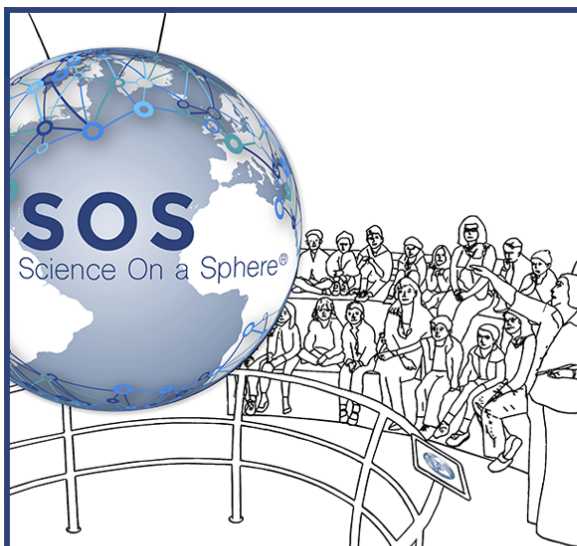


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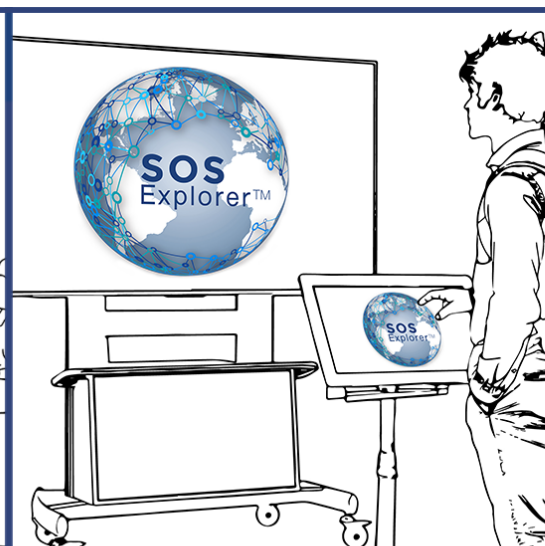
# NOAA's Science On a Sphere: Use-cases and Practitioner Insights

Prepared by Grace Bennett-Pierre, Hilary Peddicord, Beth Russell, Shilpi Gupta, Alexander Kirst, Yazelyn Benitez, Ellie Patchett, Rudi Herrig, Kathryn Hotzfeld, Carrie McDougall, and Anne Gold

CIRES Center for Education, Engagement and Evaluation  
University of Colorado Boulder  
April 2026



**Science On a Sphere®**



**SOS Explorer®**



**SOSx Mobile**

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**Authors:** Grace Bennett-Pierre, Hilary Peddicord, Beth Russell, Shilpi Gupta, Alexander Kirst, Yazelyn Benitez, Ellie Patchett, Rudi Herrig, Ren Hotzfeld, Carrie McDougall, and Anne Gold

**Illustration & Design:** Ami Nacu-Schmidt – Graphic Designer; University of Colorado Cooperative Institute for Research in Environmental Science (CIRES), Center for Education, Engagement and Evaluation

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**Contact us:** [ceee@colorado.edu](mailto:ceee@colorado.edu)



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# Motivation

Complex Earth system processes, such as climate dynamics, ocean circulation, or atmospheric change, are challenging to learn because they involve reasoning about multiple causal systems that unfold over time and space (Aksit et al., 2017; Cheek, 2010; Gold et al., 2021). For learners, Earth system concepts often remain abstract when communicated through text or verbal descriptions alone. Visualizations provide a powerful way to make such complexity tangible by turning data into interactive, interpretable, and emotionally engaging experiences.

Research in cognitive psychology shows that visual representations can enhance spatial reasoning (Gagnier & Fisher, 2020) and support conceptual understanding (Harris & Gold, 2017). Visualizations can also evoke affective responses such as awe or wonder which in turn may be linked to greater motivation to learn (Gilbert & Byers, 2017). When combined with opportunities for active participation, visualizations can transform how people connect personal decisions to global-scale challenges like climate change.

Science On a Sphere (SOS) builds on these principles by offering an immersive, three-dimensional display of global data. Unlike flat maps or charts, spherical displays reduce distortion and allow audiences to see Earth processes as they occur across the whole planet (Vega et al., 2014). This makes SOS a particularly compelling tool for science communication, informal education, and fostering climate literacy across diverse audiences (e.g., Goldman et al., 2010; Semmens et al., 2021, 2023). Here, we report findings from a survey completed in November 2024 – February 2025 of 92 past and current SOS and SOS Explorer sites. The goals of the evaluation are:

- 1) To situate the current study within the context of prior evaluations of the SOS network so that we can identify areas of change over time and gaps in knowledge,
- 2) To identify themes in current use trends for these technologies, including variation across different types of user sites,
- 3) To communicate these themes to practitioners to inform their SOS and SOSx use,

- 4) To use these themes to inform future software development and educational resources produced by the NOAA SOS Program.

### Why is it important to do this evaluation now?

Science On a Sphere was conceptualized in 1995, with the first working system completed in 2000, the first traveling installation in 2002, and the first permanent installation in 2004 (see Figs 1, 3). The last summative, cross-institution evaluation was conducted 15 years ago, in 2010 (Goldman et al., 2010). Since then, SOS technologies, the network of SOS institutions, and the SOS Program have undergone many changes. First, the number of institutions in the **SOS network** expanded significantly, from 49 museum sites in 2010 to over 200 sites in 2024 (Goldman et al., 2010; NOAA Program, pers. Communication). Further, events like the 2020 COVID-19 pandemic significantly impacted informal learning institutions (ILIs, American Alliance of Museums, 2022) and led to uncertainty about the number of still-functioning SOS installations in 2024. Second, the SOS Program introduced **new SOS platforms and modalities**: a flat-screen platform (SOS Explorer, or SOSx) in 2016 and standardized, touchscreen kiosk software compatible with both SOS in 2015 (see Fig 2). Third, the **number of visualizations available** for use on SOS and associated technologies increased, from 250 in 2010 to over 600 in 2024 (Goldman et al., 2010; NOAA Program, pers. Communication). Finally, the SOS Program moved from Research and Development in the NOAA Global Systems Laboratory to the **NOAA Office of Education** in 2021, strengthening the program's focus on building SOS and SOSx as educational tools. Simultaneously, the SOS Program was embedded into the **Cooperative Institute for Research in Environmental Sciences' Center for Education, Engagement and Evaluation (CIRES CEEE)** at the University of Colorado Boulder.

