asked if she looks up anything beforehand about a museum, one mother of a 10-year-old boy using cochlear implants said, "Not really. How to get here basically." One visitor mentioned that she would like the website to offer guides or resources that she could use as a part of her planning process to help support her daughter's learning in the Museum.

> **Mother of 11-year-old girl using hearing aids and an FM system at school:**
> *Sometimes I wish the museum website could have a pre-visit preparation area... For example, if I have a goal for today. Let's go to see the reproductive system. Then I'd like to have a fun activity or questionnaire to get the kids mentally prepared. Because this is a huge vast place. ... I think the pre-visit preparation would be really helpful. Like the hunting map.*
> **Researcher:** *Is that something that you look for before you go to museums?*
> **Mother:** *I love to have that. You know for a new exhibition, to maximize the output of visiting the museum, the education part. Sometimes I try to prepare that, but without seeing that museum or without knowing that museum really well, or the exhibition, it's hard to get the questions prepared. And also, as a parent, it's hard to do it in a fun way. And also, it's hard to present something to your own kids. And they try to ignore you.*
> **Researcher:** *When you're looking for information before you visit a museum, is there anything specific that you look for related to your daughter's hearing? Do you look for places that use the FM system like you mentioned? Or is it not something that you think about for your museum visit?*
> **Mother:** *No. That's not something that I would think about.*

The remaining seven groups reported that their planning included researching both museum offerings and hearing-related accommodations. The majority of these visitors said they would consult the website, and a couple said they would consider calling ahead. Using the website, some visitors browse the accessibility information.

> **Female, 18, uses hearing aid and cochlear implant:** *I go on the website and see what they have. I don't like to walk in being like, I have no idea what there is. I like being able to look at the schedule and know that ok, this is happening at 3:30.*
> **Researcher:** *Yeah, you knew that [there was a show today] even before we met up. Do you look for anything specific? Like resources related to your hearing? Or is it just general interest?*
> **Female:** *I usually do general stuff, but I also see what all the different tabs are on the website and sometimes they say that there's certain accessibility things. So I'll check out the accessibility things. Like exhibits. If there's another exhibit that costs extra money, if I'm not gonna be able to hear it, I'll decide against it.*

Other visitors mentioned using the website to plan their visit and look up information about special shows or exhibitions that were at the Museum, such as OMNI, Planetarium, or traveling exhibitions. In these cases, visitors were interested in knowing which shows were available and when they were being offered. Some groups even said that they planned their Museum visit around a show they wanted to see. This was true of one MOS member who said, "We come for the special exhibits, or when there's a new exhibit that comes through, we come in for that. Once

in a while we'll come in for an IMAX show" [Female, 55, uses bilateral cochlear implants]. Another woman said that she would look at the upcoming shows to decide if she would need to request an interpreter. She said,

> *My tendency is to look at the website. See what's happening or what's going on at the museum at that time. If there was a presentation or show, I know that I would need to contact the museum and request an interpreter for that.* [Female, 36, Deaf]

As described above, groups participating in the Goals & Learning Study were split in their pre-visit preparation. While half of the groups either did no planning or made general plans, the other half sought out information based on their interests and hearing-related needs. Therefore, based on this study, visitors who are DHH may enter the Museum of Science unaware of the availability of accessibility accommodations.

1.2 Visitors who are DHH often have prior experience with assistive listening technologies and report that they would look for information about any system at the theater or stage areas.

Nine of the 15 groups who took part in the Goals & Learning Study included an individual who might use an assistive listening system. This included five groups with someone using cochlear implants (CIs), two groups with an individual using hearing aids, one group with an individual using one hearing aid and one CI, and one individual who does not use personal assistive technology. Although this study cannot report on whether the new assistive listening system will be used by these participants, this section compiles data regarding how visitors talked about potential use of an assistive listening system in the Museum, whether they ever use assistive listening systems in other environments, and where they would look to find out about it at the Museum.

When asked about a potential assistive listening system, several groups mentioned that they use a system at school or in other environments. Two groups mentioned that they would prefer a system where they could use the telecoil in their hearing aids (also referred to as "looping"). For example, one woman provided her opinion of current assistive technology:

> **Female, 80, worn hearing aids for 30 years:** *Getting the assistive listening devices. I'm not terribly keen on that. I'd much rather the money be put into looping. If you looped each area where you have exhibits, it would be so much more helpful for people who are hard of hearing. And you would not have to maintain all of the devices. Do you know what an induction loop is?*
> **Researcher:** *I think so, but can you explain what you mean by that?*
> **Female:** *If you take an auditorium and you lay a loop around the floor and connect it to your FM system, then anyone with a hearing aid that has a telecoil in it can just flip a switch, press something on their remote device and everything, the sound comes right into the ear. You don't have to take your hearing aids off like you would for an assistive listening device. If you have the FM system, then you have to wear headphones or earbuds and this way all you have to do is just listen with your hearing aids.*

Another group that included a 12-year-old boy with CIs and his mother stated that a looped system would be enjoyable, but would not determine whether or not they visited the Museum.

> **Mother of 12-year-old boy with CIs:** *You could have this room looped.…if he knew this was looped, he could switch it on and he would hear his voice louder.*
> **Researcher:** *Is that something that you look for before going to a space?*
> **Mother:** *…for us, it wouldn't make a difference. It wouldn't be—[it wouldn't] decide whether or not we go. But it would make the experience more enjoyable. But it wouldn't be a deal breaker for us. But it might be for some people.*

While researchers did not advocate for one system over another, groups were asked how they would find out about available systems. As stated previously, although some groups may find out about an assistive listening system ahead of time, others who would be interested in using the system may not know about it before arriving at the Museum. In this instance, the mother of the 12-year-old boy with CIs talked about the importance of having clear signage at the stages and theaters alerting people about the presence of the assistive listening system. She said that this signage should make visitors aware that there is an assistive listening system available and should also provide instructions on what the visitor must do to use the system. She said,

> *… I would want something here [at the stage]. Just something like when you walk in that says this is looped or whatever. And hearing aid users, turn on your t-coil. Or whatever the instructions are because some of them are a little bit different depending on what you need to do.* [Mother of 12-year-old boy with CIs]

Another visitor who is a Museum member reported that she has had difficulty on previous visits obtaining information about assistive listening accommodations. Therefore, this visitor took the observing researcher through her process of learning about and obtaining the materials for the assistive listening system in the OMNI Theater. While this system has been updated and some changes have been made since the data collection period, the Museum can still learn about how to improve the process of giving the assistive listening device to visitors by looking at this example. This visitor went to three areas in the Museum and talked with two staff members before she was able to successfully retrieve the assistive listening device. The following passage is an excerpt from the researcher's debrief and reflection describing this visitor's process:

> **[Researcher reflection of adult-only group. Female, 55, uses bilateral cochlear implants]**
> A 55-year-old woman with CIs wanted to seek out an assistive listening device for an OMNI show. She grabbed a Your Visit Today map and noticed that select OMNI shows had assistive listening options. Next, we went to the box office.... She went up to the first visitor services representative and asked… which shows offered the assistive listening option. The staff member called someone to get this information for her. She then wanted to get to the show early to pick up the required technology for the assistive listening system, but we arrived too early for any staff member to be outside the theater. Because of this, she went to the Info Desk to ask them where she would pick up the device. The staff member at the Info Desk told her the general procedure for getting the device, and she asked him which type of device it was and wanted more information. He called someone to find out the details for her. She eventually got all of the information and

materials needed to see the show. The main complaint she had about this process was that it took her a long time to finally get all of the answers she needed to be able to see the show and access its content. She went to three different places and talked to two staff members before she felt like she had the information she needed. She said that if she had her two young kids with her she would probably not go through all of that effort because of their short attention spans.

Data collected in the Goals & Learning Study suggest that visitors who are DHH have prior knowledge and opinions regarding assistive technology. These visitors would benefit from additional signage near theater or stage areas indicating what accessibility technologies may be available to them and if there is a process to acquire these items.

1.3 Visitors who are DHH and use ASL report that ASL interpreters are most helpful during interactions with Museum staff members or while attending a live presentation.

Six groups who participated in the Goals & Learning Study consisted of at least one person who primarily uses ASL to communicate. All six of these groups said that they would not request an ASL interpreter for a typical Museum visit. However, two groups identified instances when they would find it helpful to have an ASL interpreter. These groups said that they would request an interpreter when visiting as part of a school group to interact with Museum staff members or if they were attending a live presentation or show. These two groups' thoughts and experiences about requesting an ASL interpreter are detailed below.

One group of Deaf adults who have professional expertise in the field of Deaf education and work at a school for the Deaf said that having an ASL interpreter present when they come with school groups allows for more effective communication with Museum staff. As one woman in this group noted,

> *It's interesting, looking back, when I come here for school field trips, we always request a sign language interpreter to come with us which is great. But you know, my family, if I came with my daughter and my husband I definitely wouldn't bring an interpreter.* [Female, 36, Deaf]

When she was asked why it is helpful to have an interpreter with a school group she responded, "to communicate [with staff members] if we have to ask questions."

Other members of this group also felt it was beneficial to have ASL interpreters for live presentations. One woman talked about a challenging experience at a "Lightning!" presentation when she did not request an interpreter.

