Exploring Earth Systems Science

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Summative Evaluation Report

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PACIFIC SCIENCE CENTER

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EXECUTIVE SUMMARY

With support from the Institute of Museum and Library Services, Pacific Science Center (PSC), implemented the Exploring Earth Systems Sciences (EESS) project with the purpose of developing and delivering scripted demonstrations utilizing the Science On a Sphere (SOS) technology in order to promote understanding of and increase interest in Earth systems sciences. Specifically, the grant allowed the Science Interpretation team to research and write 20-minute presentations, targeted towards visitors aged 11 and older, about nine unique topics such as: climate change, weather, seasons, or the Polar Regions. Staff were then provided training in content and presentation skills and were able to deliver shows daily to casual museum visitors for no additional charge or to middle school classes on pre-arranged field trips. Additionally, a Rapid Response system was set up to allow for extremely quick research and dissemination of details of current events related to some of the show topics, especially earthquakes and volcanos, in order to spread awareness and understanding of globally relevant phenomena.

In summary, over 1,800 presentations (those done as scripted demonstrations and in the casual interpretation style as well as Rapid Response shows) were presented to over 25,000 visitors from December 2013 to November 2016. Attendance at a presentation could range widely and the average was 18 guests per show. Three inter-related audiences were affected by the outputs of the EESS project: casual museum visitors, middle-school aged students, and Science Center Science Educators.

Outcomes for the two categories of audience ranged from knowledge and understating to supporting or increasing skills and are summarized below.

	Intended Outcomes	Outcome Category
Public Audiences will…	• Demonstrate new or increased interest in Earth systems topics	interest or engagement
	• Better understand the process of science	knowledge or understanding
	• Increase their knowledge of Earth systems science content	knowledge or understanding
Science Interpreters will…	• Increase their knowledge of Earth systems science content	knowledge or understanding
	• Increase their comfort and confidence delivering interactive presentations on Earth systems science	attitude
	• Increase their ability to dynamically communicate Earth systems science	skills or behavior
	• Increase their capacity to deliver regular Earth science basics and Rapid Response presentations	skills or behavior

The EESS project addressed every goal outlined in the original proposal. Some goals were met more completely than others; we acknowledge that though the respondents we heard from

cited robust takeaways and increases in both interest and abilities, there were, and remain, substantial difficulties in delivering scripted SOS demonstrations in its current location, as well as providing online content for public audiences to access at their convenience. The Science Interpretation team has already taken steps to carefully calibrate which shows are done with what degree of formality in order to maintain a range of options for both staff and visitors to benefit from this cool technology. Many other challenges and work-arounds are discussed in the final project narrative report. That said, this report details the findings of the summative evaluation studies conducted during the third, No Cost Extension, year and a selection of high level insights follows.

Highlights of the findings for **casual museum visitors** include:

- Considering all the topics together, it appears that shows about topics which visitors may be less acquainted with (Climate Change, Alien Landscapes), were able to support higher increases in interest. Less exotic topics – volcanos, earthquakes, and seasons – saw lower increases.

- Nearly two-thirds (63%) of comments about the process scientists use to study Earth sciences phenomena were references to the scientific process or examples of specific steps in the process. Earthquakes was the show that communicated this concept either most or clearest; 62% of Earthquake respondents wrote something about the process of science.

- The visuals for Alien Landscapes (Earth as the Blue Marble, Red Mars, etc.) and Our Changing Earth (Loggerhead Sea Turtle Migration, Chlorophyll Concentrations, etc.) in particular seem to have contributed to large increases (1.5 points or more) in self-assessed understanding of how to make sense of large amounts of visual data.

Highlights of the findings for **middle school students** include:

- The most circled word/feeling (that came as a result of seeing the demonstration) was "knowledgeable;" over half of students felt intelligent and well informed after seeing an EESS show and this was more pronounced for Alien Landscapes and Earthquakes – these shows may have shared more information that students hadn't learned before.

- The Science Center aims to inspire curiosity in all guests and it is heartening to see close to half of campers (41%) admitting to being "curious."

- "Ask a question" was the most common Science Toolbox step that was written, both verbatim and in various synonyms. It was almost always written first. Words relating to observing, collecting data, or tools used to collect data were next most common.

- Alien Landscapes had the widest range of responses while Volcanos had the highest combined percentage of "some" and "a lot" (78%) and Earthquakes taught the most students "a lot" (35%) about how to look at data and understand what it means.

Highlights of the findings for **Science Interpretation Program (SIP) staff** include:

- Learning, practicing, and delivering EESS content, somewhat obviously, made the biggest contribution to presenter's confidence presenting sphere shows in general. It seemed to have the least impact on confidence explaining scientific processes and methods, which staff acknowledged they did frequently via other interpretive activities.

- For the ten staff, the average contribution to overall ability as a presenter was in the middle of the scale, 4 out of 7. Still, the mode was 6 so most staff did grow greatly from the EESS experience.

- Connecting big datasets to visitors' everyday lives was seen as a way to foster interest through demonstrating relevance. There were several ways that staff were observed to do this. The most frequent (33%) was that they shared a "what you can do" type takeaway.

By going back and forth, asking and answering questions with visitors, Science Center educators are able to zoom in on the extent of existing knowledge in a crowd and build on that. By taking audience polls, welcoming brave souls to help with activities, and connecting even the most academic of data sets (for example, chlorophyll concentrations) to everyday life, a middle-school class is able to visualize how the relative positions of the Earth and sun are intricately connected to endangered species, a tourist from New Jersey is able to understand how a volcanic eruption in Washington state would impact her directly and Seattleites can see that the copious phenomena measured, tools utilized and datasets produced have provided overwhelming evidence of climate change. Pacific Science Center is deeply grateful to the Institute of Museum and Library Services for this opportunity.

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INTRODUCTION

Project Background and Goals

In 2013, Pacific Science Center (PSC) was awarded a Museums for America grant from the Institute for Museum and Library Services (MA-10-13-0107-13) with the purpose of developing and delivering programs utilizing the Science On a Sphere (SOS) technology. Pacific Science Center's Science On a Sphere globe is located in the center of an open area dedicated to space and astronomy. Benches and overhead speakers are arranged so that groups of two to 30 may be accommodated comfortably for a presentation. Due to the exposed nature of the globe any visitor on the museum floor may drop in or leave a presentation as they wish. Prior to receipt of the grant, some shows had been developed but due to lack of training, staff were unable to operate this technology with any sort of regularity; usually the datasets were displayed on the sphere in the auto run capacity. Evaluation that showed that visitors lingered longer and learned more when staff were present to help interpret the datasets, coupled with the need for structured programming (and the professional development required to facilitate it), lead to the Exploring Earth Systems Science (EESS) project. Specifically, EESS was designed to provide time and resources to create new demonstrations and prepare staff for their delivery to public audiences.

EESS **activities** were targeted to three interrelated audiences:

- Casual museum visitors: adults (aged 18 or over) who viewed the full demonstration format show (see regularly scheduled programming definition below).

- Middle school students (grades 6-8): the original aim was to work with middle school groups who booked a Sphere demo as part of their field trip package. It was rare for middle schools to visit the Science Center and further, it was also uncommon for schools of any grade range to reserve Sphere shows (usually choosing a planetarium or laser show or an IMAX documentary as their supplemental activity). Several of the Science Centers 6-8 grade summer camps were recruited to participate instead.

- Science Interpreter staff: over the course of the project dozens of staff were trained to give EESS sphere demonstrations. During the final months, when evaluation was conducted, 12 were available to share their feedback on the project.

EESS **programs** included:

- Regularly scheduled programming consisted of a set of nine 20-minute long, staff-facilitated demonstrations/presentations about various Earth systems science topics (other planets and moons, climate change, earthquakes, oceans, polar regions, storms, seasons, volcanos, and weather). Shows were regularly scheduled throughout the day

(two to five per day depending on staffing) and required no advance registration. All shows included a similar suite of content delivery methods: orientation to the Sphere itself, various animated datasets (often prepared by federal science agencies and other researchers), group questioning strategies, audience participation and hands-on props and materials; the presentations' structure mimics the process of science itself via a "Science Toolbox" (see **FIGURE 5**).

- Rapid Response programming took the place of regularly scheduled demos and were adaptations of the above mentioned shows with an emphasis on real-time or extremely recent data and photographs. Examples of events that were covered include the earthquake in Italy in August 2016, Hurricane Patricia in October 2015, and the results of the New Horizons space probe fly-by of Pluto in July 2015.

- Staff training and professional development as well as content acquisition was semi-structured in nature and consisted of direct instruction, partnered practice, and shadowing of experienced staff. More formal content training was planned but the online Lectora system that was originally proposed did not meet staff needs.

The **outcomes** of the project were varied and addressed by different activities for different audiences and are summarized in **TABLE 1** below. There were some outcomes that were included in the original proposal that we were unable to assess through evaluation. One was that "visitors view the Science Center as a resource for current information on Earth system science" and the other was that "teachers utilize PSC programming as a supplement to their classroom teaching." In the wake of several significant obstacles to developing presentations and training staff, along with technical difficulties, the objective to create a suite of online videos was not met. As we did not present for many formal education programs during the evaluation period, the impact on teachers was also not measured. The challenges with achieving these outputs is documented in the final project narrative.

TABLE 1. EESS outcomes by audience

	Intended Outcomes	Outcome Category
Public Audiences will…	· Demonstrate new or increased interest in Earth systems topics	interest or engagement
	· Better understand the process of science	knowledge or understanding
	· Increase their knowledge of Earth systems science content	knowledge or understanding
Science Interpreters will…	· Increase their knowledge of Earth systems science content	knowledge or understanding
	· Increase their comfort and confidence delivering interactive presentations on Earth systems science	attitude
	· Increase their ability to dynamically communicate Earth systems science	skills or behavior
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Evaluation Questions

Front-end and formative evaluation took place during Years 1 and 2. Summative evaluation, which is the focus of this report, took place during the No Cost Extension year (Year 3). One question which was not addressed during the formative period was incorporated into the summative work. Four studies explored the effectiveness of the public demonstrations as well as staff training. The overall evaluation questions were:

1) To what extent are the intended outcomes of EESS achieved with public audiences—general visitors and middle school students?