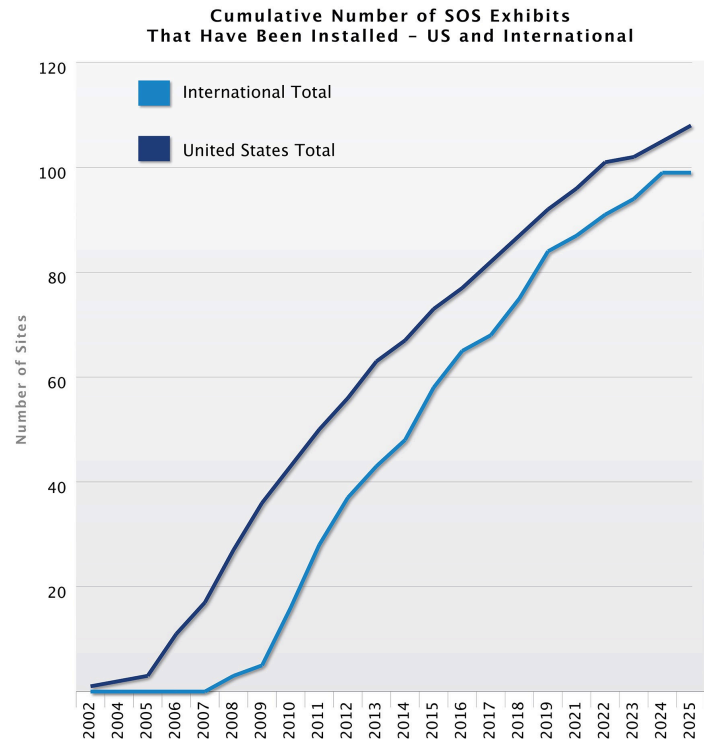
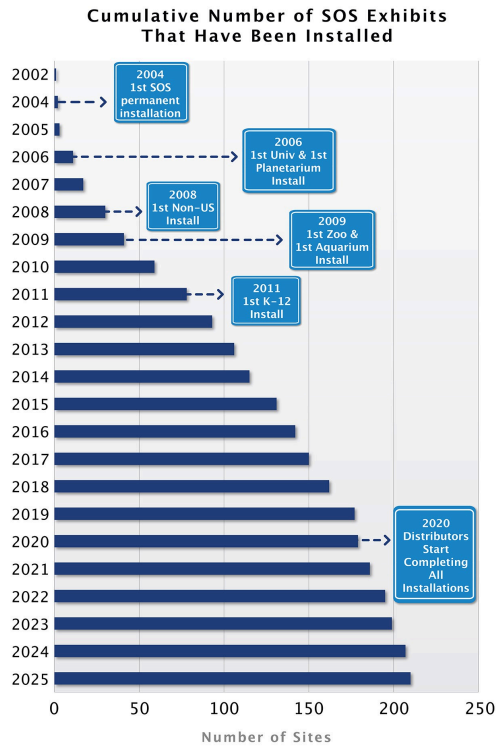




Figure 1. Initial Development of Science On a Sphere Technology



Figure 2. Timeline of Science On a Sphere Program



**Figure 3. Cumulative Number of SOS Installations from 2002 to 2025**

*Note – does not reflect exhibits that have been un-installed (n=21); 2002 was the first temporary installation while 2004 marked the first permanent installation.*

# Executive Summary

## Content

### What content is most often shown on the sphere?

- ⇒ Sites present a mixture of content on their SOS and SOSx installations, as evidenced by a low number of sites reporting “never” using visualizations from the seven content categories.
- ⇒ The most frequently reported category was “Ocean/Water” – which was also the most frequent category in the 2010 cross-site evaluation (Goldman et al., 2010), suggesting continuity in content use over time.
- ⇒ The frequency of content areas being used could also reflect the number of visualizations available in the Data Catalog. For example, there are over 200 visualizations in the “Ocean/Water” category, while there are only 15 in the “Arctic” category.

### How often are sites presenting content about climate change and are they using place-based, solutions-focused framing?

- ⇒ Climate change programming using SOS and SOSx is happening across the network and is not limited to a few sites.
- ⇒ About half of sites are incorporating solutions-focused and place-based framing into their climate change programming. Given that prior work in environmental education suggests that these framings support positive climate change learning experiences, future education work could focus on supporting sites as they develop these framings.

### What types of visualizations do sites use on SOS and SOSx?

- ⇒ Practitioners are informed users, selecting visualizations purposefully based on their perceptions of audience engagement and their knowledge of the content area they are teaching about.
- ⇒ Some visualization types are used more frequently than others, and future research should probe why. For example, visualizations with neither audio nor text are used frequently but Live Programs are used infrequently. This could reflect the relative number or the content available in each type of visualization, the conditions under which each can be used (e.g., Live Programs require a presenter, visualizations with audio require a quiet space), or knowledge of dataset types (e.g., low knowledge of Live Programs).

- ⇒ Practitioners report using both still and animated visualizations on their SOS or SOSx - 43% identify this dimension as something they consider when selecting visualizations. This suggests that the SOS Data Catalog should continue to support both types of visualizations.

### How do sites find content for their SOS or SOSx exhibit?

- ⇒ The most common way SOS and SOSx sites find out about new content is from the SOS website. Given that practitioners are already accessing the website for this purpose, the SOS Program could consider expanding opportunities to highlight new content in the Data Catalog through the website interface (e.g., a “spotlight” feature similar to the iPad app; linking or embedding social media accounts).
- ⇒ For SOS, the Education Forum serves as a valuable way for practitioners to learn about new content for their installation (~25% of SOS respondents). Future education and engagement work could focus on building out opportunities for cross-site communication and network-building for both SOS and SOSx users.

### How common is it for sites to use unaltered content from the SOS Data Catalog, augmented content, or create entirely site-custom material?

- ⇒ A high percentage of sites use visualizations from the SOS Data Catalog without altering them in any way (83%), suggesting that the SOS Program is producing and cataloguing visualizations that meet the needs of sites in the network.
- ⇒ A further 41% of sites augment visualizations from the SOS Data Catalog using customization options developed by the SOS Program. Knowledge of customization options is relatively high, but there is variation in which type of customizations sites use. Future research could identify why some customizations are used more than others, with the goal of streamlining customization options and increasing uptake of these features.
- ⇒ Over 50% of sites say that they produce new, custom datasets. Future work could explore what kinds of custom content sites are making, and why. It is possible that sites make site-custom content that would be applicable for other sites – if this is the case, the SOS Program could consider incorporating that content into the Data Catalog. Alternatively, site-custom content may truly be site-custom, and of limited use outside of an individual institution.



## Presentation Format

Which SOS platforms and modalities are sites using? Do sites ever use platforms together?

- ⇒ Few sites have both an SOS and an SOSx installation, and those who do generally do not use them together. Future research could investigate whether there are situations in which using SOS and SOSx in tandem could support learning (e.g., concepts that rely on multiple views of the Earth).
- ⇒ Both SOS and SOSx sites report having presenter-led interactions with their installations: about half of SOS sites have formal or informal presentations daily or weekly, 25% of SOSx sites have formal and 50% of SOSx sites have informal presentations always or weekly. Presentations are used for a variety of audiences, not just for school groups on fieldtrips.
- ⇒ When presentations are not happening, most sites have their SOS or SOSx in auto-run or kiosk mode.
- ⇒ Kiosk use has increased dramatically from prior evaluations: 68% of SOS and 62% of SOSx sites said that they “always” use a kiosk or touchscreen with their installation.
- ⇒ Together, these findings suggest a continued interest in and commitment to human-facilitated learning experiences with SOS and SOSx, and, simultaneously, a shift towards a lower cost interactive option (e.g., the kiosk). Future research should explore the trade-offs for learning in facilitated and unfacilitated contexts to both inform sites’ decision-making around which modalities to use and to inform the SOS Program’s work on the kiosk interface.

For sites that have facilitators, who are they, and how are they trained? Do facilitators use active learning techniques or props when presenting?

- ⇒ Facilitators are most frequently paid staff or educators; less frequent are volunteer docents or subject-matter experts (e.g., a visiting scientist).
- ⇒ Most sites (76%) provide training to presenters, but most of that training focuses on “the basics”, like how to operate the SOS or SOSx system. Few respondents report training presenters on teaching techniques (10%). Further, few sites reported employing training strategies that would allow for quality control (e.g., 9%, having an experienced presenter observe and provide feedback to a new presenter).
- ⇒ Many sites reported not using or not knowing if they use scripts for presentations with SOS (45%). Of the sites that did use scripts, many report that presenters make their own scripts, rather than using standardized scripts made for their site

or available through SOS Live Programs. Future research could investigate the reasons why sites do or do not use scripts, including site-wide scripts. For example, a lack of standardized scripts could reflect SOS and SOSx being used flexibly to present material customized to a site, specific presenter, or specific audience. It could also reflect sites' lack of knowledge around existing products (e.g., SOS Live Programs), or it could reflect a mismatch between Live Programs and site needs. In turn, more fine-grained information from sites about script utility could inform future development of educational products like Live Programs, or training around building effective SOS or SOSx scripts or programming.