> *One time I came here, I had my son with me, they had some kind of the electricity show… And my son said, well, we need an interpreter. And I said, don't worry about it. So we sat and watched it. And we missed a lot of information. It would have been nice to have an interpreter there for the show. So my son was actually right in that respect.* [Female, 50, Deaf]

A different group, consisting of a woman who is Deaf and her hearing family, echoed this sentiment about the benefit of ASL interpretation during shows. She talked about her family's recent trip to Universal Studios, where they booked an interpreter to make sure "the trip was worth it and that [she] understood everything" [Female, 36, Deaf]. Her daughter added,

> *It's more…for shows… that's what she would book an interpreter for, not just looking around and reading… but for an actual show like Universal had… things like that- they started talking and there wasn't any… captions so she couldn't understand it.* [Female, 15, hearing]

These groups' experiences at the Museum and at other attractions, like Universal Studios, provide insight into the types of Museum experiences that would benefit from having ASL interpretation, such as live presentations and interactions with staff members.

2. FINDINGS RELATED TO THE DESIGN OF MUSEUM EXHIBITIONS

The Goals & Learning Study collected data from 15 visitor groups, each which included at least one person who identifies as d/Deaf or hard of hearing. By collecting data from visitors with a range of hearing throughout their entire visit, this study examined ways in which exhibitions facilitated visitors' learning and engagement. Data presented in this section are intended to inform the future development of Museum of Science exhibits and included the following findings:

2.1 Visitors who are DHH are drawn to visual experiences, but they do not rely solely on hearing-related factors when making decisions about which exhibition to visit.

2.2 The presence of audio phones or uncaptioned videos make some visitors who are DHH feel like they are missing part of the intended content.

2.3 Multisensory exhibits and exhibit labels located within reach or where separate exhibit interactions occur foster social interaction between visitors with a range of hearing.

2.1 Visitors who are DHH are drawn to visual experiences, but they do not rely solely on hearing-related factors when making decisions about which exhibition to visit.

Visitors participating in the Goals & Learning Study were asked to visit one specific exhibition, then permitted to visit any other exhibits and programs they wished. This finding compiles data related to which exhibitions or individual exhibit components were visited and why visitors reported enjoying or disliking them.

When asked why they decided to go to various exhibitions, visitors mentioned being drawn to visual experiences, with one man who is Deaf commenting, "Deaf people rely on their eyes obviously." Additionally, several individuals who are hard of hearing mentioned their likelihood to focus on written or visual experiences, especially in areas where there is more background noise. One woman who is hard of hearing said, "Visual things for me are always better. Reading things."

Although visitors recognized an aptitude for visual exhibits, hearing-related content was not necessarily a detractor. For example, visitors to *Take a Closer Look* often used the full exhibition, including the "Hear" area. In fact, several individuals commented that they found a few of the "Hear" components interesting because the components allowed them to learn more about hearing in general. One group discussed what they thought of the "Seeing Sound Waves" component (pictured below):

> **Female, 50, Deaf:** *Oh this* ["Seeing Sound Waves" component] *is cool. Nice and visual as well. Deaf people like things that are more visual… this one is nice for Deaf people. Very Deaf-friendly environment. I feel like Deaf people would actually go and check this one out.* [She brings her husband over to use it.] *I don't think a hearing person would go up to that and put their hands on it. But when you put your hand on it there, you can definitely feel it. A hearing person would sit and listen to the speaker and get something like that…*
> **Male, 49, Deaf:** *I wonder. Does this correspond to like, to the cochlea and how the hair cells in the cochlea move? Different frequencies respond to different hair cells?*

Figure 1. "Seeing Sound Waves" component in *Take a Closer Look*

Another participant discussed her feeling about the "Listen Up!" component which asks visitors to sit across from one another and guess the direction of a sound above:

> *It's funny because with the cochlear implant especially, you can't tell direction. You can't tell any direction so it was kind of cool seeing where I thought it was from and where it actually was from because half the time it was opposite sides. So it was kind of cool seeing how the hearing aids worked to deflect where the sound comes from. So in a way, you're actually learning about your hearing.* [Female, age 18, Lost hearing post-speech; Legally deaf; Bilateral hearing loss; Hearing aid/cochlear implant]

As visitors navigated the Museum overall and decided what to visit, it was found that they did not rely solely on hearing-related reasons when choosing their path. Visitor groups decided to go to exhibitions because they previously knew of a specific exhibit, because they happened to be nearby, or because they were attracted by the signage. Examples of this are provided in Table 8.

TABLE 8. Reasons for Visiting Exhibitions

Reason for Visiting	Examples
Group wants to see a specific exhibit	• Group wants to see the *Hall of Human Life* because it is new • Group loves the *Dinosaurs* and always visits the exhibition
Group happens to be nearby	• Group sees *Cahners ComputerPlace* as they are leaving *WeatherWise* • Group looks at the gears while they wait for other group members in the restroom
Group is attracted by the signage	• Group sees *Our Global Kitchen* label and decides to visit because they like food

Visitors' goals were intertwined with these reasons for visiting exhibitions, in that some groups who had planned to see a certain exhibit found ways to include additional Museum offerings. For example, several groups explored exhibitions while waiting to view a scheduled live presentation. Additionally, groups who planned which exhibition they wanted to see often stopped by additional experiences along the way. One example of this is a family group who had a membership and were very familiar with the Museum of Science. An example of how visitors who are DHH might make additional stops while going to a particular exhibition is seen in the following excerpt from researcher field notes:

> **[Researcher reflection of family group. Includes Male, 8, with no hearing in left ear, visiting with hearing family members including mother, sister (age 11), and brother (age 5).]**
> After leaving *Science in the Park*, the group wants to visit *Hall of Human Life (HHL)* because they had heard about it on the radio. They stop at the Archimedes screw located on the aisle-side of *Investigate*. The group turns the screw a few times together while their mother explains how it works. The focus subject (male, age 8) comments that the liquid looks like grape juice and the group moves on to *HHL*. After they leave *HHL*, the children want to see dinosaurs. On the way there, mom says *"wanna stand in two cities at once?"* and they take a picture on the bridge. Walking into the Blue wing, mom says *"wanna look at illusions on the way?"* The group goes along the further wall of Level 2 to look at the illusions on their way to the escalator. At the bottom of the Lower Level escalator, the children run ahead to the *Dinosaur* exhibition and mom calls them back to look at an interpretation cart in the hallway outside *Take a Closer Look*.

Although visitors' reasons for visiting particular exhibitions did not rely on hearing-related factors, these factors did play a role in the length of time the group spent in the exhibition. Several groups commented that *Science in the Park* was crowded and that the loudness impacted their decision to leave. One mother of a 10-year-old boy with CIs said, "the only hearing thing is

that it's super noisy in there and he gets super anxious." Additionally, one 8-year-old girl with bilateral cochlear implants had a negative interaction with the drums in a diorama in *Our Global Kitchen*. Upon hearing the drums, she put her hands over her ears and left the area. In contrast to these negative examples, several groups were observed spending longer amounts of time in exhibitions that were quiet, such as *WeatherWise* and *Cahners ComputerPlace*.

2.2 The presence of audio phones or uncaptioned videos made some visitors who are DHH feel like they were missing part of the intended content.

The Museum of Science provides audio labels at all exhibits through the presence of an audio phone or hearphone located on the far left side of the component with a one-inch square button to begin the recording. This finding compiles data related to how these audio phones were used in exhibitions, as well as visitors' perceptions of their content.

Thirteen of the 15 visitor groups participating in the Goals & Learning Study included an individual who picked up the audio phone and attempted to use it. However, there were a range of experiences with the audio phones. Only one of the individuals who is Deaf and primarily uses ASL attempted to use the audio phone. The rest of the individuals were either hard of hearing or hearing. The majority of those who are hard of hearing had difficulty using the audio phone and said they were confused about what information it provided. This made several of them feel as though they were missing part of the exhibit experience. For example, two groups asked for scripts of the audio phone while a third group commented that they did not know if the phone was broken. The process of encountering the audio phone and resulting sense of confusion is best summarized through the following visitor quote and video transcript from an experience in *Take a Closer Look*:

> *So immediately I'm confused by this* [Points to audio phone]. *Because I see a speaker, but this doesn't say I need to use the speaker. … I look at this and I think, well, am I missing the big science picture because I'm not able to hear….And I can tell you right now, I won't be able to [hear the audio phone]. Well, let me see.* [She puts audio phone to ear] *Oh, I can hear this okay.* [She sits down while still holding the phone up to her ear and looking at the text label.] *Oh, so this [audio] is just giving me more information about time.* [Looks at the phone.] *Does that just turn off on its own? I don't know.* [Puts phone down.] *Okay, well, when I listen to something like this, it's a lot of work. Yes, I can hear it, but I'm focusing more on 'am I hearing the words' than what she's actually saying. And because I have no preparation for what information is going to come out of here, I don't know whether it's worth the work. So at first, it's just more directions. It doesn't say, for additional directions, listen here. And I would know whether I could ignore that or not and not have to deal with the stress of 'am I listening.' And it went from directions to information that is actually here and I could have read it instead of being stressed out by listening. So it doesn't tell me what this is for. So I'm immediately thinking, well, I just missed a lot, didn't I. And I don't think I did miss anything because I think I can read this.* [Female, age 55, gradual hearing loss since teens, uses bilateral CIs]

Although this participant commented that the audio phone was replicating the written content at the end of using this exhibit component, she did not assume that this was the case at other exhibit components. At another component she said, "If I have an unanswered question, I assume this [audio phone] is going to give me more information so it's worth it for me to struggle with."