2) To what extent has participation in EESS impacted the professional development of PSC's Science Interpretation staff?

3) What are the strategies employed by Science Interpreters that are particularly successful in communicating key concepts and engaging audiences?

Study Limitations

With almost every evaluation study, methods and sampling procedure have the potential to impact the findings. Physical attributes and staffing levels can have an influence as well. The following are suggested limitations of the study.

- The open nature of the exhibit proved difficult on two levels. First was attracting and retaining audiences. Visitors were free to walk up and leave at any time, the latter proving a severe hindrance to receiving completed feedback surveys. Visitors who were approached and who agreed to participate may not be representative of everyone who viewed a presentation.

- Lack of middle school visits was a limitation to data collection. Dedicated middle schools make up just 5% of school bookings in an average year. The substitution of youth enrolled in fee-based science camps may not be representative of the 6-8 grade students who would visit the Science Center on a field trip. Because each student dataset came from just one presentation of each topic, versus multiple for casual museum visitors, responses are only representative of a unique experience rather than a blend of feedback over time.

- The Lectora content training system was ill-suited to the Science Center's needs and content was delivered more informally. Because the training was deeply embedded within the standard practices of the Science Interpretation Program, some staff didn't identify it as such and so were unable to comment on the EESS content training's contribution to their knowledge gain.

- Scheduling conflicts necessitated smaller focus groups (of four, four and two staff). The atmosphere was more like that of a group interview rather than staff discussion so feedback was less of a view into their world and more of a structured question and answer session. Additionally, the audio recorder failed early on in the final focus group so only the facilitators notes were only available for reference. Some detail may have been lost.

METHODS

Due to the multitude of outcomes, a mixed-methods approach was used to evaluate the effectiveness of EESS. Surveys were the main method of gathering data but focus groups and observations were also used (see **TABLE 2**).

TABLE 2. Methods by audience

Audience	Method	Timing	Sample Goal
Casual Visitors	Post survey	Nov 2015-July 2016 Following each show presented in the demonstration format	30 per topic (6 topics) Administered at multiple shows Total of 180
Middle School Students	Post survey	July 2016 Immediately following the show All students given the survey	1 camp per topic (6 topics) Total of 120
Science Interpreters	Focus group	Sept-Nov 2016 After the busy summer season to allow for maximum opportunity to present	All Interpreters that repeatedly presented at least one EESS topic Total of 12-16 in two groups of six
	Observation	March 2015-May 2016 Peers conducted observations while supervisors conducted "check-outs"	12-16 Interpreters observed at least twice Total of 24-32

Methods for Visitors

Post surveys after full demonstrations: Due to staffing limitations, we decided to focus data collection on six of the nine demos that the most staff presented. A five-question (plus demographic section) self-completed questionnaire was developed for adult viewers of EESS demonstrations. Forms were usually loaded on to clipboards and left on or under seats before the show. All viewers were invited to complete the survey and completed surveys came in a few at a time and could have represented just a fraction of a large audience or the entirety of a small one.

Questions were structured so that minimal re-phrasing was necessary between shows and to increase confidence of comparability. To measure potential changes in interest and understanding of concepts, the two closed-ended items were prepared in the "retrospective-pre/post" format in order to avoid the need to administer two questionnaires.

The wording of open-ended items was clarified with "after seeing this show" or "as a result of seeing this show" to focus respondents on their sphere show experience rather than something

else they may have seen in the museum or learned recently elsewhere. These open-ended items also allowed for expression of a variety of takeaways rather than testing for just one detail of content. This was important as Science Interpreters were encouraged to adjust their presentation on the fly as audience interests and abilities dictated and not all particulars were covered equally by all presenters.

Methods for Students

Post surveys after demonstrations: Many of the practices mentioned above during development of the casual visitor survey were applied for students and the instrument was based on the adult version. Occasionally, language was modified to be simpler but otherwise the format and original methodology for data collection were similar. Unfortunately, the target audience, middle schools, rarely booked Science On a Sphere shows as part of their field trip experiences. Therefore, during the summer, the sample was expanded to include middle school-aged participants in Pacific Science Center summer camps. Much like a school class, they attended the demonstrations as part of a semi-structured day and were accompanied by Camp Teachers who kept the students focused on the show. Efforts were made to schedule camps that focused on topics related to Earth science, remote sensing, or the use of data.

Methods for Staff

Focus groups: Guided group discussions were utilized in order to allow staff to discuss, in their own words, how participation may have affected their knowledge, confidence and overall ability as presenters. The discussion guide included prompts to get to know participants and their backgrounds, a question about how staff liked doing SOS as compared to other interpretive activities they engage in and a section with questions addressing confidence and ability. A questionnaire for collection of minimal quantitative feedback was aligned directly with the discussion prompts and staff completed it during the focus group.

Supervisor and peer observations: To assess strategies that staff used that were particularly effective in engaging audiences, five open-ended items were added to an existing supervisor observation form. Both supervisors and peers completed observations and they were conducted informally as well as part of the formal "check-out" process that occurs prior to being approved to deliver a given SOS demonstration on a regular basis. The items required that the observer provide evidence of how the interpreter engaged the audience in various ways (involving children or adults, orientation to datasets, connection to real life, etc.).

RESULTS

Audience A: Casual Museum Visitors

During the entire grant period, from December 2013 to November 2016, 1,877 EESS demonstrations were presented, reaching just over 25,000 museum visitors. This total includes all nine topics. This figure also includes those done as scripted shows as well as those interactions with guests that were more causal interpretation in nature. Staff approximate that early in implementation about 70% of demonstrations were given in the scripted show format. Over time, there was a decline in the use of the show format; during the data collection period, approximately 40% of EESS demos were done as full, formal shows.

During the nine-month data collection period, a total of **155 completed surveys** were collected from adult visitors who viewed a "formal" demonstration. The number of presentations, attendance at presentations, and surveys collected varied greatly by topic (see **TABLE 3**). For an example of the visitor questionnaire, see Appendix A.

TABLE 3. Evaluated shows: presentations delivered and surveys collected

Demo	Total Presentations	Total Audience	Surveys Collected
Alien Landscapes	371	4,828	26
Climate Change	69	773	27
Earthquakes	497	8,097	27
Our Changing Earth	135	1,663	20
Polar Regions	202	1,569	25
Volcanos	382	4,915	26

Adult respondents ranged in age from 18 to 84, with the mean and median age being 42 and the mode being 44, which is in line with the general demographics at the museum. About one-third (32%) of respondents were Members which is in line with the rate of visitation of Members during the data collection period (37% Members from November 2015 through July 2016). Respondents often lived close to the Science Center, with nearly two-thirds (62%) having zip codes in King County and nearly half of those (42%) residing in Seattle itself.

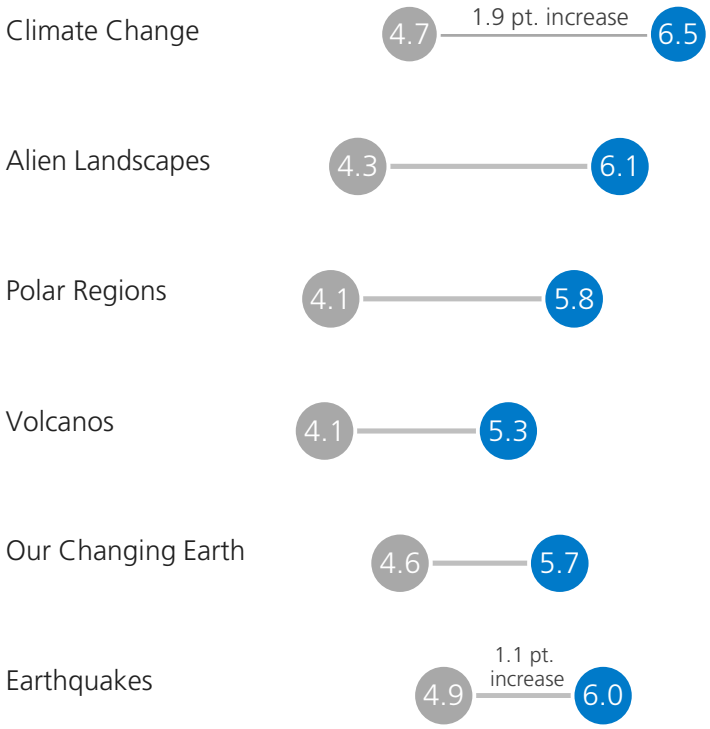
POST-SHOW SURVEY

Interest

Survey respondents completed a retrospective pre-post question about their interest in the topic of the show. All shows resulted in at least a one-point gain (on a seven-point scale) on

average in self-assessed interest from before to after seeing the show (see **FIGURE 1**). Considering all the topics together, it appears that shows about topics which visitors may be less acquainted with (Climate Change, Alien Landscapes), were able to support higher increases in interest. Less exotic topics – volcanos, earthquakes, and seasons – saw lower increases.

FIGURE 1. Interest in all topics increased from before to **after** seeing the show.
The magnitude of change ranged from 1.1 to 1.9 points (on a 7-pt scale).