- ⇒ Many sites report using low-cost active learning techniques like open question and answer or asking learners to make observations or predictions, while few use voting tools or ask learners to draw. Over half of SOS sites report not using physical props (57%) with their installation. For both active learning and props, there could be a resource barrier – asking learners to draw, using voting tools, and creating and using physical props may all require greater prep time and physical materials than other techniques or non-use. Future research should both investigate why sites choose to use or not use these teaching techniques, and test whether incorporating these techniques into SOS and SOSx presentations improves learners' motivation and conceptual learning.
- ⇒ Future education work could focus on creating and disseminating standardized training materials that include pedagogical practices to support presenters. Creating standardized materials would lower the burden on individual sites to develop their own materials and could encourage wider use of active and embodied learning techniques within SOS and SOSx presentations. Ideally, continued support for a robust training pipeline – including training materials, existing workshops, and Education Forums - would lead to more engaging and effective learning experiences with SOS and SOSx at a broader number of institutions.

### Does content, platform, modality (including presenter type and training), or teaching strategies systematically vary based on type of institution?

- ⇒ The types of presenters reflect the type of institutions, with more educators at educational institutions and more subject-matter experts (e.g., scientists) at government institutions. Across all sites paid staff are common presenters.
- ⇒ The rate of offering trainings was similar across institution types, however, educational facilities offered less information about the content included in their trainings. One limitation of the present study is that we elicited information about



training content through a free response question – future research should investigate in more detail the content of trainings to better understand this pattern.

- ⇒ Script use differs by type of institution: educational and government facilities are less likely to have scripts, and if they do, they are not site wide. We speculate that this could reflect less standardized educational programming with SOS and SOSx installations at educational and government facilities compared with ILIs. However, future research should further investigate reasons why these types of sites tend not to use scripts.
- ⇒ In terms of teaching strategies, both the rate and pattern of active learning strategy use is similar across institution types. However, ILIs are more likely to use props than educational and government institutions. We again speculate that this could reflect more standardized educational programming with SOS and SOSx installations at ILIs, though we do not have data to support this interpretation. Further, it is interesting that there are similar levels of active learning techniques used at institution types that are less likely to offer trainings.
- ⇒ The patterns of responses by type of institution highlight that there are multiple, distinct use-cases for SOS, which has been highlighted as a challenge for evaluation in prior work (e.g., Goldman et al., 2010). These use-cases are important to understand for effective software development and training or educational support. Future research or evaluation could focus on using a needs assessment approach to identify and build profiles of each distinct use-case. These “user-profiles” could then be used to inform the development of new software features, content, and training opportunities or materials, with the goal of supporting practitioners and learners at all institutions.

## Visitor Behavior and Reactions to SOS and SOSx

What do practitioners notice about visitor engagement with the sphere (e.g., age differences, movement around the sphere, responses to size and scale, engagement with the kiosk)?

- ⇒ Consistent with prior evaluations, most practitioners observed visitor surprise at the relative size and location of things on the sphere and reported affective responses like awe to both the content presented on the sphere and the technology of the sphere. This suggests that 20+ years after the first installation in an ILI, SOS remains visually striking and emotionally evocative for visitors.

- ⇒ About half of respondents said that presenters at their site ask visitors to move around the sphere<sup>1</sup>. Prior evaluations highlight the necessity of asking visitors to move around the sphere. However, these responses highlight a central tension of moving around the sphere – first, that visualizations on the sphere can be rotated, and second, the challenge of joint attention when positioned in the round (e.g., ensuring that the presenter and learners are attending to the same thing on the sphere). Future research could investigate the effect of moving around the sphere versus rotating the sphere on learning, as well as testing the effectiveness of SOS features that support joint attention (e.g., the splitter and zoom functions).
- ⇒ Practitioners' observations about the SOS kiosk or SOSx touchscreen offer an interesting contradiction. 34% of respondents thought that the kiosk allowed increased visitor choice, but 21% identify contextual challenges to using the kiosk with their installation. Given the rapid increase in use of the kiosk modality since the last cross-site evaluation, future research should focus on using naturalistic observation to understand how learners currently interact with the SOS and SOSx kiosks, as well as experimental approaches to test learning from these free-choice learning experiences.
- ⇒ Practitioners had many observations about age differences and similarities in SOS and SOSx use. Future research should investigate these themes –given increased kiosk use, understanding how age and modality interact when it comes to learning from SOS or SOSx seems crucial. This research can inform education work on appropriate scaffolding for learners of different ages, as well as development work on dataset catalog content and the kiosk user-interface.

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<sup>1</sup> A small number of sites indicated that the physical set-up of their SOS (e.g., a half-sphere) prevented visitors from walking around it.

- ⇒ Many challenges to using SOS and SOSx identified by practitioners focused on the human-technology interface and site resources. For example, 40% of SOS respondents identified training and retaining presenters as a challenge. Subthemes of the free response question about challenges included staff knowledge of how software works, and sites wanting to make their own content but lacking the resources to do so. Practitioners' observations offer two potential pathways to increasing access and decreasing challenges with SOS and SOSx: one, conducting user-interface testing on SOS and SOSx software and hardware to lower the barrier to entry for these technologies, and two, increasing standardized training materials and centralized onboarding for new users.
- ⇒ Practitioners highlighted valuable research questions that are aligned with open questions identified in our review of prior literature and evaluations. In particular, they highlighted questions about how people learn from SOS and SOSx, including individual variation in learning, the effect of different modalities on learning, and how we can understand the role learning experiences with SOS and SOSx can play in learners' actions around climate change. Practitioners' research questions demonstrate a synergy between the interests and goals of SOS and SOSx users and those of the SOS Program.

## Limitations

There were several limitations to the current evaluation. First, our response rate was 32-35%, which means that we did not have full representation of all SOS and SOSx sites. Further, we had more responses from sites located in the US than those located globally. This could be due to differences in who installed and stayed in contact with sites: many international sites were installed by third party distributors rather than the SOS Program. Second, the method we used is self-report by SOS practitioners and managers. We felt that this method allowed relatively quick collection of information from many SOS and SOSx sites and allowed respondents to contextualize SOS and SOSx use at their site. However, self-report data can be subject to biases in reporting. For example, 25% of respondents from SOS sites reported finding out about new visualizations from Education Forum meetings, which could reflect that practitioners who are more engaged with the SOS network were both more likely to attend Education Forums and to participate in the evaluation survey. Further, our data does not speak to questions about the relative efficacy of different SOS and SOSx platforms, modalities, or presentation techniques for learning. Third, many of our research questions were exploratory, meaning that in some cases we asked open-ended questions and then identified themes that emerged. As a result, for some questions, we do not know if a frequency of a response reflects the "true" frequency. For example, few sites included

having experienced presenters provide feedback to new presenters in a free response question about trainings, but the true frequency could be higher if we explicitly asked about this practice with a multiple-choice question. Future research should follow up on these themes using additional methods to ensure that we have an accurate report of the relative frequency of practices. Further, this evaluation identified many patterns of practices that future research may want to probe further to identify the “why” behind those practices.