Visitors mentioned a similar sense of confusion when they encountered a video in HHL that did not have captioning. In this case, there were no captions because the video did not have any accompanying audio. However, two visitor groups who encountered this video assumed it contained audio and commented that they wished there had been captions. Again, this illustrates that visitors who are DHH may feel that they are missing out on content if audio labels and videos are not labelled or captioned.

2.3 Exhibits that provide multisensory materials, convey instructions visually, and position exhibit labels to facilitate eye contact fostered social interaction between visitors with a range of hearing.

Groups that participated in the Goals & Learning Study were most often comprised of individuals with a range of language and communication needs (i.e. groups included both individuals who are hearing and DHH). When using exhibits, these groups would often position themselves so that the hearing individual was on a certain side of their hard of hearing friend. Additionally, all visitors (despite hearing level) at some point turned or faced one another so that their fellow group member was within eyesight. This helped visitors who were lip reading as well as those using ASL. Several exhibit design elements made it easier for visitors with a range of hearing to interact with one another because the exhibit supported these behaviors as well as other simultaneous forms of communication such as gesturing, pointing, and face-to-face communication. This finding compiles data related to how visitors used Museum exhibitions as a social group with various hearing needs and examines designs that facilitated social interactions.

Multisensory and multimodal exhibits fostered social interaction because visitors could use the exhibit materials to communicate. One example of this was the "Sense for Scents" component in *Take a Closer Look* as shown in Figure 2.

Figure 2. "Sense for Scents" component in *Take a Closer Look*

All groups who visited *Take a Closer Look* used "Sense for Scents" and were observed guessing the scents, sometimes competing with other group members to see who could guess correctly. Visitors used the stations both separately and together. As a part of their interactions, visitors pointed to the label to direct a group member to a certain instruction and used the discs which indicated what they thought the scents were to keep track of their guesses. Several individuals mentioned this component in their follow-up interview saying that it was one of their favorite components and many remembered a smell that they had gotten wrong or right. The following is an excerpt of one group's conversation in ASL while using this exhibit and corresponding follow-up interview responses:

> **Female, 24, Deaf:** D*o you want to smell it first? Go right ahead.*
> **Female, 27, Hearing:** *Wait a second. Grease? What is that?* [Lifts tab] *A rose.*
> **F, 24:** *Very nice*
> [F, 24 moves to other side and smells while F, 27 stays at her station.]
> **F, 24:** *I think that one's chocolate.*
> **F, 27:** [smells] *Right on the money.*
> **F, 24:** *I don't smell anything in that one.*
> **F, 27:** *I don't know what that is.*
> [F, 24 lifts tab.]
> **F, 27:** *No. No way. It's the same one over here! But it is not the same smell.*
> **F, 24:** [smells third scent.] *That one stinks* [lifts tab].
> **F, 27:** [smells the same scent and says] *It's not too bad.*
> **F, 24:** *All right. I'm all set with that one.* [They move to the next exhibit.]
>
> [Follow-up interview]
> **Researcher: *And you guys spent a pretty long time at the smell area, what were you guys talking about there?***
> **F, 24, Deaf:** *I'd say that was very interesting, the smell exhibit. I was able to pick out some of the smells and some of them were a little harder to identify, but I was very interested in that area. Yeah.*

F, 27, Hearing: *Yeah that was fun, but it was interesting to see the difference between the two sets. I mean obviously they weren't in the same order, but there was one in her set there was no smell and in my set it was very strong and I knew what it was right away. And it was funny that she was like "oh my god, coconut is disgusting" and I was like "what is that smell," and it was the one I just smelled and I thought "oh, that's not bad."*

These visitors' use of the "Sense for Scents" component and follow-up interview responses illustrate how the multisensory and multimodal nature of the component facilitated the social interaction of visitors who use different languages. While one woman primarily uses ASL, her friend identifies as a novice user. Their language communication, which occurs mostly through fingerspelling, is supported through the use of this component's activity.

Some visitors benefited from having instructions conveyed visually rather than through text or accompanied by text. For example, at *Science in the Park*'s "Run!" component, all groups who used that exhibit were observed using the yellow arrow lights at the beginning of the track to know when to run. In another case, groups in *Take a Closer Look* were able to use the "Vibration Patterns" component after watching the video instructions. The following is an excerpt from transcribed videotape showing the value of including graphics in instructions at the "Hover" component with a beach ball in *Science in the Park*:

Female #1, 8, uses CIs: [Reads label aloud] *"Place the ball."*
[Both girls look at the label briefly without speaking. They stop looking at the label and start playing with the beach ball. They put their heads over the air tunnel to see their hair fly.]
Female #2, 8, uses CIs: *"Ok. Now after this. It says we have to make the ball go over there. See?"* [She points at the label picture while reading aloud to her friend.] *"So the ball goes down and then you see it bounce."* [She pushes the ball.] *"See. And then it goes back and forth."*
[They push the ball back and forth together.]

Finally, the placement of exhibit labels sometimes supported social interaction. Participants in the Goals & Learning Study often benefitted from exhibit labels placed within reach or in multiple component locations. Many groups visiting *Science in the Park* used the exhibit labels located strategically at a component such as where you would wait in line, where you would observe a group member, or where you would interact with the exhibit. For example, one mother used both labels of the "Balance" component (pictured below) when engaging with her 8-year-old son with no hearing in his left ear. She was able to point to the label and read aloud while her son could follow along and manipulate the table-top balance. Another group of two 8-year-old girls with CIs used this component while standing across from one another enabling them to look at each other's faces when lip-reading.

Figure 3. "Balance" component in *Science in the Park*

These data illustrate the impact that exhibition design can have upon visitors' social interactions, especially those who are DHH. Exhibits that provide multisensory materials, convey instructions visually, and place exhibit labels to facilitate eye contact supported visitors with a range of hearing.

3. FINDINGS RELATED TO THE DEVELOPMENT OF MUSEUM PROGRAMS

Data from all four of the sub-studies shed light on visitors' experiences with Museum of Science programs. This section highlights the findings from the studies about live presentations and programs. In some of these cases, programs were modified to be more inclusive to audiences who are DHH. These included some programs being interpreted in ASL (Sign Language Saturdays Study), some programs incorporating an avatar interpreter in the presentation slides ("Super-Cold Science" TBI Study), and some videos of Museum programs having captioning (Programs Online Study). However, in some cases there were no specific actions taken to make the shows more inclusive to visitors who are DHH (Goals & Learning Study).

This section addresses how visitors who are DHH and hearing[7] reacted to these programs. The section is organized by the following findings:

  3.1 The majority of visitors, both hearing and DHH, reported that the ASL interpretation and inclusion of an avatar using ASL in a presentation either did not impact or added to their experience.
  3.2 A few people visited the Museum specifically because of the ASL-interpreted shows for Sign Language Saturdays, all of whom use ASL and one of whom was hearing.
  3.3 Programs that applied the principles of universal design were better for visitors who are DHH than those that did not apply these principles.

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[7] The question used on the Sign Language Saturdays survey which asked about visitors' hearing levels was "Is anyone in your group hard of hearing or D/deaf?" with a yes/no checkbox. Throughout this section, the phrase "hearing visitors" is used to identify visitors who selected "no."

3.4 Some visitors suggested adding live captioning to Museum live presentations.

3.1 The majority of visitors, both hearing and DHH, reported that the ASL interpretation and inclusion of an ASL term signed by an avatar either did not impact or added to their experience with live presentations.

The Sign Language Saturdays Study survey asked visitors "How, if at all, did the ASL interpretation impact your experience?" A summary of responses can be found in Table 9. Of the 315 visitors who completed the survey, 177 visitors (56%) responded that their experience with live presentations was not impacted by the ASL interpretation. 174 of these visitors were hearing and three of them are DHH. Of the three visitors who are DHH and said they were not impacted, two of them did not use ASL and one of them did use ASL. Additionally, there was one hearing visitor who uses ASL and said that the ASL interpretation did not impact their experience.

TABLE 9. Sign Language Saturdays Visitors' Responses to "How, if at all, did the ASL Interpretation Impact your Experience?" (N=315)

Response	Number of Participants	Percentage of Participants
It did not impact my experience	177	56%
It added to my experience	94	30%
I did not notice it	17	5%
It took away from my experience	7	2%
No response	20	6%

Although visitors most commonly said that they were not impacted by the ASL interpretation, many visitors (94 of 315; 30%) said that the ASL interpretation actually added to their experience. This included 85 visitors who are hearing and nine visitors who are DHH. Of the nine visitors who are DHH that said it added to their experience, eight people use ASL. Additionally, four of the 94 hearing visitors who said that the ASL interpretation added to their experience said that they use ASL.