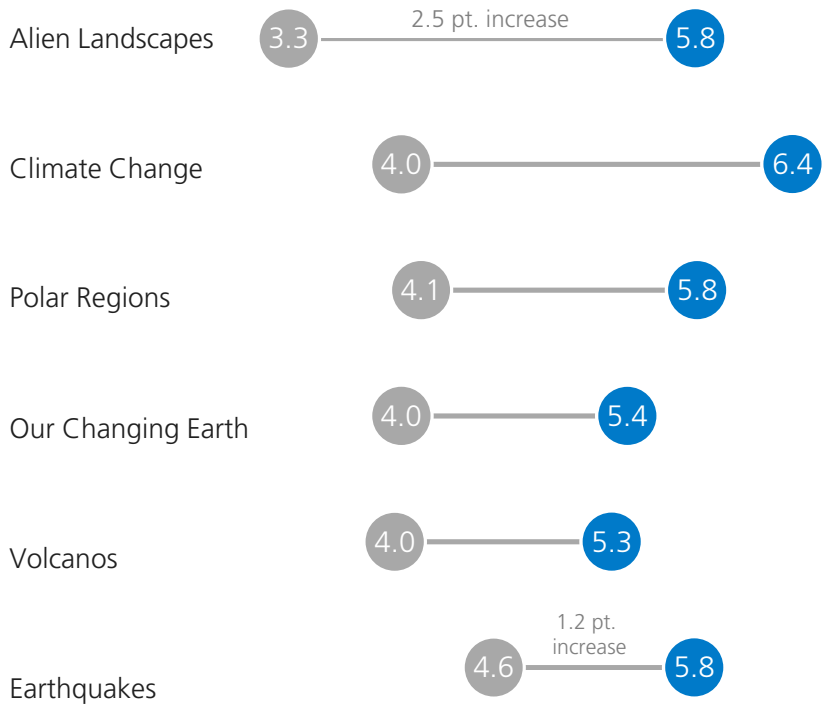
It was rare for any interest ratings to decrease; in fact, just one person indicated a loss of one point although their "after" interest was still 5 out of 7.

The range of increase in interests on an individual level spanned one to six points. The three individuals whose interest progressed from "1: no interest" to "7: extreme interest" saw the Climate Change presentation. These folks also indicated five or six points of increase in their self-assessed ability to make sense of large amounts of visual data. There were 25 individuals (16% of the sample) who expressed moderate increases from three to five points. The only show not represented in this set of folks was Earthquakes which is consistent with its comparatively low overall change average interest.

Many individuals (n=46 or 30%) experienced no change in interest. Of those, nearly half (48%) had already indicated "extreme interest," the maximum amount, before the show. The remaining "no change" respondents indicated interest ranging from three to six on the seven-

point scale. When the change in interest of the 129 respondents who *did not* already indicate the maximum interest level are averaged by show, we see even higher degrees of increase (see **FIGURE 2**).

FIGURE 2. When visitors who had the maximum amount of interest in the topic before the show started are removed, the average increases in interest are higher for all shows.



Respondents were also asked to share what fascinated them most about the topic, as a result of seeing the show. The item was presented as a "complete this sentence" format in order to encourage complete thoughts and consistency of language. The top four per show are shown below in **TABLE 4**. That there was such a range of things that inspired interest speaks to the variety of datasets and aspects of a topic that can be shared in 20 minutes.

It should be noted that a minority of respondents didn't respond to the prompt with a comment on the topic but rather praised the Sphere itself – a selection of quotes is included at the bottom on the table below.

TABLE 4. What visitors are fascinated by most, by show

Show	Code	n=	Example Quotes
Alien Landscapes	differences and similarities; the variety and diversity	9	*how similar they are to Earth* *how different each planet is*
	the possibilities; our ability to search; the options	7	*the reality that this is possible!* *All of the exciting possibilities*
	physical features or other bodies	7	*the different landscapes show evidence of oceans/water/life on the planets & moons*
	everything we've learned; our knowledge	2	*That we know as much as we do*
Climate Change	the effect of people	7	*how much of an effect we have on climate change*
	the "obvious" nature of the problem	6	*how apparent the problem is once you've been exposed to a few historical facts*
	how people are or could be helping	5	*Learning what part I can play in fighting against it!*
	rapid rate of change	4	*how fast it's happening*
	delicate balance	4	*how a small portion of CO2 ppm can cause such a change*
	degree/extent of change	3	*change over past century*
	global nature of issue	2	*how it is a global issue*
Earthquakes	causes	6	*the pressure and energy involved*
	effects; tsunamis	6	*the destruction* *tsunamis*
	scale/magnitude	5	*how the Richter scale works*
	frequency	4	*frequency of tremors in PNW [Pacific Northwest]*
Our Changing Earth	effect on animals	8	*migratory patterns*
	effect on ocean/water	3	*seasonal effect on water temp*
	how humanity adapts	2	*Man's ability to adapt*
	Earth's angle	1	*Earth angle to the sun and its effects on the season*

TABLE CONTINUES ON FOLLOWING PAGE

Show	Code	n=	Example Quotes
Polar Regions	comparisons (animals, poles, ice)	7	*penguins only live near the S pole and polar bears only near the N pole* *I didn't know that the South Pole was mostly land and that's why it [sic] melting is more important than the North Pole* *the difference between sea and glacial ice regarding sea level rise*
	ice melt or loss	7	*The shrinking of ice caps* *the way the arctic ice appears to melt unevenly*
	albedo	2	*the reason the poles are melting has to do with reflections on the lighter areas*
	ice structure	2	*the changes in the ice structure*
Volcanos	lahar, ash, lava	5	*the lahar* *Their ashes – so heavy but flies so high* *lava flow*
	quantity and locations	5	*how many exist globally*
	how they work	4	*tectonic plates* *when it erupts*
	human effects	4	*how much damage besides lava* *safety and preparedness*
ALL SHOWS	the Sphere itself; the technology; datasets	6	*the globe visual was awesome* *being able to see the process on the globe* *I really like the display on the big "planet"* *the visual of the ice melting over 30 years – really illustrates the issue!*

Understanding of the Process of Science

Visitors were asked to share what they thought the show told them about the process scientists use to study various topics. Responses were coded broadly into nine categories (see **TABLE 5**). Codes that covered just one or two comments were grouped into the "other" category. Nearly two-thirds (63%) of comments were references to the scientific process or examples of specific steps in the process. For this code, Earthquakes was the show that communicated this concept either most or clearest; 62% of Earthquake respondents wrote something about the process of science.

TABLE 5. What shows told viewers about the process a scientist uses

	Alien Landscapes	Climate Change	Earthquakes	Our Changing Earth	Polar Regions	Volcanos	TOTAL
Scientific method	5	8	13	2	6	8	42
Data		8		6	4		18
Tools to collect data	7	2		4	3	2	18
Things measured/observed	1	3	2	2	1	3	12
Over time/history		2	1	1	5		9
Quantity	1	1	3		1	2	8
Compare	6						6
Adjectives about process		1			1	2	4
Generic things scientists do	1	1				1	3
Other	1	1	2	1		4	9
TOTAL	**22**	**27**	**21**	**16**	**21**	**22**	**129**
No answer	*4*		*6*	*4*	*4*	*4*	*22*

In a similar manner, other shows had concepts that they were particularly effective at conveying. Or, they presented a balance of take-away concepts about the scientific process.

- The Alien Landscapes show was unique in that it was only one where comparisons were often referenced; this was the purpose of the show – highlighting similarities and different between Earth and other planets or moons that could potentially sustain life. The tools that were utilized to take measurements were brought up often as well.

- Climate Change show viewers referenced data in nearly one-third (29%) of their comments sharing that data were collected globally, were used to model conditions, took time to collect and analyze, or could be used as evidence for a phenomenon.

- The presentation about seasons and migration, Our Changing Earth, had the smallest sample but comments were somewhat spread out amongst data, the tools used to collect data, things that were measured and the scientific method.

- Polar Region and Volcano comments were similarly dispersed with emphasis on the long-term nature of the dataset and the sorts of things that are measured, respectively. The volcano show had the greatest number of "other" comments as viewers focused on safety measures and types of volcanos that exist and tracking of eruptions.

The Science On a Sphere technology is notable for its ability to show large amounts of data in context and in a dynamic and interactive way. Beyond understanding the general process of science, the hope was that by using the SOS to show real NASA and NOAA generated datasets, the public would begin to better understand these extremely large collections of information. The visuals for Alien Landscapes (Earth as the Blue Marble, Red Mars, Io, Europa) and Our Changing Earth (Loggerhead Sea Turtle Migration, Sea Surface Temperatures, Chlorophyll Concentrations) in particular seem to have contributed to large increases (1.5 points or more) in self-assessed understanding (see **FIGURE 3** for increased data comprehension results and **FIGURE 4** for examples of datasets).

FIGURE 3. Some shows increased viewers' ability to make sense of large amounts of information more than others.
Increases in average scores ranged from 1.6 points to .8 points (on a 7-point scale).