# Introduction

The research questions and methods used in the current evaluation are informed by what we know from formative and summative evaluations and research studies focused on SOS conducted over the last 20 years. We started by organizing existing findings into three themes: what we know about the content shown on SOS at sites, the modalities in which learners interact with SOS, and observations of learner behavior and reactions to SOS. In addition, we introduce key terms necessary for understanding the evaluation results. Our goal in synthesizing across the past 20 years of work is to both theoretically ground the current study and offer a basis for moving research, practice, and operations for SOS forward.

## Key Terms

**SOS Network:** the community of practice made up of institutions that have SOS or SOSx exhibits; includes educators, researchers, and evaluators who have generated prior evaluations of SOS sites.

**Platforms:** the different software and hardware options developed by NOAA's SOS Program (Fig. 4).

Science On a Sphere (SOS): the original, 6-foot in diameter spherical projection screen, computers, and four simultaneous projectors, controlled with the SOS Remote App for iPads

Science On a Sphere Explorer (SOSx): a flatscreen version of SOS available for Windows computers; SOSx Mobile is available for iOS and Android, including mobile phones



Figure 4. *Science On a Sphere Platforms*

**Modalities:** the different ways that learners can interact with SOS and SOSx, analogous to “presentation formats” used in prior evaluations (Fig. 5)

Formal presenter-led: A facilitator (paid staff, volunteer docent, expert scientist) leads a presentation

Informal presenter-led: A facilitator guides an individual or small group of visitors through visualizations of their choice

Auto-run: A narrated movie or pre-set “playlist” of visualizations selected by an institution is displayed on a loop

Independent exploration (kiosk): A visitor uses an interactive touchscreen kiosk to select, manipulate, and explore visualizations

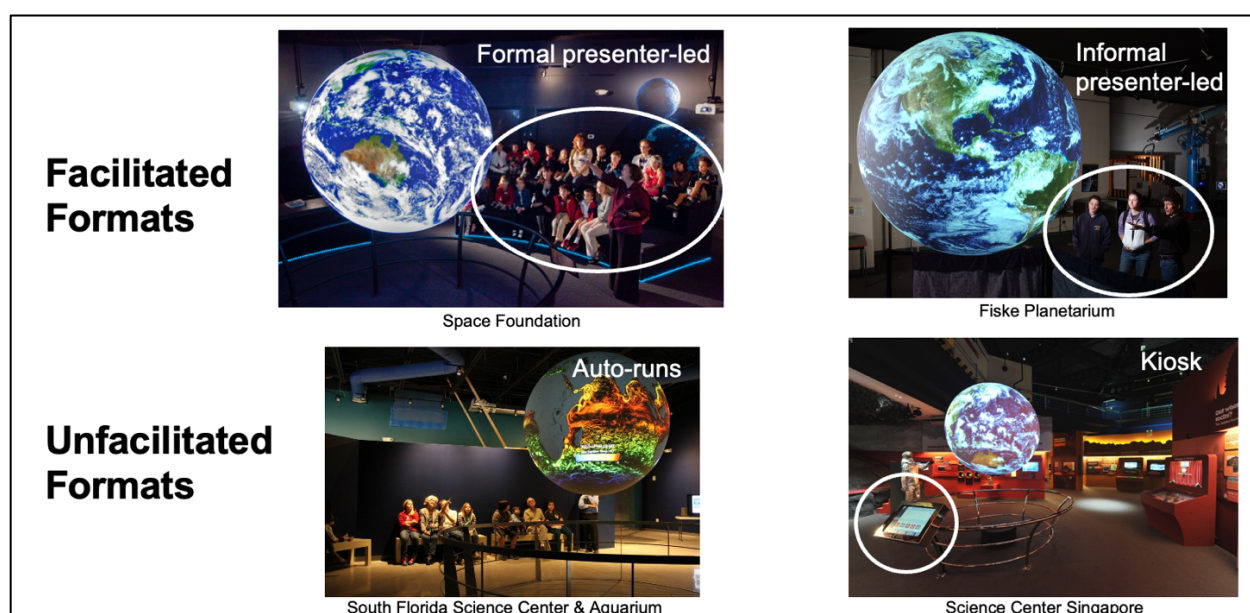


Figure 5. *Science On a Sphere Modalities*

**SOS Data Catalog:** a searchable online catalog of 600+ visualizations or “datasets” maintained by NOAA’s SOS Program

**Types of Visualizations (“Datasets”, Fig. 6)**

Real-time Datasets: visualizations built from data collected by NOAA and others that are updated frequently (e.g., every 20 minutes or daily), often showing Earth or space phenomena (e.g., Real-time Earthquakes). Generally, these show data



going back one month or one year depending on the update frequency of the data

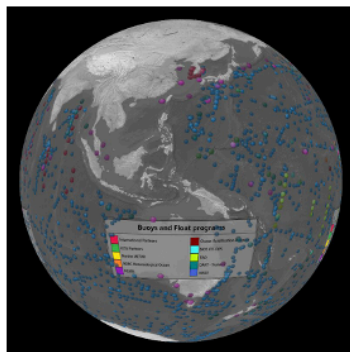
Static Datasets: visualizations that are a single image with no moving or animated elements (e.g., Buoy and Float Locations)

Animated Datasets: visualizations that include animation, often showing change over time or space (e.g., Carbon Tracker, Climate Model Sea Surface Temperature Change SSP1-5)

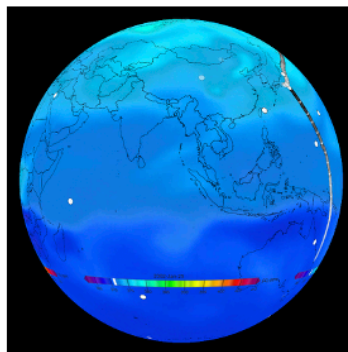
Narrated Movies: a spherical movie that includes voice-over – these may be spherical videos or have datasets interspersed with spherical videos

Live Programs: SOS presentations with accompanying scripts that have been created by users of SOS, including scientists, educators, museum staff and student interns. They are carefully crafted presentations that use SOS datasets to tell a story and teach audiences about a specific topic such as ocean currents or extreme weather events

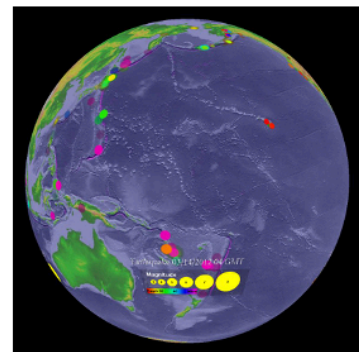
Site-Custom Datasets: visualizations that users at SOS or SOSx sites have created for use at their site alone; not included in the SOS Data Catalog



**Ocean/Water**  
Ex. Buoy and  
Float Locations



**Atmosphere**  
Ex. Carbon  
Tracker



**Land**  
Ex. Real-time  
Earthquakes

Figure 6. *Examples of Visualization Content Areas Available in the SOS Data Catalog*

**Playlist**: a collection of visualizations or “datasets”, which could include real-time, static or animated datasets, or narrated movies, that have been selected and grouped

together to be used in a presentation or in Autorun mode using the iPad SOS Remote App

**iPad SOS Remote App** (Fig 7): the primary way to control an SOS system. The app displays a list of datasets in the current presentation playlist and has intuitive orientation and playback control for the dataset loaded on the sphere. The app also supports many features such as annotation, zooming, layering, quickly searching and browsing through the entire SOS Data Catalog, and quickly creating a presentation playlist on the fly

**Visual Playlist Editor (VPLE, Fig 7):** The SOS Visual Playlist Editor is a tool that allows users to create, modify, and extend presentation playlists, as well as visually lay out, modify, preview, and create SOS datasets