Although most visitors' experiences were enhanced or not impacted by the ASL interpretation, 2% of visitors (7 of 315), all hearing who do not use ASL, said that the ASL interpretation took away from their experience. Four of these visitors left comments at the end of their Sign Language Saturday survey that shed some light on why they felt the ASL interpretation detracted from their experiences. The comments revealed that the interpreter's location on the stage led to some visitors being distracted. Two visitors who saw "Lightning!" pointed out the position of the interpreter in relation to the speaker, one of whom recommended that the interpreter stand "to the side of the stage instead of front and center" and another who said, "ASL [interpreter] stood too close to the speaker." One visitor who saw a CS&T presentation and one who saw the Live Animal show on the Science Live Stage also commented about the placement of the ASL interpreter as being distracting.

Similar to visitors' reactions to having the shows interpreted in ASL for Sign Language Saturdays, 64% of visitors (35 of 56) who watched the "Super-Cold Science" show as a part of the Team-Based Inquiry Study felt that the inclusion of the ASL term added to their experience. An additional 12 visitors (21%) said that including the ASL term did not impact their experience (or "made no difference either way"). See Table 10.

TABLE 10. "Super-Cold Science" Team-Based Inquiry Study. Visitors' Responses to "Do you Think that the ASL Animation: 1) Added Something to the Program, 2) Made no Difference Either Way, or 3) Detracted from the Program?" (N=56)

Response	Number of Participants	Percentage of Participants
Added something to the program	35	64%
Made no difference either way	12	21%
Detracted from the program	5	9%
No response	3	6%

Some visitors, both hearing and DHH, left positive comments about the ASL interpretation at the end of their Sign Language Saturdays Study survey or the use of the ASL term on the "Super-Cold Science" Team-Based Inquiry Study survey. Five hearing visitors commented that they appreciated that the Museum of Science had ASL interpreters for the live presentations. One of these visitors stated, "I have family members that are deaf and if they were here would be appreciative of the ASL services provided. Well done MOS." Another wrote "I thought it was great that there was an ASL interpreter present." A visitor who took the "Super-Cold Science" TBI Study survey wrote "More sign language! Great for kids!" Four visitors who are DHH wrote similar comments, thanking the Museum for providing an ASL interpreter:

- *Thank you for offering this service!*
- *Thank you for providing the interpreter!*
- *Appreciate provid[ing] the interpreter that we need!*
- *It was awesome to see ASL interpreters at the MOS! I wish more kids were here to take advantage of them- could you offer this on a weekday and give a discounted group rate to schools for the Deaf, like Beverly?*

These data suggest that, for the most part, visitors were not impacted by having an ASL interpreter present during live presentations. In fact, many visitors actually reported that the ASL interpretation added to their experience and only 2% of visitors felt that the ASL interpretation took away from their experience.

3.2 A few people visited the Museum specifically because of the ASL-interpreted shows for Sign Language Saturdays, all of whom use ASL and one of whom was hearing.

As mentioned in the Methods section, the Sign Language Saturdays events were advertised on listservs followed by people who are DHH and through the MOS Research and Evaluation Department's contacts who are DHH. The events were also advertised on the MOS Facebook page. However, there were no discounts or free tickets given to people who were visiting the Museum during the Sign Language Saturdays events. To see if ASL-interpreted shows made an impact on visitors' motivations for visiting, a question was added to the survey asking visitors whether they visited the Museum because shows would be interpreted in ASL.

Of the 315 visitors who filled out a Sign Language Saturdays Study survey, nine visitors (3%) responded that they visited the Museum because they heard the shows were going to be interpreted in ASL. Eight of these nine visitors identified as being DHH and one of them was hearing. However, all nine of them responded that they use ASL. It is also worth noting that eight of the nine visitors who were visiting because of the ASL interpretation had been to the Museum before, although the dates of their last visit varied (Table 11). Therefore, this event brought in one visitor who is DHH and uses ASL who had never visited the Museum before.

TABLE 11. Last Visit to the Museum for Visitors who came because of ASL-interpreted Shows (N=9)

Last Visit to the Museum of Science	Number of Participants
Never	1
Within the past 3 months	2
3-6 months ago	1
6 months to 1 year ago	0
1-2 years ago	2
2-5 years ago	3
5-10 years ago	0
More than 10 years ago	0

3.3 Programs that applied the principles of universal design were better for visitors who are DHH than those that did not apply these principles.

Goals & Learning Study and Programs Online Study groups' experiences with programs shed light on the aspects of the programs that worked well for them and facilitated learning, as well as parts of the programs that hindered their experience. There were a number of times during programs when the principles of universal design (UD) were not applied to the program, hindering visitors' experiences. Conversely, there was one live presentation that applied the principles of universal design throughout the program, providing a great experience to the visitor. This program, which led to a positive visitor experience and the two programs whose design elements hindered visitor understanding are described below.

Three Goals & Learning Study groups said that they would typically see a live presentation when visiting the Museum and decided to see a show during the study. One group who wanted to see a show had a very positive experience while seeing a live animal presentation about turtles. The researcher's notes on this presentation were as follows:

> **[Researcher reflection]**
> The educator used the microphone, PowerPoint, and close up camera to show details of the turtles. The slides reinforced main ideas like describing the main questions at the beginning then showing difficult terminology like the names for the top and bottom shells. Near the beginning of the show, the educator asked the audience if they could hear okay or if she should turn up the microphone.

During the interview, the visitor who wears a hearing aid and cochlear implant called the PowerPoint slides "really useful." This woman, age 18, felt that having words that were new to her on screen, such as "the names for the [turtle] shells," helped because "those are the words [she] wouldn't understand lip reading." She also told the researcher that she could hear the educator during the show and that "it was easy to understand her."

Other visitors' experiences with live presentations and cart demonstrations were not as positive. One of the main concepts suggested in *Universal Design Guidelines for Public Programs in Science Museums* (NISE Network, 2008) is providing physical and sensory access to all aspects of the program. There were a number of times during programs when physical and sensory access was not provided, hindering the visitors' experiences. For instance, unlike the example above, two live presentations did not include slides or other visuals to support what the educator was saying to the audience. During one of these presentations, a 12-year-old who uses a cochlear implant turned to the researcher, pointed to the black screen (where slides would have been projected), and said it would be better "if he had used that."

Along with having slides or other visuals available that reinforced what the educator was saying, one Programs Online Study participant, who saw a captioned video of a show, suggested adding something tactile or hands-on to the live presentation. In the comment box of the survey, he said that the show could be improved if there were "hands-on activities for the participants to [better] understand [the show's content]."

Other data indicated that some study participants were hindered in their understanding of the programs because they had difficulty lip reading. Visitors mentioned having trouble reading the educators' lips on three occasions: during one live presentation (Goals & Learning Study), one captioned video of a live presentation (Programs Online Study), and one cart demonstration (Goals & Learning Study).

In the live presentation, an educator was presenting a live animal show about a scorpion and wanted the audience to see the scorpion glowing in the dark. To do this, she turned off the lights for a period of time while continuing to tell the audience about the animal. Once the lights were turned off and did not come back on quickly, the study participant got up and left the show. During her interview, it was clear that she left because she could not access the content of the

presentation. In fact, she was not even sure which animal was being presented in the show. She describes her experience in the following quote,

> *I knew she was talking about predators, but I had no idea what she was going to do about predators. I had no idea what kind of creature that was up on the screen. And then, of course, when the room went dark I couldn't understand anything at all. Because the only way I was really understanding her was with lip reading.* [Female, 80, has worn hearing aids for 30 years]

One Programs Online Study participant gave feedback about the educator's actions on a captioned video of a Current Science & Technology show. When asked if there was anything difficult to understand from the video, the woman who uses two hearing aids said "Not difficult to understand, but I read lips and she kept turning away to face the screen. I suspect that wouldn't happen in a live environment." In the comment box, her suggestion was to "have [the educator] stand still and face [the audience]."

Difficulties with lip reading also came up for a visitor who visited a cart demonstration. This woman who is Deaf, age 36, walked up to an interpreter in *Take a Closer Look* who had a demonstration about scanning electron microscopes. During this experience, the volunteer was pointing to the microscope and to the magnification levels, all while talking about them. The visitor was observed nodding and looking at both the interpreter and the microscope, which left the researcher thinking that this was a positive experience for the visitor. However, during the interview, this visitor talked about the experience with the volunteer interpreter as being a negative one. During her interview she said,

> *I felt like I couldn't ask a bunch of questions. I can lip read… I'm not sure how well I could ask questions myself using my voice. I would have to use a piece of paper and a pen to be able to talk to him. We tried gesturing our way through it… but that's something the people working in the Museum need to be aware of- how to gesture their way through the conversation.* [Female, 36, Deaf]

When asked if she felt the interpreter did a good job gesturing, she added,

> *No. He didn't really because I noticed when I looked [at the microscope] he was still talking… So it would be good for museum staff [members]to be kind of sensitive to the fact that Deaf people might be coming into the museum and they might be able to gesture a little bit to be able to communicate.* [Female, 36, Deaf]

Similar to the above examples about live presentations, this one-on-one interaction with a volunteer was negative because the visitor was not able to lip read the volunteer. In this case, she could not lip read because the volunteer would point at something for her to look at and when she turned to look at it he continued talking. Everything he said while she was looking away was not accessible.