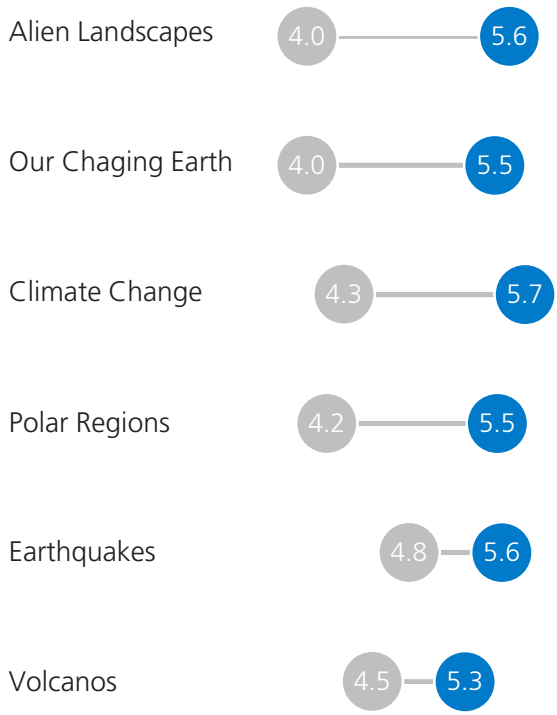
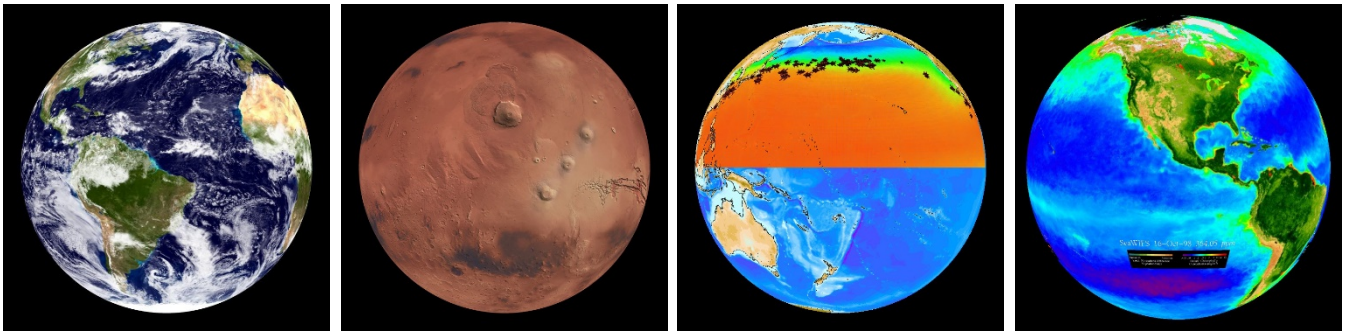


FIGURE 4. Datasets: Blue Marble, Red Mars, Loggerhead Sea Turtle Migration, and Chlorophyll Concentrations



Content Knowledge

To assess content knowledge, the gain of which was tertiary to interest or understanding of the process of science in general, respondents were asked to share what they learned *from the show* about a singular learning goal of each show. The main takeaways were different for each topic and are shown below in **TABLE 6**. Earthquakes was the show where most respondents provided answers that were clustered around the same idea resulting in just two codes – those that related to the geology of the Earth's crust and those that did not. Two shows, Our Changing Earth and Polar Regions, elicited a very wide range of comments from viewers.

TABLE 6. What each show told visitors about content specific to each topic

What did this show tell you about…	Code	n=	Example Quotes
Alien Landscapes how other planets and moons are similar to Earth (n=25)	physical features	17	*canyons, water, ice, mountains, atmosphere* *geology, landscapes, atmosphere*
	specific planet or moon mentioned	4	*Mars, Europa* *Europa has liquid water*
	comparisons	3	*Sometimes quite similar* *several are like earth and others are very different*
	life	1	*how some have life sustaining properties, water/O2*
Climate Change how carbon dioxide is related to climate change (n=28)	heat	10	*Carbon dioxide makes the planet hotter and hotter* *co2=heat*
	human impact	4	*Human choices are the main cause of the problem* *The negative our living does to the planet and how it causes it to get so warm*
	it is important	4	*that it's the main factor* *It is a large part of determining it*
	other (2 or less per code)	10	*carbon dioxide balance in the atmosphere* *the effects of temperature rise* *the comparison to Venus was really effective*
Earthquakes why Seattle is likely to experience an earthquake in the future (n=27)	tectonic plate / fault lines / subduction zone / ring of fire	22	*because of the tectonic plates* *it is on a fault line* *sits on the Ring of Fire* *subduction zones and location* *we're by two plates*
	other	5	*because we have soft lands* *we have more durable rocks than other places on the west coast faults*

TABLE CONTINUES ON FOLLOWING PAGE

What did this show tell you about…	Code	n=	Example Quote
Our Changing Earth how changing seasons impact animal migration (n=17)	causes of migration	3	*animals migrate to food* *they follow their favorite ocean temps because plant life changes with the seasons*
	sea turtles	3	*Sea turtle migration happens off the coast of Japan all the way to Mexico* *where turtles move*
	degree of impact	3	*great impact* *They are important and affect every living thing*
	patterns	2	*great to see patterns* *predictable patterns*
	causes of seasons	1	*affected by currents, rotation of the earth and most importantly axis position*
	other	6	*Confirm with what I know* *The future will be interesting* *I liked seeing the ocean plankton*
Polar Regions the changes we have observed in the polar regions over time (n=27)	ice melting	7	*reduction of ice caps* *the polar area ice is shrinking over the past 30 years* *that the ice is getting smaller*
	rise in temperature	5	*that the cold areas are getting warmer, and we should find a solution for it* *ice is melting, the regions are getting warmer* *It told me about how warming is more drastic and noticeable at the poles than the rest of the globe*
	sea level rising	3	*water level rising*
	problem is accelerating	2	*change is accelerating*
	it is happening	2	*Global warming is real!*
	other	8	*how much impact the population can have on the environment*
Volcanos the local hazards we would face if Mount Rainier erupts (n=41)	hazard examples	26	*air quality and air travel, lahars may be the biggest concern* *hot lava, houses and property destroyed, ash* *melted snow and ice* *lava, ash, lahars*
	safety / being prepared	9	*evacuation signs* *how to prepare for a volcano eruption, food, water, flashlight, etc.* *to help us prepare and have escape routes, first aid kids*
	other	6	*about what I expected* *not just local!* *Could happen*

Audience B: Middle School Students

During the summative data collection period, few middle school groups booked Sphere shows. Summer camps for grades 6-8 were invited to participate instead. Weekly camp schedules were packed and four groups were able to participate, one for each of four shows (chosen based on Science Interpreter availability as they needed to be presented prior to museum open hours). Camp capacity is 20 youth each, and most campers completed a survey following the show resulting in **129 completed questionnaires**. As with the adult form, questions were written in as similar formats as possible, swapping out only topical phrases, and addressed interest, understanding of the process of science and content knowledge. No demographic questions were included.

Interest

Student interest in Earth systems sciences was assessed through two questions; one a closed-ended circle-common-feelings format and one open-ended complete-the-sentence format. From a bank of six, students were asked to circle the two words that *best* describe how they felt about the topic presented after seeing the show. Most circled two words but some only circled one. The full range of responses is shown below (see **TABLE 7**).

The most circled word/feeling was "knowledgeable;" over half of students felt intelligent and well informed after seeing the show and this was more pronounced for Alien Landscapes and earthquakes – these shows may have shared more information that students hadn't learned before. "Meh" was included as a description of general neutrality, take-or-leave-it feelings; – the word was tested and found to be understood by tween-aged youth and this was somewhat common for most shows except Earthquakes. The Science Center aims to inspire curiosity in all guests and it is heartening to see close to half of campers (41%) admitting to being "curious." On the other end of the spectrum, the hope is that attendees are not "bored" or "confused" and it was nice that these words were circled least (by 11% and 3% of all respondents, respectively). The two students who were "confused" provided correct and thoughtful responses on the rest of the survey so it is unclear what they were confused about. The other word that both individuals circled was "curious" so they may simply be intrigued by the topic. That about one in ten 11 to 14 year olds admitted to being "bored" is acceptable and not surprising.

TABLE 7. Words that describe how students felt about each topic

Show	Knowledgeable	Meh	Curious	Excited	Bored	Confused	*Responses (Campers)*
Alien Landscapes	12	11	8	3	0	0	*34 (19)*
Earthquakes	14	2	9	3	1	0	*29 (17)*
Our Changing Earth	9	12	7	1	4	2	*35 (20)*
Volcanos	8	8	7	5	3	0	*31 (19)*
TOTAL	**43**	**33**	**31**	**12**	**8**	**2**	*129 (75)*
Percent of Campers	**57%**	**44%**	**41%**	**16%**	**11%**	**3%**	

Students were asked to share what interested them most about the topic presented after seeing the show. Their responses were wide-ranging, reflecting the variety of data viewed and points discussed in each show. Most students completed this question and while a few left irrelevant or indecipherable comments the rest were coded into four or five categories per show (see **TABLE 8**).

TABLE 8. What students are interested in most, by show

What interests me most about…	Code	Example Quotes
Other planets and moons	presence of atmosphere	*How not very many moons have an atmosphere*
	specific plant/moon	*Titan looks like a good planet*
	differences/similarities	*their different landscapes and structures*
	presence of liquid/lakes	*how some of them used to or now have water/liquid*
	the possibilities	*the possibility of life on Europa!!!*
Earthquakes	the effects/tsunamis	*that tsunamis huge killer waves that sometimes happen after earthquakes can destroy a building or house*
	their timing/historical quakes	*when the next earthquake will happen* *the next big one could happen soon*
	their magnitude/Richter scale	*What the Richter scales uses exactly to measure the size of the earthquake*
	causes and locations of	*what causes them and why*
The impact of the seasons to life on Earth	that seasons have an effect or exist at all	*how it causes one thing to shift causing another etc.*
	migration or animals following food	*everything tracks its food*
	position of the Earth or Sun	*that the Earth is tilted*
	further questions	*How else do seasons impact planets?* *Do animals even realize there is seasons?*
Volcanos	how dangerous ashes are	*that ash could kill us*
	safety	*That we can just do simple things to move out of the way and not get hit and be in danger*
	lava and lahar	*the lahar and lava*
	locations/types/causes	*That there are more types of volcanos than I thought* *learned what was under the ground and how the volcanos start*

Process of Science

FIGURE 5. The Science Toolbox and examples of steps in the scientific process

Students were offered a semi-structured way to describe the process a scientist could use to study the topic presented. They were instructed to provide three words or phrases. The components of the process that are actually included in the "Science Toolbox" were: Ask a Question, Define a Problem, Make an Observation, Investigate, Use a Model, Analyze Data, Construct an Explanation, Design a Solution, and Communicate Information (see **FIGURE 5**). These phrases were never all presented in a single show but are all parts of the new scientific method and are aligned with the Science and Engineering Practices in the Next Generation Science Standards. Students were not expected to repeat these verbatim but it was hoped that they would describe actions or steps in a similar vein. The order in which they provided responses was not considered when scoring.