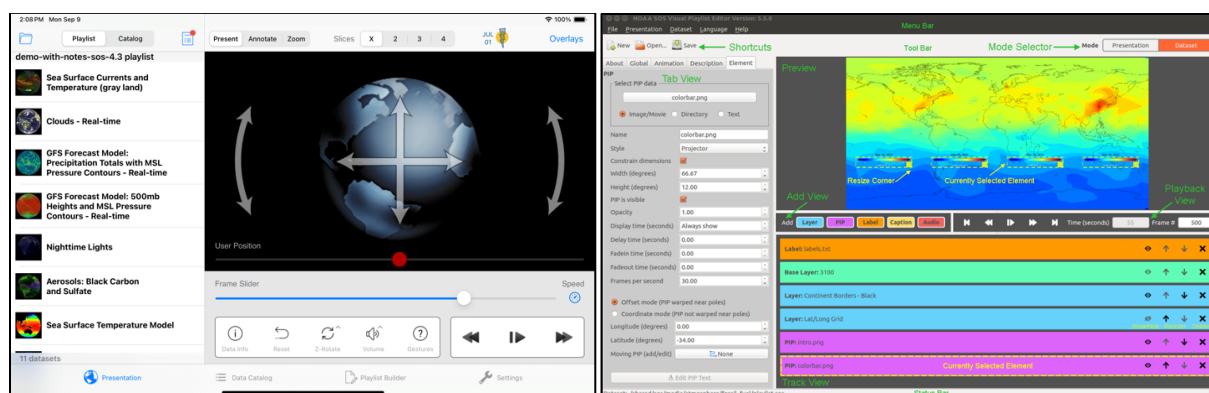


Figure 7. iPad SOS Remote App (left) and Visual Playlist Editor (VPLE, right)

**Dataset Customizations:** a variety of features created by the SOS Program that allow individual users to alter existing visualizations in the SOS Data Catalog. These include:

Image/Movie “Picture in Picture” (PIPs): a feature that allows users to superimpose a single image, series of images, or a video on top of an SOS visualization. These may include color bars, charts and graphs, logos, and other images that supply supplemental information. Image/Movie PIPs must be created in separate visual editing software, saved as an image or video file, and then added into SOS.

Text PIPs: a feature that allows users to superimpose text over an SOS visualization. Unlike image/movie PIPs, text PIPs can be added to visualizations through the PIP Text Editor in the Visual Playlist Editor.



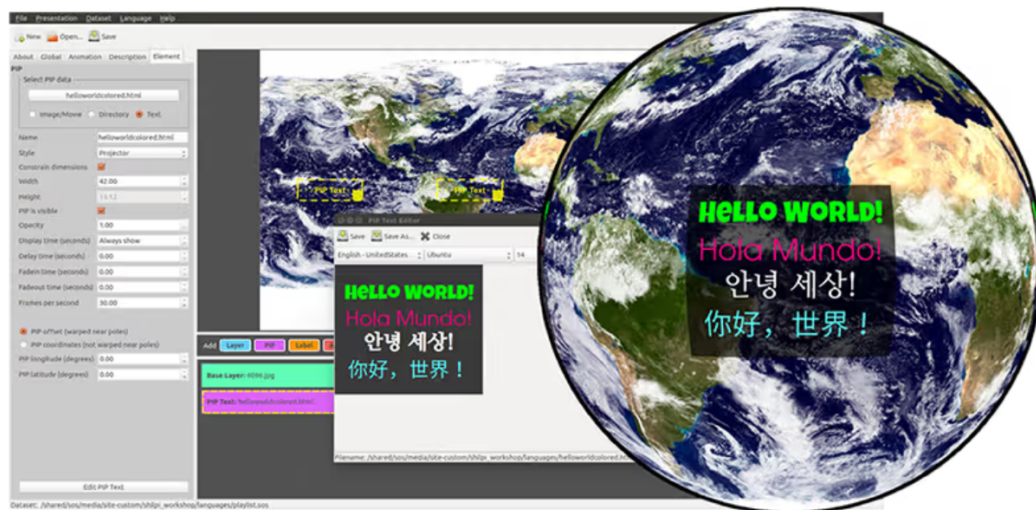


Figure 8. Example Text PIP on Science On a Sphere

**Layers:** Added global visual information that can be put on top of datasets (e.g., country borders, country names, winds)

**Presenter Notes:** Notes for presenters that are associated with a presentation playlist or a Live Program. Presenter Notes are accessed from the iPad SOS Remote app's Presenter Notes button.

**Captions:** Text displayed on the sphere that matches the narration of the audio file, if available, typically for the narrated movies

**Audio:** Audio narration that can be paired with visualizations

**Dataset Descriptions:** text that describes a dataset and is available in the SOS data catalog

**External Screens:** external monitors that work in tandem with an SOS installation (e.g., to display captions or show corresponding slides) that exist at some sites

## Content That Can Be Shared with SOS

Visualizations used with SOS and SOSx span many topics, with a primary focus on Earth and planetary systems. In the past 10 years, there has been a growth in institutions' interest in using SOS to teach about climate change. Institutions with SOS installations have used the platform to teach about climate change by offering programming based on existing (e.g., Smithsonian, 2017; Schollaert Uz et al., 2014) or custom visualizations that address processes underlying climate change (e.g., Norlander et al., 2016; People, Places and Design, 2015; Semmens et al., 2020; 2023). Prior work has identified several strategies for effective climate change instruction that have also been used with SOS: increasing the personal relevance of climate change through place-based connections, using engaging teaching methods (e.g., inquiry-based instruction, field trips, visual imagery), and moving from teaching about climate change as a problem to teaching about climate action and solutions (Schweizer et al., 2013; Monroe et al., 2019; Vaughter, 2016).

Informal education institutions, such as many SOS sites, offer an opportunity to engage young people in solutions-based climate change education and action (Kretsner & Chandler, 2020) and to reach people who are no longer engaged in the formal education system (Vaughter, 2016). Aligned with findings from the climate education literature, SOS visitors reported interest in learning about climate change solutions that are accessible to them (e.g., riding public transit versus buying an electric car) and appreciated local connections (Norlander et al., 2016). Visitors also reported greater personal connection to Earth systems after viewing SOS (Semmens et al., 2020) and felt motivated to take action around the topics they learned about on the sphere (Goldman et al., 2010; Semmens et al., 2020; Maggie Miller, 2010; Norlander et al., 2016; Smithsonian, 2017). At least one SOS site has used solutions-based climate change instruction, including information on green jobs, embedded within place-based arts programming (Semmens et al., 2020) as well as place- and inquiry-based instruction (Semmens et al., 2021).

### *Open Questions*

A comprehensive understanding of which content is presented with SOS or SOSx is limited. For example, we do not know either the frequency or content of site-custom

visualizations. We also do not know what percentage of SOS and SOSx programming is devoted to teaching about climate change across sites, nor how sites tend to approach the topic (e.g., teaching about phenomena versus place-based or solutions-oriented framings) in their programming. Finally, we lack any evaluations of SOSx, so we do not know to what extent prior work on SOS generalizes to SOSx.

## Interaction Modalities (“Presentation Formats”)

Content can be presented on SOS and SOSx in both facilitated and unfacilitated formats (see Fig 3 in “Key Terms”). Prior evaluations of SOS have identified two modes of facilitated use: first, a facilitator can lead a presentation (“formal presenter-led”), or a facilitator can guide an individual or small group of visitors through visualizations of their choice (“informal presenter-led”). For unfacilitated use, a narrated movie or pre-set “playlist” of visualizations can be displayed on a loop (“auto-run”), or a visitor can use an interactive kiosk to explore visualizations (“independent exploration”). We are not aware of any evaluations of presentation formats for SOSx sites.