The above examples from the Goals & Learning and Programs Online studies align with suggestions provided within the guidelines for UD principles for Museum programs. This

includes having visual and tactile elements in a show that reinforce the content, and for educators and interpreters to behave in a way that allows visitors to lip read. Lip reading behaviors that allow visitors who are DHH to access the content include facing the audience during a live presentation and being sure not to talk when directing a visitor to look at something in a one-on-one interaction.

3.4 Some visitors suggested having live captioning during Museum live presentations.

Data from three studies show that captioning and ASL interpretation can be helpful to some visitors who are DHH. As mentioned in finding 1.3, two groups from the Goals & Learning Study said that they may request an ASL interpreter to see a live presentation at the Museum. Both of these groups also mentioned that captioning during live presentations would have helped them understand the content if an ASL interpreter was not present. One woman who is Deaf talked about her past experience with a "Lightning!" show when there was no ASL interpreter and no captioning (see her full quote in finding 1.3). After saying that she "missed a lot of information" during the presentation, she said "it would have been nice to have an interpreter there for the show… Or to have captions to have it accessible. I know that's not equivalent to having an interpreter, but it's nice to have as a backup." Although she preferred ASL interpretation, captioning would have helped her access the content in the presentation.

Similarly, the hearing daughter of a woman who is Deaf explains that they would book an ASL interpreter for a live show because "there wasn't any closed captioning or captions so [her mother] couldn't understand it." Although in this specific case the group was talking about a visit to Universal Studios, they associated that visit with coming to the Museum for a day and watching a show.

Both of these visitors seem to prefer having ASL interpretation of Museum shows; however, when there is no interpreter available, these guests reported that they would benefit from having the shows live-captioned.

A similar feeling was shared by three visitors who took the Programs Online survey, one of whom is "deaf" and "an intermediate ASL speaker," another who is "Profoundly deaf" and an "advanced ASL speaker," and a third who is "severe/profound loss with aid in R ear… [and] cochlear implant L ear" and "do[es] not know ASL." Although these visitors were watching captioned videos and not the live shows, they all noted the difficulties they would have without the captions if they were in the Museum watching the show. Therefore, these participants suggested that live captions should be added to the in-person show. The woman who has "severe/profound loss" saw a captioned video of a "Lightning!" show. When asked "What, if anything, was difficult to understand?," she responded, "It was not only very easy to understand but eye-opening to me as I've seen this demonstration probably about 15 times with my own children yet I've never fully been able to hear or understand it (due to my inability to hear it)." The other two Programs Online Study participants suggested live captioning of the shows in the comment box of the survey. In these examples, the captioning provided by the video version of the shows allowed visitors to access the content. They felt that captioning during the live shows would be helpful for them if they were visiting the Museum.

IV. IMPLICATIONS

The sections below describe the implications of the data collected through the Museum of Science Signing Science sub-studies for MOS practices. These sections are split into the following:

1. Implications for accessibility accommodations,
2. Implications for exhibit design, and
3. Implications for program development.

1. IMPLICATIONS FOR ACCESSIBILITY ACCOMMODATIONS

The findings from these studies have implications for the Museum's accessibility offerings, including the assistive listening system and the service available to request ASL interpreters.

1.1 The Assistive Listening System

The data reported above indicate that not all visitors who are DHH look into the Museum's accessibility offerings in advance. Participants in the Goals & Learning Study were split in that half of them typically seek out information related to their interests and hearing-related needs, while the remaining half do not. If fact, three groups do no planning at all. Therefore, the Museum should not expect that visitors who may take advantage of the accessibility offerings at the Museum will know about these accommodations ahead of time.

Because some visitors who may use the assistive listening system will not plan their Museum visit in advance, it is important for the Museum to enable visitors to learn about the system upon arriving. Visitors participating in the Goals & Learning Study report that staff members and signage at stage and theater areas are important resources as these are the locations where visitors are most likely to seek out information about the availability of and instructions for using the Museum's assistive listening system. Therefore, it could be helpful to post signage in the stage and theater areas that spells out where visitors should go to find the materials they need and what they need to do to access the accommodation. This would make visitors aware that there is an assistive listening system available, would point them to the location where they can find the materials they need, and would help direct them on how to successfully use the technology.

Additionally, the example of the 55-year-old woman who uses CIs that was looking for information and materials for the assistive listening system speaks to the importance of educating front-line staff members about the availability of accommodations. This visitor went to three areas in the Museum and talked with two staff members before she was able to successfully retrieve the assistive listening device she needed to see an OMNI show. At the box office, the staff member did not know which shows were offered with an assistive listening option, and so he had to check in with other staff members. Additionally, although the visitor did not ask him specific questions about the logistics of getting the assistive listening device at the box office, he could have provided her with more logistical information including: where to get the device, when the doors would open to the show, and whether the OMNI staff members could help with

using the technology once she had it. To ensure that other visitors do not need to go to multiple locations to learn about the assistive listening system, it would be beneficial to visitors who are DHH if all front-line staff members had access to information about possible shows and how to get the materials and instructions.

It is worth mentioning here that the Museum website (www.mos.org/accessibility) has detailed information about the new assistive listening system, including where the system is installed in the Museum, where the receiver and headset can be found, and contact information for the Accessibility Coordinator. This information is helpful for those who prepare before a Museum visit and should continue to be available. However, for those individuals who do not look to the website in advance, the Museum needs additional ways to provide visitors with this information once they get to the Museum. Possible steps could include signage and staff member training.

1.2 ASL Interpretation

The findings indicate that none of the individuals who primarily use ASL would request an interpreter for a typical Museum visit with their family or friends. This was generally because they could already communicate with the people in their group without the help of an interpreter. However, two groups pointed out times when having an interpreter would be helpful. They said that an interpreter would be useful for visiting as a school group (where communication with staff members happens more often) and attending live presentations.

As a part of the preparation for Sign Language Saturdays, the Museum hosted three one-hour staff trainings about interacting with visitors who are DHH on the floors, which included insightful information about the work and role of ASL interpreters. The two presenters from The Learning Center for the Deaf talked about the role of ASL interpreters as being solely to facilitate communication. The trainings detailed how ASL interpreters are the voice of the person who is D/deaf and the hands of the hearing person. Therefore, the interpreters are helping both sides. Because the ASL interpreter is a neutral party in the conversation, staff members should always talk directly to the person who is d/Deaf and not to the interpreter.

This training also provided information about how ASL interpreters do their job. For instance, it is often helpful to book two interpreters who can work as a team. This is because the interpreters take turns signing and will act as a check for each other. While one interpreter signs, the other provides visual cues to let the partner know they are on track and supplies corrections for anything that is misheard or misinterpreted by their partner. Language misinterpretation also came up two times during the Goals & Learning Study. One visitor who is Deaf gave two reasons that he would not request an interpreter at the Museum. He said that "sometimes they can act like devil's advocate and [add] human factor errors." He said that there could be mistakes in meaning or misinterpretation with ASL interpreters. Although this visitor was not asked about the two-interpreter method explicitly, it is possible that this would help alleviate some misinterpretations. In another case, when two ASL interpreters were present, a hearing visitor corrected them in multiple instances when she felt that her signs were being misinterpreted. Because ASL interpreters are interpreting English and ASL, rather than directly translating, and English and ASL rely on different grammar constructions, minor variations in content should be

expected. To mitigate misinterpretation, staff members should keep this in mind when booking interpreters for Museum events and shows and provide the interpreters with advance notice of any technical terms or specific content.

These findings suggest that besides offering ASL interpreters on an ad hoc basis and making sure to provide ASL interpreters for appropriate school groups, having live presentations offered with ASL interpretations on some weekends, and advertising for it, may give visitors who use ASL an extra reason to visit the Museum and may even attract some visitors who have never visited before. Additionally, the data indicate the importance of booking more than one ASL interpreter in these situations so that the interpreters can act as a team and a check for one another.

While this section discusses when ASL interpreters are likely to be needed, there is information in the implications for program development about how ASL interpretation impacts the visitor experience.

2. IMPLICATIONS FOR EXHIBITION DESIGN

Findings from the Goals & Learning Study highlight the following implications for Museum of Science exhibitions related to navigating the Museum, audio phones, and designing for social interaction.

2.1 Navigating the Museum

Data from the Goals & Learning Study provide evidence that visitors who are DHH are drawn to visual experiences, but hearing-related content can become interesting if made accessible. For example, a few visitors who are DHH recognized that they had learned something about their own hearing from the "hear" area in *Take a Closer Look*. One visitor who is Deaf especially enjoyed the "Seeing Sound Waves" component because its large vibration and resonance could be felt and observed visually.

Yet, visitors who are DHH do not rely solely on hearing-related factors when making decisions about which exhibition to visit. While visitors who are DHH recognized their interest and aptitude for visual experiences, they also made decisions about which exhibitions to visit based on proximity and content interests. Groups stopped by nearby exhibitions while waiting for a live presentation or traveled across the Halls because of attractive signage.

However, visitors who are DHH were observed leaving exhibitions due to extreme background noise, such as *Science in the Park*, or negative responses to specific exhibit components, such as the drums in the *Our Global Kitchen* diorama.