"Ask a question" was the most common Toolbox step that was written, both verbatim and in various synonyms. It was almost always written first. Words relating to observing, collecting data, or tools used to collect data were next most common. Some steps came up more in some shows than others. For example, about half the students who saw Our Changing Earth wrote about studying, researching or investigating which were uncommon responses from other shows. Three students each from Earthquakes and Our Changing Earth wrote about sharing results or showing data to others.

Shows follow a prepared, though flexible, script and interpreters are free to adjust what they discuss based on their rapport with the audience. As such, some shows presented multiple steps more successfully than others (see **TABLE 9**). All but one student that saw Our Changing Earth responded to this question and all were correct. While correct response rates are average for the Volcanos group, 17-39% of students skipped the process of science question. This could be that only the question and investigation items were covered, or as may be more likely, that the group itself was particularly off-task during the show.

TABLE 9. What each show told students about the process scientists use

Topic studied	Word 1 % correct	Word 2 % correct	Word 3 % correct	Notes
Other planets and moons	71%	82%	69%	n=18, 1 student didn't respond
Earthquakes	76%	76%	76%	n=17, the same 4 students provided responses that weren't from the show
The impact of the seasons to life on Earth	100%	100%	100%	n=19, 1 student didn't respond
Volcanos	86%	75%	82%	n=18, 3, 6 and 7 students skipped words 1, 2, and 3

The extent to which students gained understanding of a specific step in the process was assessed by asking them how much they thought the show taught them about how to look at data and understand what it means. This closed-ended question had four options ranging from "nothing at all" to "a lot." The range of responses is shown in **FIGURE 7**. Alien Landscapes had the widest range of responses while the volcano show had the highest combined percentage of "some" and "a lot" (78%) and the earthquakes show taught the most students "a lot" (35%). Only one student each from Alien Landscapes and Volcanos said they didn't learn anything about how to look at and understand data (see **FIGURE 6** for examples of datasets).

FIGURE 6. All shows taught two-thirds or more campers **Some** or **A lot** about how to look at data and understand what it means.

Earthquakes was most effective at teaching A lot.

n varied from 17 to 20

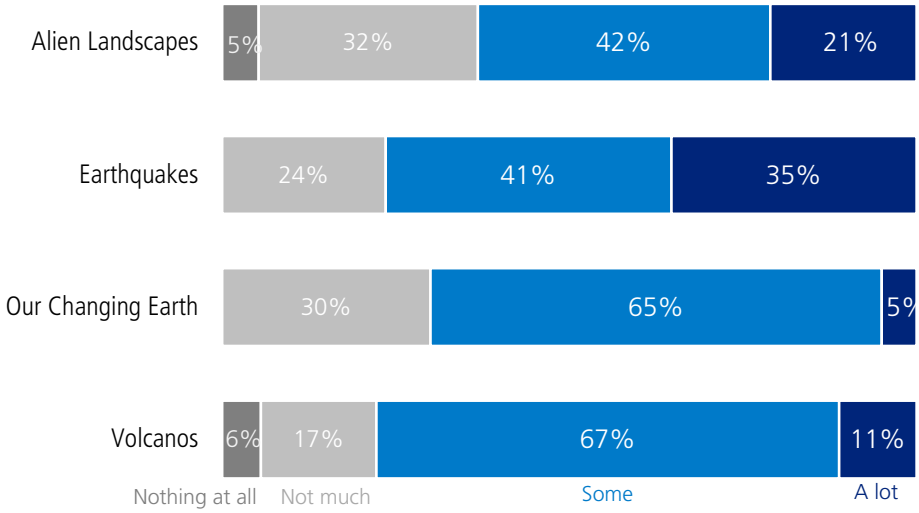
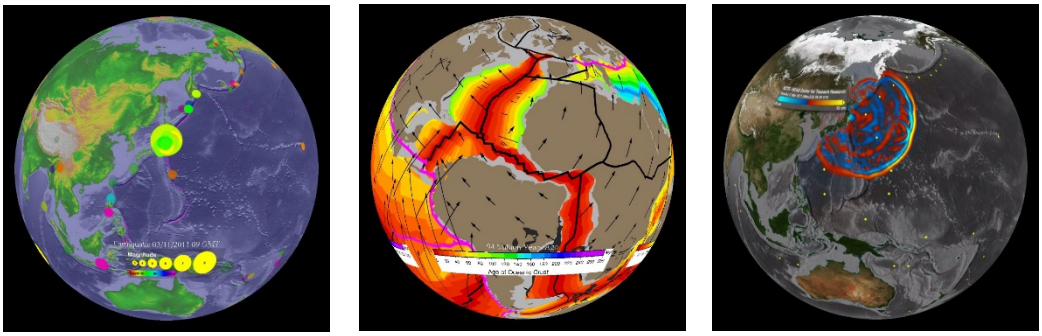


FIGURE 6. Datasets: Japan Earthquake, Plate Movement, and Tsunami Wave Propagation



Content Knowledge

While passing on large volumes of facts is not the primary goal of delivering Science On a Sphere demonstrations, we do hope viewers take away some knowledge; to that end each show has a few main points built in and supported by various datasets, audience questions, and hands-on activities. Because the student responses come from single presentations of each topic, rather than a large sampling, they are well suited to capturing the potential of this technology as an educational tool.

During analysis care was taken to code responses as either directly answering the question as written (see column 2 of **TABLE 10**) or a technically correct statement that did not answer the prompt on the survey (see notes on number of these statements in column 1). Of all 71 responses, just one wrote "nothing" and just four provided genuinely incorrect statements.

TABLE 10. What each show told students about content specific to each topic

What did this show tell you about…	Target Take-away(s)	Example Quotes
how other planets and moons are similar to Earth (correct statement but didn't answer question, n=11)	physical features in common (n=8)	*on how it could have things Earth has like Mars and Titan has an atmosphere!* *the atmospheres and landscapes of moons/planets compared to earth*
why there will be an earthquake in Seattle in the future (correct statement but didn't answer question, n=4)	tectonic plates or fault lines (n=11) we are due for one (n=2)	*there is a fault line that runs through Seattle* *Because earthquakes usually happen every 200-250 year, and the last earthquakes was in the 1700s*
how changing seasons impact animal migration (correct statement but didn't answer question, n=6)	animals follow their food (n=10)	*animals migrate according to their food* *the turtles follow their food who are migrating to the cooler waters*
the local hazards we would face if Mount Rainier erupts (correct statement but didn't answer question, n=8)	ash, lahar and/or lava (n=7)	*Lahar, lava, or ashes*

Audience C: Science Interpreter Staff

Three small focus groups were held during the final three months of the project. Four staff participated in the first two and two staff were present for the third for **a total of 10 participants**. This represents half of the 20 that had presented an EESS demonstration by the end of summer 2016. The discussions each lasted 55-65 minutes. Staff shared their background and experience with PSC generally and EESS specifically, as well as explaining a bit about their science knowledge in general. The group worked through questions on a variety of topics including: how presenting EESS content compared to doing other interpretive activities, how much EESS contributed to their knowledge of various Earth systems science topics, to what extent their participation contributed to their confidence in presenting Sphere shows, Rapid Response shows, and the scientific method, and finally how it may have impacted their overall ability as a presenter.

Along with participating in discussion, focus group participants were asked to complete a short questionnaire during the discussion. They were asked to rank how much they like doing other interpretive activities that they participate in at the Science Center as compared to doing EESS demonstrations and also to rate how much their participation in the EESS project contributed to their knowledge of and confidence with the various concepts mentioned above. See Appendix C for the discussion guide and questionnaire.

FOCUS GROUP

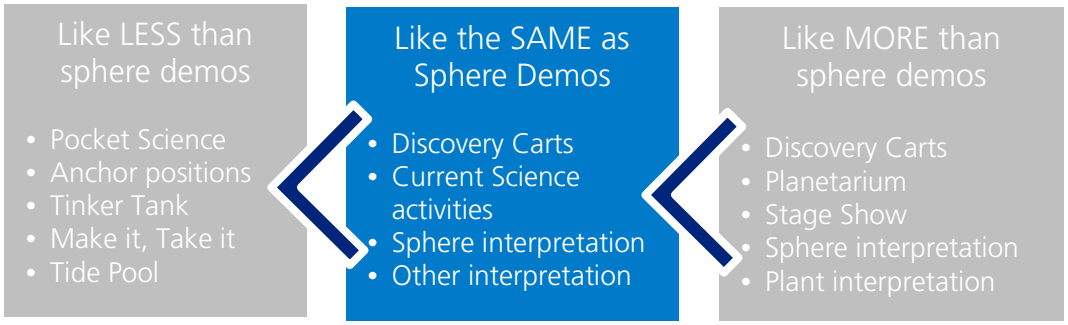
Overall, focus group participants were generally new to their interpretation roles at the Science Center; most had been in their current position less than two years. The Science Center has two categories of interpreters: standard floor educators and performance educators. The latter category additionally includes among their daily activities the presentation of Live Science Stage Shows and Planetarium Shows. Focus group participants were evenly split between the two categories and additionally created an even mix in each focus group (one or two of each position attended each focus group). Almost all had experience with one, two, or three shows; one interpreter could present five topics. The favorite demonstrations to present were Volcanos and Earthquakes because folks were very familiar with them (having been the longest running EESS demos) or they had the most props to interactive with and "most opportunity to have fun."