Each SOS or SOSx modality has both positive affordances and potential drawbacks. Facilitators of both formal and informal presentations can flexibly provide scaffolding for the potentially wide range of visitors to the SOS or SOSx, tailoring information to meet the prior knowledge levels of learners. For example, visitors who saw a docent-guided presentation on the sphere reported greater perceived learning compared with auto-run and visitor-initiated sphere interactions (Goldman et al., 2010). Further, visitor suggestions for improvement to an SOS exhibit at the Denver Museum of Natural Science clustered around adding supplementary explanations about what visitors saw on the sphere (DMNS Baseline Visitor Study, 2010). Formal presentations led to more time spent at an SOS or SOSx exhibit compared with informal presentations or auto-runs (Smithsonian, 2017). However, staffing an SOS or SOSx with a presenter, who may be a volunteer docent, paid museum staff or educator, or an expert scientist, is costly (salary, training time, scheduling logistics) when compared with unfacilitated modalities.

Informal presentations and independent exploration on a kiosk provide an opportunity for increased visitor choice of content to explore compared to an auto-run and

potentially a formal presentation. Increased choice in a learning context can increase learners' intrinsic motivation, with positive effects on both persistence and learning (Sheldon, 2007). This finding is illustrated by a study of museum visitors who reported highest levels of enjoyment in an informal presenter-led SOS interaction (79% high rating), compared with a formal presenter-led show (66% high rating), and an auto-run (60% high rating) (Hayward and Hart, 2015). However, prior work in cognitive psychology cautions that although kiosks can allow learners to flexibly interact with content, they can also split learners' attention, especially if the kiosk interface is non-intuitive (Hegarty, 2004).

In prior work, unfacilitated "autoruns" are common: two-thirds of sites across two evaluations reported using them (Goldman et al., 2010; People, Places & Design Research, 2015). Prior evaluations also show relatively low rates of kiosk use with SOS (e.g., 16.5% Goldman et al., 2010; 32% People, Places, and Design, 2015). However, in 2015, the SOS Program made public kiosk software freely available for SOS sites that were able to purchase the necessary additional hardware (NOAA's SOS Program, pers. Communication), which we hypothesize may have increased kiosk use after this point. In past studies, sites reported heterogeneous data across sites with respect to presentation frequency: 21.2% of visitors in the cross-site evaluation saw a docent-led presentation, while 60% of sites in a 2015 study reported at least one daily sphere presentation (Goldman et al., 2010; People, Places & Design Research, 2015). Some sites reported having volunteer docents at the sphere over 80% of the time (Hayward & Hart, 2015). Further, there was heterogeneity within a given site, with format varying by visitor type. For example, school groups were more likely to see a presentation facilitated by a teaching staff member, while unscheduled visitors were more likely to see auto-runs or presentations facilitated by volunteers (People, Places & Design Research, 2015).

### *Open Questions*

Several open questions remain about the modalities that SOS and SOSx sites currently use. First, we lack data on SOSx sites and do not know if patterns observed with SOS sites can be generalized to the flatscreen modality. Further, to the extent that sites have both an SOS and an SOSx, we do not know if sites are using them together. Second, we do not know if modality patterns have shifted, or if the introduction of the NOAA SOS

kiosk software has changed the number of sites using the touchscreen kiosk with SOS (or SOSx). Third, much of the prior work on modality has focused on formal presenter-led and informal presenter-led learning experiences as broad categories, instead of examining variation within each. For example, the extent to which a presentation has been effectively scaffolded based on learners' prior knowledge and allows opportunities for interaction and learner choice depends on presenter practices. Drawing on research in psychology and education, we identified active learning strategies, including use of learner gesture, physical objects that support the presentation ("props"), and selection of still or animated datasets as potentially effective instructional practices and areas of inquiry in this evaluation.

Active learning strategies such as clicker questions, raising hands, think-pair-share, and making predictions allow facilitators to tailor the learning experience and give learners the opportunity to construct conceptual knowledge (Idsardi, 2020). In a meta-analysis comparing active learning and traditional lecture techniques in undergraduate STEM courses, active learning increased student exam scores, made students less likely to fail out of a course compared with lecture, and increased their conceptual understanding of the material (Freeman, 2014). However, open questions remain about how to define active learning and how to test which practices are most effective, in which contexts, and with which learners (Lombardi et al., 2021). Gagnier and Fisher (2020) identified evidence-based spatial practices - sketching, spatial gesture, spatial comparison (or analogy), and spatial language – that can be used in conjunction with visualizations to enhance science learning (Gagnier & Fisher, 2020). Static and dynamic (or animated) visualizations may have unique affordances for learning: for example, animated visualizations helped learners most when the goal was learning about change over time or space (Ploetzner et al., 2020). Finally, physical materials ("props") may be used as part of an SOS presentation to represent physical or abstract entities "off of the sphere" (e.g., showing the relation and movement of Earth around the sun by displaying the Sun on the sphere and having a small Earth on a stick). Work in spatial and math cognition suggests that adding concrete manipulatives, or physical materials that learners can touch, boosts spatial and math learning (Hawes et al., 2022; Byrne et al., 2023).

## Visitor Behavior and Reactions to SOS



We identified several sets of findings about visitor behavior and reactions to SOS across prior evaluations: first, visitors' interest in the sphere, second, visitors' affective responses to the sphere, and third, the amount of time visitors spent with and their movement around the sphere. Across studies, visitors expressed high levels of interest in the sphere (DMNS Baseline Visitor Survey, 2010; Hayward & Hart, 2015; Norlander et al., 2016). Often, visitors were curious not only about content presented on SOS, but also about the technology that makes SOS work (47-79%, DMNS Baseline Visitor Survey, 2010; Hayward & Hart, 2015; Semmens et al., 2020; Maggie Miller, 2010). Affective reactions like awe or reflections on the beauty of the sphere were observed (e.g., Maggie Miller, 2010), though Goldman and colleagues (2010) note that affective responses in their exploratory study were mentioned by a minority of surveyed SOS visitors (25%), compared with more frequent reactions related to the realism of SOS (e.g., how realistic or tangible phenomena feel when presented on SOS) and how visitors perceived it to support visualizing complex Earth and other planetary processes, including time, size, and scale.

Time spent at an SOS exhibit varied from 36 seconds to 21 minutes (Grack Nelson & Ellenbogen, 2006; DMNS Baseline Visitor Study, 2010). Visitors may stand or sit when engaging with an SOS exhibit, depending on the affordances of the exhibit space, and two prior evaluations identified visitors' tendency to stand (DMNS Baseline Visitor Study, 2010; Goldman et al., 2010). Despite the spherical nature of SOS, many visitors did not move around the sphere unprompted, citing an understanding that whatever was shown on the other side of the sphere would rotate around to where they could see it (DMNS Baseline Visitor Study, 2010). Goldman and colleagues (2010) highlight that presenters may need to prompt visitors to move around the sphere to ensure that they take advantage of the spherical affordance of SOS.

### *Open Questions*

Several open questions remain in what we know about visitors' behavior and reactions to SOS and SOSx. First, we do not know if patterns of visitor engagement are similar to prior evaluations or if there have been shifts over time. We also do not know if prior work on SOS generalizes to SOSx. Second, SOS and SOSx are used in many different types of institutions (e.g., ILIs, K-12 and university settings, government buildings) and by many different types of learners (e.g., children, adults, expert scientists, the public). Indeed, Goldman and colleagues (2010) highlight the heterogeneous use cases of SOS as a key challenge for evaluation. Prior evaluation work focused primarily on adult

visitors to ILIs (e.g., Goldman et al., 2010), or K-12 students on field trips to ILIs (e.g., Hayward & Hart, 2015; Semmens et al., 2020). Key questions remain about whether and how patterns of visitor engagement vary based on institution type or learner type. Third, prior evaluation and research focuses almost exclusively on visitors self-reporting their interest and perceptions of learning – given the design of this evaluation, we were not able to address this limitation of prior work but felt that it is important to highlight.