Together these data suggest that areas easily accessed during transitions between exhibitions or those near programmatic stages can provide opportunities for additional, though potentially brief, learning and visitor engagement. While all visitors might capitalize on these moments, visitors who are DHH would benefit especially from visual experiences with limited sound. When

selecting content for these areas, hearing-related content does not need to be avoided but should be conveyed in a multisensory way.

2.2 Providing Audio Phones

The Museum of Science provides audio labels with the intent that they could be used by any visitor, but will be especially useful for visitors who are blind, sighted visitors who want to read along with the audio text, younger children learning to read, those who speak English as a second language, or for those who have learning disabilities (Museum of Science Universal Design Plan). In the Goals & Learning Study, many visitors who are DHH also used the audio phone. These visitors often thought the audio phone contained additional content and that they could not access this additional content. Even after discovering that one component's audio phone recited the written label, some visitors did not think that this was the same for all components. Two visitors asked for scripts of the audio phone's content.

Additionally, captioning is provided throughout the Museum on all videos. Yet, two groups who encountered a silent video commented that the video was uncaptioned because they were not aware that it had no audio elements.

These experiences suggest that visitors who are DHH would benefit from knowing what types of information is included in the audio phones or whether there is no sound in a video. Although audio phones are an effort to be more inclusive, it is possible that they lead visitors who are DHH to view a component as inaccessible. When visitors engage with an interactive that they view as inaccessible, it send the potential message that the Museum has not considered their needs. However, as the Museum is committed to inclusion and accessibility, the presence of audio phones or sharing their purpose provides an opportunity to further communicate that commitment to any visitor, including visitors who are DHH.

2.3 Fostering Social Interaction

The majority of groups in the Goals & Learning Study were made up of visitors with a range of hearing, and participants who are DHH reported that they often visit the Museum with their hearing friends or family members. These groups could have diverse language and communication needs. For example, individuals who identify as DHH might use signed communication or express him/herself orally, they might use a range of assistive listening technologies, and they might have lower than average reading levels in English (Marschark & Hauser, 2012). This study explored exhibition designs which fostered social interactions among visitors with a range of hearing.

The Goals & Learning Study data suggest that multisensory exhibits and exhibit label location can impact social interaction among visitors with a range of hearing. These designs enabled visitors to use multiple strategies that facilitated communication such as pointing at the exhibit label, gesturing about the exhibit materials, and facing one another. Additionally, a notable study of family learning in science museums identified similar characteristics that promoted successful

family learning such as being multi-sided so a family can cluster around or multi-modal so as to appeal to different levels of knowledge (Borun & Dritsas, 1997). Therefore, these characteristics could support all visitors who come with a social group yet be especially important for visitors who are DHH. For example, while standing within eyesight is important for a range of reasons, such as watching over a child, it is especially necessary for groups including visitors who are DHH who might rely on the visual language of ASL or lip reading.

3. IMPLICATIONS FOR PROGRAM DEVELOPMENT

Findings from the studies illuminate many implications for Museum of Science programs about the addition of ASL interpretation, live captioning, and universal design principles.

3.1 ASL Interpretation

The Sign Language Saturdays and "Super-Cold Science" TBI studies found that, in general, hearing visitors were not negatively impacted by the inclusion of an ASL interpreter or a video clip of a signed term as a part of live presentation. In fact, many visitors reported that these additions actually added to their experience. This aligns with findings from Poveda et al. (2008) about the experience of hearing patrons who attended live storytelling events interpreted in sign language. They argue that all children in the audience were part of a multilingual, multimodal narrative created by both the storyteller and the interpreter and that "hearing children are enriched by the presence of a signed version of the story" (p. 339). This study, in addition to the earlier suggestion that providing ASL interpretation could be a possible audience draw, indicate that the MOS should consider providing regular ASL interpretation for its programs. This is because visitors are generally not negatively impacted by the addition of ASL to a live presentation, and many actually feel that the ASL added to their experience

For the few people who said that the ASL interpretation took away from their experience, some attributed this to the location of the ASL interpreter. These visitors commented that the interpreter often stood close to the presenter, which they felt was distracting. Although this was a distraction for a few visitors, it is necessary for people who use ASL to be able to see both the interpreter and the presenter at the same time (Pelz, Marschark, & Convertino, 2008; NISE Network, 2008). Therefore, these data indicate that the needs of the visitors who are distracted by the ASL interpreter and the needs of visitors who use ASL should be considered together and compromise solutions should be determined that will allow the interpreter to be easily seen but not in the way of the presenter.

3.2 Live Captioning

Although ASL users reported that they prefer to have ASL interpreters for live presentations, when no interpreter was available, some of these visitors felt that they would still benefit from live captioning being added to live presentations. This might be a way to alleviate some of the issues with providing ASL interpreters, including the fact that guests sometimes do not know that they can request one or that they do not request this service at least two weeks in advance. It

is possible that providing open captioning could also benefit visitors beyond those who are DHH. For instance, during two of the Sign Language Saturdays shows, the speaker system was not working and many survey respondents reported not being able to hear the presenters. The addition of live captioning could have lessened this issue.

Besides this indication, some of the non-ASL users who took the Programs Online survey talked about the importance of captioning in being able to access the content. Some of these study subjects suggested that live captioning would benefit the live presentation. This system may be especially beneficial in stage areas with more background noise where it may be more difficult for visitors to hear, such as the Current Science & Technology stage.

3.3 Universal Design for Programs

Finally, findings from the Goals & Learning Study illuminated the importance of using principles of universal design when creating and presenting live presentations. Shows that included multi-modal reinforcement of the content such as providing a picture of a tortoise shell with the term in written form and saying the term aloud, as well as shows that included physical and sensory access to all aspects of the presentation were most successful for visitors who are DHH. This indicates that these guidelines, which were created as a part of the NISE Net (NISE Network, 2008) and refined through the "Universally Designed Museum Programming" project funded by the Institute for Museum and Library Services [*LG-45-11-0049-11*] (Goss, Reich, Stoessel, & Iacovelli, 2012), should be shared widely with museum educators and always used when creating and presenting live presentations.

Another aspect of program presentation that was clearly crucial for people who are DHH was the ability to clearly see an educator so that they could read their lips. This is important for both educators presenting live presentations and for those who are interacting with visitors one-on-one at cart demonstrations. All staff members should make an effort to face visitors while speaking.

V. CONCLUSION

This report summarizes the work of four sub-studies collected at the Museum of Science and illuminates the effectiveness of the MOS accessibility accommodations, exhibitions, and programs for visitors who are DHH and their group members. Members of the Research and Evaluation Department collected data throughout visitors' entire Museum visit (Goals & Learning Study), solicited targeted responses via email regarding captioned videos (Programs Online Study), and collected surveys during a month-long period of Saturdays with free ASL interpretation (Sign Language Saturdays). Additionally, MOS educators conducted a team-based inquiry study of the "Super-Cold Science" show in order to test visitor response to incorporating ASL terms. Across these four sub-studies, the Museum of Science team has learned a great deal about how the Museum can support visitors who are DHH.

The following items are key takeaways based on data collected across the four sub-studies.

Visitors who are DHH might not plan for their visit.
- It is important to remember that visitors (hearing or DHH) to the Museum might not be aware of accessibility accommodations prior to arriving. Visitors might only look for this information when it becomes necessary, such as at a live presentation, and it would benefit them to have clear signage or instructions about available systems near the stage or theater areas.
- Visitors who want to use the assistive listening system need to know where to access the system and how to use it. Having this information available at one location or by talking to one staff member, rather than needing to contact several, would be easiest for visitors.

Visitors who are DHH might have negative opinions of the Museum environment.
- Some visitors who are DHH who participated in this research mentioned that the presence of an audio phone or uncaptioned video made them feel like they were missing part of the intended content. Whether it is the Museum's intent to provide greater access through audio phones, or a video does not have captions because it does not contain audio, it is important to remember that visitors who are DHH might view these efforts as inaccessible.

Hearing-related content can be personally relevant to visitors who are DHH if it is conveyed in a multisensory way.
- When navigating the Museum, visitors who are DHH were drawn to visual experiences but also noticed when programs and exhibits included something that was personally relevant to their hearing. One visitor who is Deaf noticed a volunteer wearing a hearing aid while another visitor who is Deaf noticed an ASL sign in an exhibit's video. Some visitors who are DHH mentioned learning something about their own hearing from a hearing-related exhibit. However, visitors left exhibits and programs when it was inaccessible to their hearing because of too much background noise or impacted their ability to lip read. It is important to remember that hearing-related content isn't necessarily bad, but inaccessibility to hearing-related content is.

Exhibit and programmatic designs which include visitors who are DHH are also beneficial for hearing visitors.

- Multisensory exhibits, exhibit labels that facilitate eye contact, and programs based on the principles of universal design were all elements which enhanced the experience of visitors who are DHH. While these foster social inclusion for a wide range of groups and families (Borun & Dritsas, 1997; Goss et al., 2012; NISE Network, 2008), these studies highlight their significance for visitors who are DHH. Future exhibits and programs should include ways for visitors to point or use the exhibit material to gesture, ways for group members to be positioned face-to-face, ways to introduce multisensory elements, and ways to use non-text strategies to convey the desired message.