When asked how they would describe the EESS shows one interpreter said, "We get to use the coolest video game system in the world, looking at things on and off Earth. It's a very good means of communication," and "It's a marvelous tool. Fun to use." The SOS system was also seen as a way for interpretive staff who were interested in becoming performance educators to get some experience with scripted, prop-based shows.

Part A: Sphere Demonstrations versus Other Interpretive Activities

Staff acknowledged that the SOS was just one in a suite of activities that they do. As far as ranking it with other interpretive tasks, everyone's preferences were different though a few small trends appeared (see **FIGURE 8**). About half of participants preferred Discovery Cart facilitation best but an equal amount liked Carts about the same as Sphere demos. Staff who do planetarium and live stage shows definitely preferred those to sphere demos. Staff also liked doing activities in the Science Center's two current science exhibits about the same amount. Sphere shows were enjoyed more than many of the "anchor positions" on the museum floor such as "pocket science," "tropical butterfly house positions," "make it take it" tables, or the touch tide pool.

FIGURE 8. Enjoyment of doing Sphere demos compared to doing other activities (in staff's own words)



Part B: Impact of the EESS Project

After situating SOS demos within their sphere of experience, participants were then invited to discuss how their participation in the EESS project impacted their knowledge, confidence, and ability as a presenter (see **TABLE 11**). To supplement discussion, they also recorded quantitative ratings, on a scale of 1-7, on questionnaires. Average ratings were varied across measured impacts. Learning, practicing, and delivering EESS content, somewhat obviously, made the biggest contribution to presenter's confidence presenting sphere shows in general. It seemed to have the least impact on confidence explaining scientific processes and methods, which staff acknowledged they did frequently via other interpretive activities. Each impact will be discussed in detail below, with supporting evidence from the focus group discussions included.

TABLE 11. Measures of central tendency for rating of the contribution of EESS to staff development

On a scale of 1-7, rate your:	Knowledge of Earth systems science (n=17)	Confidence presenting Sphere shows (n=10)	Confidence presenting Rapid Response (n=6)	Confidence explaining scientific methods (n=10)	Overall ability as a presenter (n=10)
Mean	4	5.2	4.8	3.2	4
Minimum	2	2	3	2	1
Maximum	7	7	6	5	6
Mode	3	7	5	3	6

Knowledge of Earth Systems Sciences

The contribution of the project to their knowledge of Earth systems sciences was not consistent between staff as there were six regularly presented topics and individuals all had quite differing education and experience backgrounds (such as theater, English, geology, biology, or formal education). Still, EESS had some impact. Staff were invited to rate the contribution of EESS to their knowledge of each topic they had taught separately so in the end there were 17 ratings to average. On a scale of 1-7 (where 1 = the EESS did not contribute at all, to 7 = EESS completely contributed), focus group participants gave a mean rating of 4, while the most common rating they gave was slightly lower (3) with regards to how much their participation contributed to their knowledge of Earth systems sciences. The ratings ranged from 2, with the participant explaining, "I knew a lot about climate change" to 7, which was qualified with, "I didn't know anything about ocean currents." One interpreter summed up the general consensus with their comment, "I already knew about 95% of volcanos. I didn't know squat about oceans. It depended on where the gaps were in my previous knowledge."

Confidence Presenting Sphere Shows

Because the IMLS grant provided for the first intentional development and training for scripted SOS demonstrations, it is not surprising that participation had the highest overall impact on staff confidence presenting sphere shows in general. Staff said things like "I hadn't done a sphere demo before so, [it impacted my confidence] a lot," "It's the only place I would have encountered a sphere and I wasn't so sure at first," and "it's all I've done with the Sphere." Accordingly, the most common rank staff chose was 7 and the average from all ten staff was 5.2 out of 7. There were exceptions, however. More tenured staff did not gain as much from the rollout of EESS; one commented, "[I gave a low rating] because I'd done some sphere demos. I knew how they worked." A perspective that only came up once was described as "backwards" by one staff member. They said, "I actually use my experience with other things to do the Sphere better."

Confidence Presenting Rapid Response Shows

Rapid Response shows were necessarily dependent on relevant events happening in the world. Twenty Rapid Response presentations took place during the grant period so while staff were aware of them and trained on procedures, few had a chance to deliver a current event show. Just six folks felt they could give a rating at all but when they did, they talked less about confidence and more about other outcomes such as awareness, "knowing about the earthquake in Italy – I would not have kept with those things as extensively." Another said, "It's nice that we have a system in place to get the most current info before we go out on the floor. And it's also empowering us to look up info."

There was also an interesting exchange during one focus group highlighting some of the limitations of being able to do Rapid Response:

> *If you don't do earthquakes and volcanos you miss out on the Rapid Response.*

There's also hurricanes.

Not many people do hurricanes.

Confidence Explaining Scientific Methods

Explaining the process of science is a core delivery objective at the Science Center. Scripted EESS shows were structured around following the scientific method and highlighted the "tools" that scientists and researchers use by the use of a clever visual pun. Not all steps in the process were used in each show but at least a few always were (see **FIGURE 5**). Staff reported being fairly confident with this already, with most rating the contribution of EESS to their confidence as 3 out of 7. They clarified that they were knowledgeable already with some saying "I got them from getting a degree," or "I worked on science textbooks. I've done so much of it in a previous life." Still, as mentioned above, not all interpreters come from a science background and were able to grow significantly: "As a person who did not study science in college, I had never seen anything like this. We use different toolkits for each show – so we use different methods for different types of science."

Overall Ability as a Presenter

Focus groups wrapped up with discussions on whether and to what extent participation in the EESS project had an impact on staff's overall abilities as a presenter. Staff had strong reasoning behind each of their ratings here, some were already very comfortable performing, some found doing sphere demos nerve-wracking and still others credit the experience with the majority of their recent growth. The average contribution to overall ability for the ten staff was in the middle of the scale, 4 out of 7. Still, the mode was 6 so most staff did grow greatly from the EESS experience. Reasoning, in their own words, is presented below.

Two performance educators rated 3, citing their experience on the Live Science Stage:

"I'm pretty afraid of performing in front of people. If anything what helped me most was [doing] the stage [shows]. I'm more afraid of the sphere.

"Having been a presenter for a long time, I brought my skills from the stage to them [the EESS demonstrations]."

Folks who rated higher:

"I rated it higher because it's hard not to be a teacher. [when I started doing the shows] I had to find ways of leading people to find stuff. Banter, asking questions without answering them… it's so much harder."

"Frequency [of shows – up to five presented a day] was a nice way to figure out what your communication style is with large groups rather than one-on-one."
"Yeah, the frequency helps. I've done two in a day before."

OBSERVATIONS

From March 2015 to May 2016, Science Interpreters were observed by their supervisors or peers while delivering EESS shows . Twelve staff were observed two or more times each and four were observed once. In addition to the usual metrics that are observed during a standard "check-out" observation (proper set up and post-demo procedures, content covered, presentation style and use of tech), five open-ended items were added to the instrument. The items addressed visitor engagement and required observers to provide evidence of how the presenter addressed each of the following: how guests were oriented to the datasets, how children and adults were engaged, what visitors shared, and how the information was connected to real life.

How viewers were oriented to datasets

One of the first strategies that presenters used to engage visitors was orienting them to the sphere datasets. Of the 31 observations, just two staff did not do this and the omissions occurred during the Alien Landscapes show which focuses less on animated overlays of data and more on images of other planets and moons. Six interpreters did provide some orientation for viewers during the Alien Landscape show so it is possible, though different methods are called for than for the rest of the shows. The most common method that 29% of staff used was to explain what the colors and icons of the datasets meant. They often did this by asking audience members to share what colors often mean and then explaining if the current set followed that formatting or not; this was the second most frequent strategy that observers noted.

Other methods that were observed two to four times among the sample included: explained what was on the screen (especially in the case of the Alien Landscapes images), showed where "we" (Seattle) were on the map, pointed out the running date "timer," explained where the data came from, whether that was the agency providing data or the tool that collected it, and talking the crowd through the changes as they were happening.

How adults and children were engaged

The number one way both adults and kids were engaged was that presenters asked them questions, which is a core principle of how the Science Center encourages learning and curiosity. This was written down by 61% and 43% of observers for adults and kids, respectively. It was supplemented by its counter-part action, "answered guests' questions." The open nature of the prompt allowed for observers to respond from the perspective of the visitor as well, so other similar responses were readily supplied such as: adults/kids asked questions, adults/kids answered questions. When all four of these variations are combined the basic ask/answer questions method was observed 80% of the time for adults and 83% of the time when children were present.

A couple of advanced refinements of the questions strategy were observed as well; this included waiting for an answer from the crowd as well as repeating the crowd questions or answers so everyone could hear.

Other strategies that came up infrequently for both age groups were to ask for or appoint volunteers, ask the audience for a vote, and use humor. One observer praised a staff member for looking directly at kids in the crowd and another admired that they got down to child level to explain something.

What visitors shared

Visitors were usually (88% of the time) encouraged to be active participants in the presentation by sharing thoughts, opinions or stories. In line with what was discussed above, the most frequent way this occurred was that they answered questions. It is likely that nearly every comment that observers noted was instigated by a question. However, when observers were specific, they indicated that some individuals made observations about what was happening on the sphere or shared a personal experience with the phenomena being displayed.

How the information was connected to real life

Connecting big datasets to visitors' everyday lives was seen as a way to foster interest through demonstrating relevance. There were several ways that staff were observed to do this. The most frequent (33%) was that they shared a "what you can do" type takeaway. For some shows this took the form of a discussion on safety preparedness (Earthquakes, Volcanoes) and for others it was a message on the individual or community solutions to global warming (Climate Change, Polar Regions). Presenters also often emphasized the locality of the causes or effects of the phenomena that were shown or simply showed today's weather as a dataset. They also provided compelling appeals to common experiences such as huddling under a blanket, laying outside in the summer time, or visiting the ocean. Occasionally, analogies were extremely effective such as when one presenter likened weather to one's oft-changing mood, and climate to one's more enduring personality.