# Research Questions

We investigated current use cases of SOS and SOSx exhibits by surveying program managers and educators at SOS and SOSx sites around the world. We explored five research questions aligned with the three areas of prior evaluation findings and identified gaps that, together, will advance our understanding of current use of these educational technologies and provide a springboard for future empirical work on learning with SOS technologies.

## Content

- 1) What content is most often shown on the sphere?
- 2) How often are sites presenting content about climate change and are they using place-based, solutions-focused framing?
- 3) What types of visualizations do sites use on SOS or SOSx?
- 4) How do sites find and, if relevant, customize content for their SOS or SOSx exhibit?
- 5) How common is it for sites to use unaltered content from the SOS Data Catalog, augmented content, or create entirely site-custom material?

## Interaction Modalities (“Presentation Formats”)

- 1) Which SOS platforms and modalities are sites using? Do sites ever use platforms together?
- 2) For sites that have facilitators, who are they, and how are they trained? Do facilitators use active learning techniques or props when presenting?
- 3) Does content, platform, modality (including presenter type and training), or teaching strategies systematically vary based on type of institution?

## Visitor Behavior and Reactions to SOS and SOSx

- 1) What do practitioners notice about visitor engagement with the sphere (e.g., age differences, movement around the sphere, responses to size and scale, engagement with the kiosk)?



# Methods

## Participants

A survey was sent to all institutions with an SOS or SOSx exhibit (i.e., members of the SOS Network) inviting two respondents from each site to participate, one program manager and one staff member who regularly engaged with visitors to SOS or SOSx exhibits. Invitations were sent to the list of all past and current SOS sites (n=202) and exhibit-style SOSx installations (n=65) that the SOS Program maintains; for some sites only partial contact information existed (68% of SOS sites, 57% of SOSx sites, with additional emails unassociated with site name). As of October 2024, the SOS Program was aware of 19 sites that had once exhibited an SOS but no longer did. We surveyed these former SOS sites to learn about reasons why they no longer had SOS exhibits installed (see Appendix A).

We conducted two rounds of study recruitment: the first in November-December 2024, and the second in February 2025. In the second round, we sent reminder emails to institutions that did not respond in the first recruitment round and for whom we had contact information matched with site name (98 SOS and 30 SOSx sites). In each round of data collection, we sent three reminder emails. In addition to direct sampling, we also used snowball sampling by asking respondents to share the survey with their professional contacts in the SOS and SOSx network.

Respondents completed the Qualtrics survey on their own computers. Respondents identified their role at the site (SOS/SOSx program manager or educator) at the beginning of the survey and were then presented with the survey questions relevant to their role. As an incentive for their participation, respondents were invited to enter a drawing for Amazon gift cards. Study procedures and materials were approved under the University of Colorado's Institutional Review Board (IRB) protocol 24-0718.

**Site Level Information.** We received responses from 92 sites, 85 of which currently exhibit SOS (Appendix B; n=71 SOS, 35% response rate; n=21 SOSx, 32% response rate). A variety of institution types, such as museums, zoos, government or higher education facilities, were represented (Table 1). Sites had a range of annual visitor numbers with a little under half of sites reporting 50,000 visitors or fewer per year (Figure 9, but note low response rate for this question). Respondents identified K-12 students and the public most frequently as the primary audiences of their SOS and SOSx exhibits (Figure 10).

	All Active Sites (n = 85)	SOS Active Sites (n = 71)	SOSx Active Sites (n = 21)
Site Type	Number (%)	Number (%)	Number (%)
Government Facility	11 (13%)	9 (13%)	5 (24%)
Higher Ed	19 (22%)	13 (18%)	6 (29%)
K-12	3 (4%)	3 (4%)	0
Museum	42 (49%)	37 (52%)	9 (43%)
Planetarium	4 (5%)	4 (6%)	0
Visitor Center	2 (2%)	1 (1%)	1 (5%)
Zoo/Aquarium	4 (5%)	4 (6%)	0