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APPENDIX A: GOALS & LEARNING STUDY THEORETICAL FRAMEWORK

This appendix includes further detail of the Disability Creation Process model that was used as a foundation for the Goals & Learning Study. This framework did not extend to the other Signing Science sub-studies.

The Goals & Learning Study is grounded in the work of Fougeyrollas, Cloutier, Bergeron, et al. (1998) and their development of the Disability Creation Process (DCP) model. The DCP aims to provide "an explanatory model of the causes and consequences of disease, trauma and other disruptions to a person's integrity and development" (Fougeyrollas et al., 1998, p. 10). As shown in Figure 1, the DCP identifies the importance of the interaction between intrinsic characteristics (personal factors) and extrinsic characteristics (environmental factors). Through this interaction, a life habit is able or not able to be participated in and individuals can either achieve full social participation or experience handicap.

Figure 1
Disability Creation Process (DCP) model
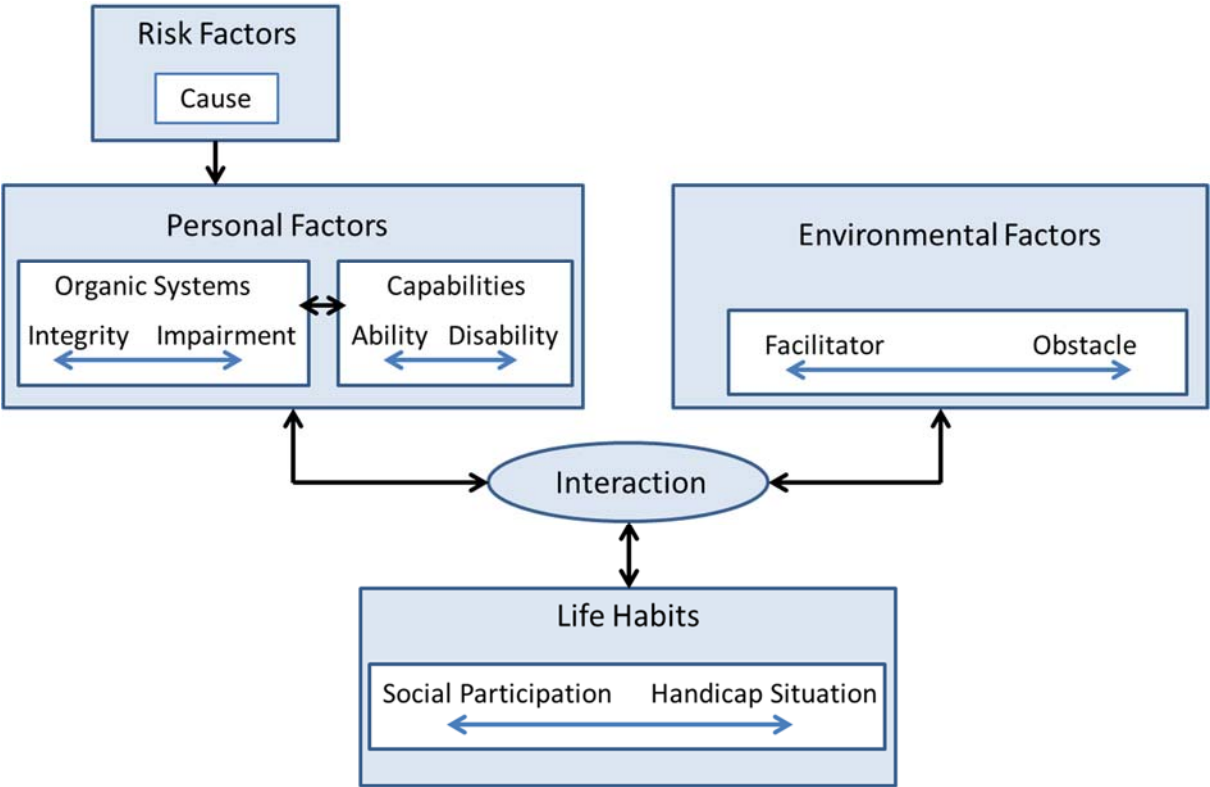
In order to further describe the DCP model, definitions of each component are provided here:

- A risk factor is an element belonging to an individual or within the environment that is likely to cause a disease, trauma or any other disruption to a person's integrity or development.
- Personal factors correspond to a person's intrinsic characteristics, such as age, sex, socio-cultural identity, organic systems, capabilities, etc.
  - An organic system is defined as a group of bodily components sharing a common function.
  - Capability is defined as a person's potential to accomplish a mental or physical activity.
- Environmental factors are defined as physical or social dimensions that determine a society's organization and context.
- A life habit is defined as a daily activity or a social role valued by the person or his/her socio-cultural context according to his/her characteristics (age, sex, socio-cultural identity, etc.) (Fougeyrollas et al., 1998, pp. 13-16).

Adaptation of the DCP model

Because the DCP was conceptualized for the field of occupational therapy and rehabilitation, it represents an expansive model that extends beyond the purview of informal learning. For example, the DCP provides the ability to analyze causes or risk factors which could contribute to trauma, resulting in differences in personal factors. The DCP can also be used to investigate a wide range of life habits such as the ability to cook a meal or plan a budget. However, the model developers have identified methods in which this model can extend to other disciplines or fields as necessary. As stated by Fougeyrollas et al. (1998),

> The conceptual model is a practical tool that helps to understand all of the human development process and the variables that influence the disability creation process. It is a generic tool that one can transpose according to the user's field of application… One of the most frequent uses is to carry out an evaluation, a profile, or a portrait of a person or population at a moment in time. This profile would clearly show the relevant characteristics of the field of use, such as the profile of a person who has experienced a traumatic brain injury upon entry to the functional rehabilitation centre…(p. 17).

Upon this encouragement, this study adapted the DCP model for an investigation of the informal learning context in the following ways:

- **The study did not investigate "risk factors".** DCP model developers acknowledge that aetiology (or the cause(s) of a disease) is not very important for some applications. Instead of including "risk factors" in this analysis, the Goals & Learning Study concentrated on the three interacting domains (personal factors, environmental factors, and life habits) as that is the location of a museum visit.
- **Environmental factors included the visiting group members.** DCP model developers have suggested that this model can extend an investigation beyond an individual and look at groups saying that a family group becomes part of the environment of the person with a disability. Therefore this study investigated the visiting group which includes at least one person who is DHH.

- **Life habits were identified as museum-driven goals, visitor-driven goals, and visitors' perceptions of goals for a museum experience.** Because "life habits" can be perceived in broad terms, it is important to define the habits in question for an informal learning environment. To do so, this study included both museum-driven goals and visitor-driven goals. Because it is a goal of the Museum of Science that visitors learn exhibition-related content, learning will be included as a life habit under investigation. This study also asked visitors about their motivations and goals for visiting the museum in order to determine the individual's desired museum experience. Finally, this study attempted to discern visitors' perceptions of goals for a museum experience. Because Fougeyrollas et al. (1998) assert that society drives the level of participation that is possible, it is important to investigate visitors' perceptions of social norms that accompany a museum experience. The DCP model suggests visitors could encounter discomfort if they feel expected to do something they do not wish to do.

This model allows for the investigation of an informal learning context because of the focus on interaction between the three large domains of personal factors, environmental factors, and life habits. Museum experiences have been "characterized as learner-motivated, guided by learner interests, voluntary, personal, ongoing, contextually relevant, collaborative, nonlinear, and open-ended" (National Research Council, 2009, p. 24). When visiting a museum the environmental factors of science content, social group, exhibit design, etc. collide with personal factors of previous knowledge or interest in the content as well as ability to interact with exhibits' features or content. Disabling features cannot be measured by an objective environmental context, such as an obstacle's height. Maintaining that disability occurs at the intersection of personal and environmental factors, disabling features must also be measured across these two lenses. Therefore instead of just looking at an obstacle's height, a researcher would also need to investigate the participant's perception of that height. By focusing on the achievement of life habits and full social participation, it is necessary to explore the interaction between two groups of determinants.

APPENDIX B: GOALS & LEARNING STUDY INSTRUMENTS

Pre-visit Questionnaire for Adult[8]

This is voluntary. You don't have to answer a question if you do not want to.

1. Please describe yourself:

Age:_____

Sex:_____

Race:_____

2. Please describe your level of hearing.

3. When was the last time that you visited the Museum of Science? (Please check one)
❑ Never
❑ Within the past three months
❑ 3 – 6 months ago
❑ 6 months to within the last year
❑ 1 – 2 years ago
❑ 2 – 5 years ago
❑ 5 – 10 years ago
❑ More than 10 years ago

4. When you visit the Museum of Science, why do you decide to visit?
   (Check **up to two** that most apply.)
❑ Not applicable - I've never visited the Museum of Science.

❑ To spend time together as a group/family
❑ To bring out of town friends/family
❑ Educational experience for group members/children
❑ Educational experience for myself
❑ For fun/entertainment for group members/children
❑ For fun/entertainment for myself
❑ To see a specific exhibit, program, or show
   Which exhibit, program, or show? _____
❑ Had a coupon/free pass
❑ Something to do while visiting Boston
❑ Something to do in poor weather

5. Is there anything that you're hoping to do during your visit today? Please explain.

6. How would you rate your interest in science on a scale of 1 to 10?

No Interest									**Extreme Interest**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

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[8] All spacing and pagination has been adjusted for use in this report.