DISCUSSION

Visitor Outcomes

As a result of their attendance at an EESS Science On a Sphere presentation, casual museum visitors were anticipated to grow in two categories ,knowledge and attitude, as defined by three specific outcomes listed below. Each will be discussed in turn, using evidence from the results of the post-presentation survey used with this audience.

	Intended Outcomes	Outcome Category
Visitors will…	• Demonstrate new or increased interest in Earth systems topics	Interest or engagement
	• Better understand the process of science	Knowledge or understanding
	• Increase their knowledge of Earth systems science content	Knowledge or understanding

INTEREST

In the Science Center, it was not surprising that 15% of EESS show viewers indicated that they were "extremely interested" in the topic of the show – the maximum end of our scale. All of those individuals indicated sustained interest the conclusion of the show. When they are removed from the sample, the remaining 129 visitors reported average increases of 1.2 to 2.5 points on a seven-point scale for individual shows. Alien Landscapes, or other planets and moons, grew from the least interesting topic (3.3) to tie for second most interesting (5.8) likely due to the "exotic" and usual content for the average adult. Climate Change, another topic whose mechanics are likely less known, experienced a 2.4 point increase. Topics which are fairly common in the Pacific Northwest, earthquakes and volcanos, saw the smallest increase although no topic rated an average of less than 5.3 out of 7. While it makes sense to maintain delivery of the most relevant topics to the Seattle region, it would also be wise to keep staff knowledgeable about shows that can capture the imagination and provide the greatest impact on interest.

Adults noted a very wide range of things that fascinated them about the show topic, so much so, that only the top four coded areas of interest could be included in a summary report of this nature. One theme that was consistent was the impact of and on humans as a result of geologic, oceanic, and atmospheric phenomena. This suggests that connecting even difficult topics to daily life is an important strategy.

PROCESS OF SCIENCE

Nearly one-third of adults connected the scientific method to the processes that scientists use to study phenomena. When they did not make direct appeals to that phrase, they provided

specific components of the process such as data itself or they described tools used to collect said data or aspects of the world that are measured. Different shows highlighted some concepts more than others but these takeaways were all in line with learning goals from scripts that staff prepared. For example, a wide variety of datasets were shown to support the existence of human-impacted climate change and in surveys, viewers of that show commented often on the process of collecting, analyzing and sharing data. Similarly, comparisons between the Earth and other moons and planets in our solar system drive the Alien Landscapes show. Responses to the question about the process of science for that show centered around similarities and differences. In a nutshell, visitors were picking up what interpreters were putting down.

Similar to the increases seen in interest, visitors' average self-assessed ability to understand large amounts of data went up more for what are likely unfamiliar topics – Alien Landscapes (other planets and moons) and Our Changing Earth (seasons). And again, Earthquakes and Volcanos showed the least degree of improvement. The takeaway here is that the SOS is uniquely equipped to help visitors understand the conclusions that scientists come to the data they use to make those decisions.

CONTENT KNOWLEDGE

Like interests, there were many content-based take-aways even within single topics. A few respondents for each topic provided off-topic comments but aside from those, everyone answered the question that was asked and they were generally correct in their statements. Because the samples sizes for each topic were small, it is difficult to pinpoint trends in take-aways with any more specificity save that everyone had them.

Student Outcomes

As a result of their attendance at an EESS Science On a Sphere presentation, middle school aged students, like adults, were anticipated to grow in two categories –knowledge and attitude– as defined by three specific outcomes listed below. Each will be discussed in turn, using evidence from the results of the post-presentation survey used with this audience.

	Intended Outcomes	Outcome Category
Students will…	• Demonstrate new or increased interest in Earth systems topics	Interest or engagement
	• Better understand the process of science	Knowledge or understanding
	• Increase their knowledge of Earth systems science content	Knowledge or understanding

INTEREST

Though middle school students proved to be a difficult audience to capture, they responded favorably to the EESS demonstrations they saw. We do not have baseline data to compare to but it stands to reason that over half (57%) of students' feeling knowledgeable after seeing a show is positive. Slightly more students felt not much of anything, "meh," than those who felt "curious" so one suggestion, should this segment continue to be a target audience, would be to aim to reverse those two metrics. Like adults, youth provided many unique things that interested them suggesting that, at least to science-minded campers, EESS shows can provide something for everyone.

PROCESS OF SCIENCE

Two-thirds or more of campers in each show thought they learned "some" or "a lot" about how to look at data and understand what it means. The Earthquakes show was most effective at teaching "a lot" likely due to the varied colorful and generally easy to interpret datasets. Volcanos was also successful at teaching data analysis, over two-thirds (67%) of students thought they learned "some" from this show. The Science Toolbox was particularly effective with the age range of this audience. Nearly every student recalled that "asking a question" was an important part of the process that scientists use to study phenomena. In one instance, 100% of campers provided three correct responses. Another six or seven students (out of 20) skipped the question or parts of it. For delivering group shows, this highlights the importance of classroom management skills, which prove even more important in circumstances such as the experience Science Center's SOS display provides (open and distracting).

CONTENT KNOWLEDGE

The quality of students' response to the content questions rivaled that of adults. Only four of 129 provided genuinely incorrect statements. The rest of the comments were divided between

correct comments that directly answered the question posed, and correct comments that didn't. For most topics, except Alien Landscapes where students were preoccupied with simply naming planets, those that responded to the prompt outnumbered those who didn't. As stated earlier, because the presenter and circumstances were not variable within topics, the findings are well suited to capture the full potential of the SOS technology as an educational tool. That such high percentages of students displayed interest and content comprehension provides further evidence that the Science On a Sphere is an engaging and effective learning technology.

Staff Outcomes

As a result of their training for and delivery of EESS Science On a Sphere presentations, Science Interpreters were anticipated to grow in three categories –knowledge, attitude, and skills– as defined by four specific outcomes listed below. Each will be discussed in turn, using evidence from the results of the two methods used with this audience: focus groups (with accompanying questionnaires) and supervisor/peer observations.

	Intended Outcomes	Outcome Category
Science Interpreters will…	• Increase their knowledge of Earth systems science content	Knowledge or understanding
	• Increase their capacity to deliver regular Earth science basics and Rapid Response presentations	Attitude
	• Increase their comfort and confidence delivering interactive presentations on Earth systems science	Skills or behavior
	• Increase their ability to dynamically communicate Earth systems science	Skills or behavior

CONTENT KNOWLEDGE

The amount of new content that staff needed to learn in order to present EESS demonstrations was variable. Therefore, the amount of knowledge gain that they could attribute to their participation in the EESS project was variable as well. On questionnaires they reported that EESS training contributed little (minimum rating of 2) to their knowledge of various topics to being the only reason or way they learned about others (maximum rating of 7). Staff were more able to talk in depth about learning to present the shows, as opposed to process they went through to learn the content. The switch to a less formal, blog style learning format may have made the experience less prominent in interpreter's minds as they did not mention it during the focus groups. This is likely a happy, unexpected outcome of not using the Lectora system. The idea of online training itself was well-liked and successfully adapted to fit the needs of the interpretation team and was a great learning experience in and of itself.

CAPACITY TO DELIVER BASIC AND RAPID RESPONSE DEMOS

Somewhat obviously, staff report that participation in the EESS project contributed greatly (mode rating of 7 out of 7) to their ability to deliver SOS scripted demonstrations as well as informal interpretations. About half of focus group participants said they "don't really do Rapid Response" but this was for two logical reasons, 1) only a few events of significance occurred during the grand period and 2) these events necessitated that staff know the Earthquakes, Volcanos, Hurricanes or Alien Landscape shows. For those who had done a few demonstrations or interpretations on global event days – they acknowledged that the timely access to information and ability to "free-style" a show to help museum visitors understand the event was highly valuable. In the months since the grant has officially ended, the

Interpretation team has decided that the Earthquakes and Volcanos shows will be the first that staff learn with regard to the SOS as these phenomena are of great local relevance and most frequently related to global events.

COMFORT AND CONFIDENCE

The Science On a Sphere presents an interesting interpretive experience for science educators. Maintaining the attention of an audience that is not captive in a loud, sometimes chaotic space is challenging and staff mentioned as much during the focus groups. Those who were performance educators preferred doing Live Science Stage shows and Planetarium shows to sphere demonstrations for this reason. Performers did not feel the EESS project increased their confidence a lot (ratings of 2 or 3) citing that they felt comfortable doing performances already or that they were, in fact, more nervous doing sphere shows. The individuals who were nervous clarified that continuous practice certainly helped but more often they tried to bring skills and audience engagement strategies learned on the stage or in the planetarium out to the sphere. Those who were not performers liked doing EESS shows either the same as, or less than, the closest equivalent interpretive activity – Discovery Carts. Educators are hired for their out-going nature or ability to communicate confidently with the public (among other things) in the first place but most acknowledge some stretching or strengthening of their ability overall as a result of the EESS project. The average contribution to overall ability for the ten staff was in the middle of the scale, 4 out of 7. Still, the mode was 6 so most staff did grow greatly from the EESS experience.

DYNAMICALLY COMMUNICATE SCIENCE

Based on adult and student take-aways, as well as focus group feedback, the Science Toolbox is a successful and engrossing way to present and deliberately work through the scientific method. The EESS project had the least, though still moderate, impact on staff's ability to explain how the process of science works. The most common rating here, on a 7-point scale, was 3 and the individual scores ranged from 2 to 5. While many staff came from science backgrounds or had extensive experience at the Science Center already, some were new the world of science altogether and cited large increases in understanding of the concept.