Post-Focus Exhibition Interview

1. Thinking of this exhibit overall, tell me about your experience.
    What did you think about that exhibit? Did you like it or dislike it? Why or why not?

2. In general, what did the Museum want you to learn about in this exhibit?

3. Did you learn anything at this exhibit that you didn't know before? If yes, what did you learn?
    Was there anything that surprised you at this exhibit?

4. Was there anything that was difficult about that exhibit?

Additional probes based on observation.

Post-Visit Interview

1. At the beginning of your visit, you mentioned that you were hoping to [survey question #5]. Did you feel that you had the opportunity to do that?

2. If you were going to tell a friend about one thing you did today, what one activity would you tell them about?

3. If I wasn't with you, is there anything you would have done differently?

4. We work with a team who is developing a smartphone app which is a Signing Science Dictionary. It includes a vocabulary term in ASL, English, and a definition. Is that something you would be interested in? Why or why not?

5. Before visiting a science museum, would you look for an app like that? For example, would you search the internet or the museum website?

6. During your visit today, were there any terms that you would want to look up if you had an app like that with you?

Additional probes based on observation.

Please tell us about yourself.
Age [Type here]
Sex [Drop down]
Hearing level [Type here]

Which of the following options best describes your level of American Sign Language (ASL) fluency?
I do not know ASL.
I am a novice ASL speaker. I can understand words or phrases I have learned and can produce some signs about topics that are familiar to me.
I am an intermediate ASL speaker. I can understand the main ideas and some details about a topic that is familiar to me and can produce signs that describe me and my preferences.
I am an advanced ASL speaker. I can understand details from longer passages even when I am not familiar with the topic and can talk about abstract thoughts.

When was the last time you visited the Museum of Science?
Never
Within the past three months
3-6 months ago
6 months to a year ago
1-2 years ago
2-5 years ago
5-10 years ago
More than 10 years ago

Please rate your level of interest in the topic of genetically modified foods.
Very interested
Interested
Somewhat interested
Not at all interested

How familiar are you with the topic of genetically modified foods?
Very familiar
Familiar
Somewhat familiar
Not at all familiar

Below is a video of a Museum of Science presentation on genetically modified foods. The video is about 20 minutes long. While you watch the video, please be thinking about any scientific terms that are difficult to understand. These could be:
> **1. Words that you have never heard before,**
> **2. Words you have heard before but are difficult to understand,**
> **3. Words that you do not know how to sign in ASL (if you speak ASL), or**
> **4. Words that still don't make sense after watching the presentation.**

[Embedded YouTube video of live presentation]

How interesting was this presentation?
It was so interesting that I would see it again
It was interesting, but I wouldn't see it again
It was not very interesting
It was not interesting at all

How easy was it to understand the presentation?
Easy
Somewhat easy
Somewhat difficult
Difficult

What, if anything, was difficult to understand?
[Type here]

Please check off any of the words below that you thought were difficult to understand. These words could be difficult because:
> **You had never heard them before,**
> **Their meaning was difficult to understand,**
> **You did not know the word in ASL (if you speak ASL), or**
> **The meaning of the word was not clear after watching the video.**
Bacteria
DNA
Gene
Mutation
Organic
Selective breeding

Please list any other words that were difficult to understand.
[Type here]

What, if anything, did you learn from the presentation that you didn't know before?
[Type here]

There is currently a smartphone and iPod app called Signing Science Dictionary that has ASL-English translations of math and science words along with their definitions. How, if at all, might you use an app like this while viewing Museum of Science live presentations?
[Type here]

When might you be interested in using this app as part of your experience with live presentations?
Before the show
During the show
After the show
I would not be interested in using this app

Please leave any other comments or suggestions about how we could improve our live presentations.
[Type here]

APPENDIX D: SIGN LANGUAGE SATURDAYS STUDY SURVEY

1. Please select the start time of this live presentation.
     ❑ 10:30 AM   ❑ 11:30 AM   ❑ 12:00 PM   ❑ 12:30 PM

2. What is your sex?
     ❑ Male
     ❑ Female

4. How old are you?
     ❑ 18-24
     ❑ 25-29
     ❑ 30-34
     ❑ 35-44
     ❑ 45-54
     ❑ 55-64
     ❑ 65+

3. When was the last time you visited the Museum of Science?
     ❑ Never
     ❑ Within the past 3 months
     ❑ 3-6 months ago
     ❑ 6 months to within the last year
     ❑ 1-2 years ago
     ❑ 2-5 years ago
     ❑ 5-10 years ago
     ❑ More than 10 years ago

5. Who came with you to the Museum today?
     ❑ Adults only
     ❑ Adults and children
     ❑ I came alone

6. Is anyone in your group hard of hearing or D/deaf?
     ❑ Yes   ❑ No
     If yes, please describe their level of hearing.

7. Does anyone in your group use American Sign Language (ASL)?
     ❑ Yes
     ❑ No

8. Did you come to the Museum of Science today because the presentations would have ASL interpretation?
     ❑ Yes
     ❑ No

9. How, if at all, did the ASL interpretation impact your experience?
- ❏ I **did not notice** the ASL interpretation
- ❏ The ASL interpretation **did not impact** my experience
- ❏ The ASL interpretation **added to** my experience
- ❏ The ASL interpretation **took away from** my experience

10. How interesting was this presentation to you?
- ❏ It was so interesting that I'd see it again
- ❏ It was interesting, but I wouldn't see it again
- ❏ It was not very interesting
- ❏ It was not interesting at all

11. How familiar were you with the content of the presentation before attending?
- ❏ Very familiar
- ❏ Familiar
- ❏ Somewhat familiar
- ❏ Not at all familiar

12. How easy was it to for you understand the presentation?
- ❏ Easy
- ❏ Somewhat Easy
- ❏ Somewhat difficult
- ❏ Difficult

13. What, if anything, was difficult for you to understand?

14. What, if anything, did you learn from the presentation that you didn't know before?

15. There is currently a smartphone and iPod app called Signing Science Dictionary that has ASL-English translations of math and science words along with their definitions. When, if at all, would you be interested in using this app as a part of your experience with live presentations? (Check all that apply.)
- ❏ Before the presentation
- ❏ During the presentation
- ❏ After the presentation
- ❏ I would not be interested in using this app

16. Please leave any other comments or suggestions about how we could improve our live presentations.

Survey instrument

If a friend asked you what this live presentation was about, what would you say?

If they asked your favorite part of the program was, what would you tell them?

What elements of the show did you find MOST helpful to learning about Super Cold Science?
❑ Visual images ❑ Oral presentation ❑ Tactile experiences ❑ Big board
❑ Personal Q&A ❑ Review quiz ❑ None of the above

What elements of the show did you find LEAST helpful to learning about Super Cold Science?
❑ Visual images ❑ Oral presentation ❑ Tactile experiences ❑ Big board
❑ Personal Q&A ❑ Review quiz ❑ None of the above

How would you describe the content level?
❑ Too easy ❑ Too hard ❑ Just right

Did you watch the American Sign Language (ASL) animation?
❑ Yes ❑ No

Did you practice any of the signs during the show?
❑ Yes ❑ No

Do you think the ASL animation:
❑ Added something to the program ❑ Detracted from the program ❑ Made no difference either way

If we could do anything to improve our shows, what would it be?

Are you here as: ❑ School group ❑ family group ❑ Adults only group?

Do you or someone you came with to the museum today identify as having a temporary or permanent disability?
❑ Yes ❑ No

If yes, how would you describe that disability? (check all that apply)
❑ Mobility ❑ Visual ❑ Auditory ❑ Learning ❑ Cognitive ❑ Other

What is your Age? ❑ Under 18 ❑ 18-29 ❑ 30-39 ❑ 30-39 ❑ 40-49 ❑ 55+

Observation Instrument

Observation:	Participants:		
	Pre-K-8	9th Grade-12	Adults
1. Raised a hand to ask or answer a question	N-F-S-M-A	N-F-S-M-A	N-F-S-M-A
2. Watched the sign language animation	N-F-S-M-A	N-F-S-M-A	N-F-S-M-A
3. Practiced signing	N-F-S-M-A	N-F-S-M-A	N-F-S-M-A
4. Participated in the quiz	N-F-S-M-A	N-F-S-M-A	N-F-S-M-A
5. Discussed science with a partner	N-F-S-M-A	N-F-S-M-A	N-F-S-M-A
6. Showed visible excitement or surprise	N-F-S-M-A	N-F-S-M-A	N-F-S-M-A
7. Stayed after the show to see props, ask a question, or talk to the presenter	N-F-S-M-A	N-F-S-M-A	N-F-S-M-A
8. Overall Excitement/Enthusiasm Rating:	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Intro/Rules:	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Observation of LN2	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Modeling molecular motion	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Water Balloon	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Rubber Band	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
H2o Molecule models	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Ice Model	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Air Balloon Model	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Quiz	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Snowstorm	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Cloud	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5
Personal Q&A	1-2-3-4-5	1-2-3-4-5	1-2-3-4-5