In addition to making an academic process literal and hands-on, staff also excelled at engaging the audience directly and in many ways. In nearly every observation made, staff were seen first orientating viewers to datasets and images on the screen. They engaged guests by asking and answering questions and some astute observers noted additional tactics such as repeating audience questions or answers back to the whole group and simply waiting and allowing time for someone to answer. These are standard teaching devices that the Science Center promotes and it is heartening to see that they can be adapted with such success to the Science On a Sphere. One way of teaching that the EESS shows also supported was the connection of global events to local and personal life; this was seen often as presenters shared how to react safely to or decreased their contribution to various phenomena such as earthquakes or climate change.

CONCLUSION

This summative evaluation of the Exploring Earth Systems Science project set out to answer three evaluation questions:

1) To what extent are the intended outcomes of EESS achieved with public audiences—general visitors and school groups?

2) To what extent has participation in EESS impacted the professional development of PSC's Science Interpretation staff?

3) What are the strategies employed by Science Interpreters that are particularly successful in communicating key concepts and engaging audiences?

The short answers are to a great extent, also to a great extent, and through direct engagement or by creating relevance. The caveats to the former questions acknowledge that though the respondents we heard from cited robust takeaways and increases in both interest and abilities, there were, and remain, substantial difficulties in delivering scripted SOS demonstrations in its current location. The Science Interpretation team has already taken steps to carefully calibrate which shows are done with what degree of formality in order to maintain a range of options for both staff and visitors to benefit from this cool technology.

Public audiences, adults and students alike, were able to articulate something about the show they saw that fascinated them. And both said that the show taught them at least "some" about how to look at and understand large amounts of data which is becoming an increasingly important ability – there is no other display or technology in the Science Center, or in most informal learning institutions, that can claim this outcome. Based on previous research done here and elsewhere, however, we know that the guidance of other friendly human beings is critical.

By going back and forth, asking and answering questions with visitors, Science Center educators are able to zoom in on the extent of existing knowledge in a crowd and build on that. By taking audience polls, welcoming brave souls to help with activities, and connecting even the most academic of data sets (for example, chlorophyll concentrations) to everyday life, a middle-school class is able to visualize how the relative positions of the Earth and sun are intricately connected to endangered species, a tourist from New Jersey is able to understand how a volcanic eruption in Washington state would impact her directly and Seattleites can see that the copious phenomena measured, tools utilized and datasets produced have provided overwhelming evidence of climate change. Pacific Science Center is deeply grateful to the Institute of Museum and Library Services for this opportunity.

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APPENDIX A: INSTRUMENTS USED WITH VISITORS

Tell us what you think…

…about the Science On a Sphere show you just saw! Your honest feedback helps us make our shows better.

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1. **How would you describe your interest in climate change** BEFORE **and** AFTER **the show?**

   BEFORE ☐ 1: No interest ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7: Extreme interest

   AFTER ☐ 1: No interest ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7: Extreme interest

2. **Complete this sentence. After seeing this show, what fascinates me most about climate change is...**

3. **What did this show tell you about the process a scientist uses to study climate change?**

4. **What did this show tell you about how carbon dioxide is related to climate change?**

5. **How would you describe your ability to make sense of large amounts of visual data** BEFORE **and** AFTER **the show?**

   BEFORE ☐ 1: No ability ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7: Expert ability

   AFTER ☐ 1: No ability ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7: Expert ability

Tell us about you, so we know that we've collected data from a diverse range of museum guests.

What is your zip code? _____

THERE'S MORE ➔

In what year were you born? (YYYY) _____

Are you currently a Pacific Science Center member? ☐ No ☐ Yes

Would you be willing to answer follow-up questions about this program in 2-4 weeks? Your feedback directly impacts future programs and we love to hear from you.

☐ No thanks

☐ Sure – if so, provide your contact info below. Please PRINT CLEARLY.

Your first name: _____

Email address: _____

*Your name and email will ONLY be used to send you a link to an online survey.

Thank you!

APPENDIX B: INSTRUMENTS USED WITH STUDENTS

Earthquakes/School Groups

Tell us what you think…

…about the Science On a Sphere show you just watched! Your feedback helps us make our shows better.

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1. **After seeing today's show, circle the two (2) words that BEST describe how you feel about earthquakes.**

Excited	Bored	Meh
Curious	Confused	Knowledgeable

2. **Finish this sentence:**
"After seeing this show, what interests me most about earthquakes is…"

_____

_____

3. **Tell us three (3) words or phrases that best describe the process a scientist could use to study earthquakes.**

1. _____ **2.** _____

3. _____

4. **What did this show tell you about why there will be an earthquake in Seattle in the future?**

_____

_____

5. **How much did this show teach you about how to look at data and understand what it means?**

☐ Nothing at all ☐ Not much ☐ Some ☐ A lot

Thank you!

APPENDIX C: INSTRUMENTS USED WITH STAFF

EESS Staff Focus Group Guide
Pacific Science Center
Updated 9.29.16

Project Experiences

☐ By way of introduction, tell me your name (for the recorder), how long you've been working at PSC and specifically how long you've worked as an Educator.

This conversation is focused specifically on your experiences with the Exploring Earth System Science (EESS) Science On a Sphere project. An important note is this project includes all the SOS demos EXCEPT the Pale Blue Dot and Ancient Earth shows–those're from a different grant project and aren't part of this discussion today. EESS SHOWS (9):

- Earthquakes, Volcanoes, Alien Landscapes
- Ocean: The Motion Potion, Hurricanes, What's the Weather?
- Climate Change, Changing Earth, Polar Regions

☐ Which of the EESS shows do you know? How long have you been doing them? Which do you prefer presenting?

☐ How would you describe that project to someone who knew nothing about it?

☐ How would you describe your involvement in the Exploring Earth System Science project? (**Facilitator will add description of any EESS activities not mentioned.**)

Project Impacts

☐ Do you think the EESS project has had any impact on you as a presenter?

- If yes, how has it impacted you?
- If no, why do you think it hasn't had any impact on you?

A. Thinking about your role as a presenter, how do you feel about doing Sphere shows as compared to other shows or interpretive activities? Use the scale on the paper in front of you to answer (I like doing Sphere shows: less than, the same as, or more than other interpretive activities). *{Ex: stage, planetarium, carts, tide pool, butterfly exit, make it take it, pocket science}*

☐ Explain your answer. Why do you feel that way about doing Sphere shows?

☐ Are there any Sphere props you love or hate? Which ones and why?

☐ If you could change anything about the Sphere what would it be and why? What about the format or content of the demos themselves?

☐ Tell me if, and how doing the demos for school groups is any different than doing them for the general public?

☐ Did you learn anything or gain any skills that are applicable to other interpretive areas at the Science Center?

☐ Tell me about your experience training for and practicing doing EESS demos? How is it different or similar to training for other interpretive activities? Any other thoughts on training or practice?

1

B. I'm going to read you some statements about possible impacts that the Exploring Earth System Science project might have had on you. For each statement, I want you to use the scale on the paper in front of you to rate it from 1-7, where 1 is not at all and 7 is completely. After you rate each statement, we'll talk about it and I'll ask you for an ex.

1. How much do you think the Exploring Earth System Science project contributed to your **knowledge of earth systems science** (for example, weather, climate, geology, oceans are all part of earth systems science)?
   - ☐ In what ways did EESS contribute to your knowledge of earth systems science?
   - ☐ Can you give me an example?

2. How much do you think the Exploring Earth System Science project contributed to your **confidence in presenting Sphere shows**?
   - ☐ In what ways did EESS contribute to your confidence in presenting shows on earth science?
   - ☐ *In what ways did it contribute to your confidence in doing other interpretive activities?*
   - ☐ Can you give me an example?

3. How much do you think the Exploring Earth System Science project contributed to your confidence in presenting Sphere shows that **deal specifically with rapid response to current events** that you haven't necessarily researched?
   - ☐ In what ways did EESS contribute to your confidence in presenting shows that deal with rapid response to current events?
   - ☐ *What experiences have you had during other interpretive activities where you've utilized rapid response training or responded to questions about current events that you haven't necessarily researched?*
   - ☐ Can you give me an example?

4. How much do you think the Exploring Earth System Science project contributed to your **confidence in explaining scientific methods** and processes that scientists follow?
   - ☐ In what ways did EESS contribute to your confidence in explaining scientific methods and processes?
   - ☐ Can you give me an example?

5. How much do you think the Exploring Earth System Science project contributed to your **overall ability as a presenter**?
   - ☐ In what ways did EESS contribute to your ability as a presenter?
   - ☐ Can you give me an example?

C. Is there anything else you want to tell me about the Exploring Earth System Science project?

Tell us about the "Exploring Earth Systems Science" project!

A. How do you feel about doing Sphere shows as compared to other interpretive activities? List other activities you do below the phrase that describes how you feel about them compared to Sphere shows.

I like doing Sphere shows **less than:** **the same as:** **more than:**

_____

_____

_____

_____

B. How much do you think your **participation in the project** contributed to...

1	...your knowledge of earth systems science (You may list different responses for different topics such as weather, climate, geology, oceans, etc.)?	Not at all Completely 1 2 3 4 5 6 7
2	...your confidence in presenting Sphere shows?	Not at all Completely 1 2 3 4 5 6 7
3	...your confidence in presenting Sphere shows that deal specifically with rapid response to current events that you haven't necessarily researched?	Not at all Completely 1 2 3 4 5 6 7
4	...your confidence in explaining scientific methods and processes that scientists follow?	Not at all Completely 1 2 3 4 5 6 7
5	...your overall ability as a presenter?	Not at all Completely 1 2 3 4 5 6 7