Table 1. *Percentage of Each Type of Active SOS or SOSx Site*

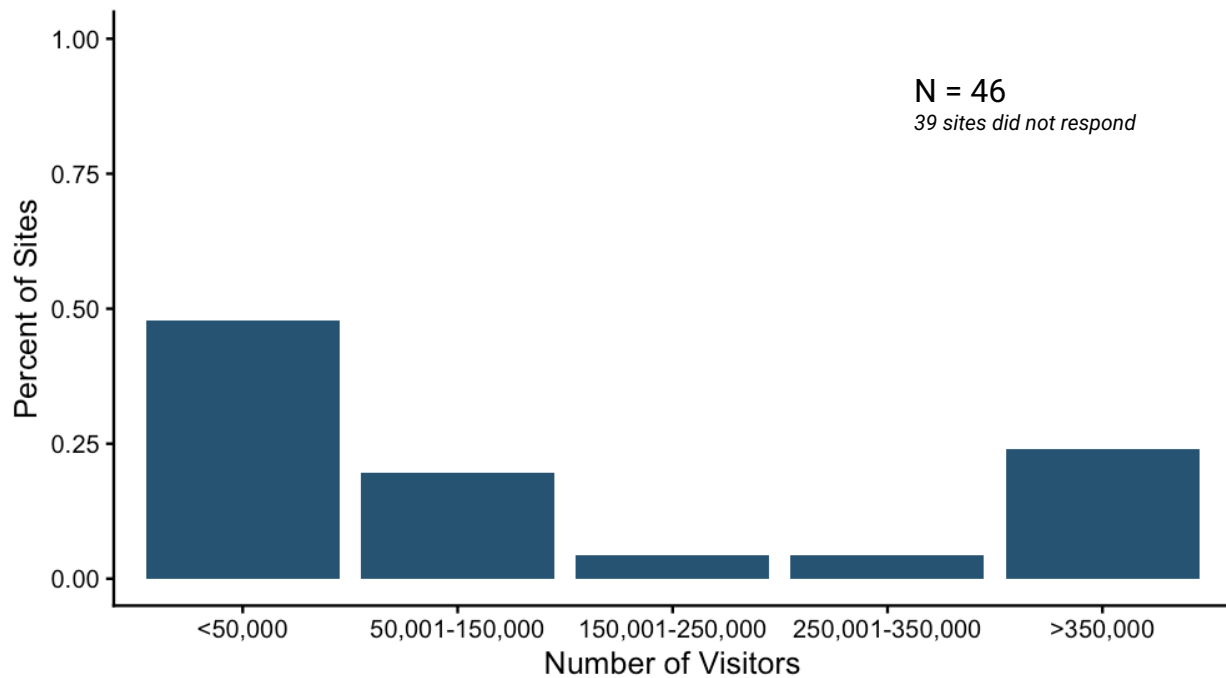


Figure 9. *Number of Annual Visitors at Participating SOS and SOSx Sites*

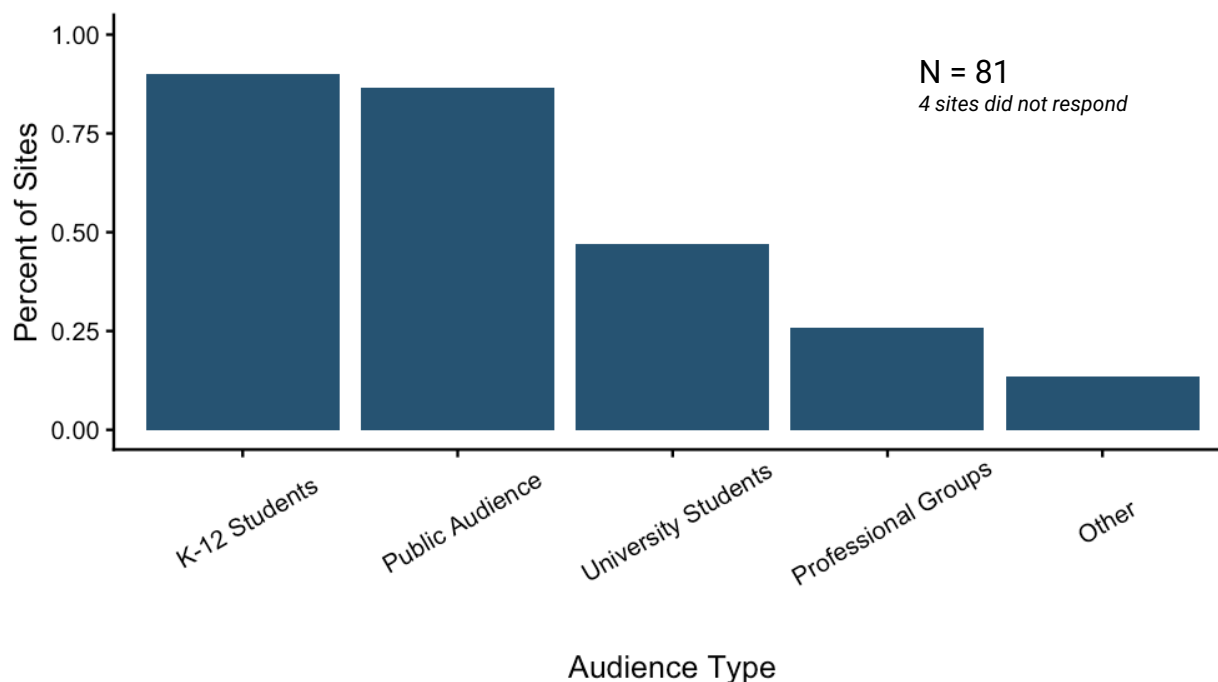


Figure 10. Frequency of SOS and SOSx Exhibits' Primary Audience (Select-All)

**Respondent Level Information.** Most ( $n = 60$ , 66%) sites had one respondent while 23 (25%) had two respondents, and some sites (9%) had more than two responses: seven sites had three, and one had four respondents. The length of time that respondents worked at their institution is reported in Table 3 with a median of 4-7 years, indicating regular employee turnover in the field. We note that only 4% of respondents had been at their site for >15 years.

	SOS ( $n = 107$ )	SOSx ( $n = 29$ )
Time Spent at Institution	$n$	$n$
< 1 year	13	1
1-3 years	30	13
4-7 years	22	7
8-15 years	38	6
>15 years	3	2

Table 2. Distribution of Years at Institution for SOS and SOSx Sites

Most respondents reported having directly led an SOS or SOSx presentation, served as a docent, or otherwise guided visitors' use of SOS or SOSx at their site (86%). Further, most had led a presentation recently (SOS:  $M = 2.03$ ,  $SD = 1.19$ , SOSx:  $M = 2.25$ ,  $SD = 1.29$ ; where 1 represents in the last week, and 6 represents more than 5 years ago) and generally do so frequently (SOS:  $M = 2.57$ ,  $SD = 1.42$ ; SOSx:  $M = 2.42$ ,  $SD = 1.18$ , where 1 represents multiple times a week, and 6 represents less than once a year). Respondents reported a range of knowledge about SOS and SOSx features (Table 3). About half to two-thirds of respondents who spent <1 to 7 years at their institution knew about built-in captions. Around one third of respondents were aware of the filter function that allows users to search the data catalog based on alignment with the Next Generation Science Standards (NGSS) to support standard-aligned instruction.

	Knew About Captions ( $n = 131$ )	Knew About NGSS Filter (SOS) ( $n = 106$ )	Knew About NGSS Filter (SOSx) ( $n = 29$ )
Time Spent at Institution	$M (SD)$	$M (SD)$	$M (SD)$
< 1 year	.63 (.52)	.33 (.52)	1.00
1-3 years	.50 (.51)	.41 (.51)	.50 (.71)
4-7 years	.55 (.51)	.33 (.50)	1.00
8-15 years	.41 (.50)	.45 (.51)	.67 (.58)
>15 years	.40 (.55)	0.00	0.00

Table 3. Respondent Knowledge of SOS Features by Years at Institution

## Measures

We developed the survey instrument through a collaborative, iterative process that was driven by the research questions and informed by findings from prior evaluation work and a literature survey around the gaps in knowledge. The instrument was refined through several rounds of discussion and feedback from SOS experts and practitioners. For example, the first author conducted three interviews with education staff from SOS sites to establish content validity, item interpretability, and alignment with questions practitioners had about SOS and SOSx. In response to feedback, we refined terminology throughout the survey and added several survey items. Further, NOAA's SOS Program contributed to both initial survey items and provided a final review to prioritize survey items to shorten the survey. The final survey instrument included 58 items (Appendix C).

## Data Processing and Analysis

Format of items in the evaluation survey varied: some were multiple-choice questions for which respondents could select a single response, others were “select-all” questions for which respondents could select multiple responses, some were matrix questions, and 12 were free-response items. The type of item is indicated in the figure captions. For “select-all” items, percentages may add up to more than 100% because a respondent could select more than one response.

For the free-response items, the research team developed qualitative coding schemes based on the principles of thematic analysis (e.g., Braun & Clark, 2006). To do so, the first author read through the free responses from the first round of data collection and developed initial themes that emerged for each item. Next, the first, sixth, and seventh authors practiced using the coding scheme on a subset of the responses in two rounds, meeting to discuss and make adjustment to the coding scheme in between (for full coding scheme, see Appendix D). Once we finalized the coding scheme, the sixth and seventh authors coded the full dataset, with 20% of the responses coded by both to establish reliability (percent agreement: .25-.79).

We report descriptive statistics about both respondent-level and site-level data.

**“Respondent-level data”** refers to questions that could meaningfully vary among respondents from the same institution. An example would be the number of years a respondent had been employed at their institution. We also treated all free-response items as respondent-level data.

**“Site-level data”** refers to questions where a single response could be most meaningfully understood if it is representative of an institution.

For sites that had more than one respondent, we first checked if respondents from the same site agreed in their responses to each question. We found that there was often agreement from multiple respondents, but there were some disagreements. We made two rules to resolve these conflicts: first, for “select all” items, we kept all responses made by all respondents (e.g., the most inclusive response), and second, for ordinal items, we kept the lower value (e.g., if one respondent said “always” and the other said “sometimes”, we kept the “sometimes” response).

# Results

## Content

### What content is most often shown on the sphere?

Sites reported using SOS and SOSx to visualize Earth science datasets (Figure 11). Relatively few sites report “never” using visualizations from any of the seven categories. The Ocean/Water category was selected most frequently as being used “often” and “sometimes”, while few sites responded that they were “often” presenting on the Arctic. Ten sites selected that they presented on “Other” topics, such as custom visualizations (n=2), space or space exploration (n=3), climate studies (n=1), navigation (n=1), cultural stories (n=1), special events (n=1), and Pictures, logos for corporate events, weddings, etc. (n=1).

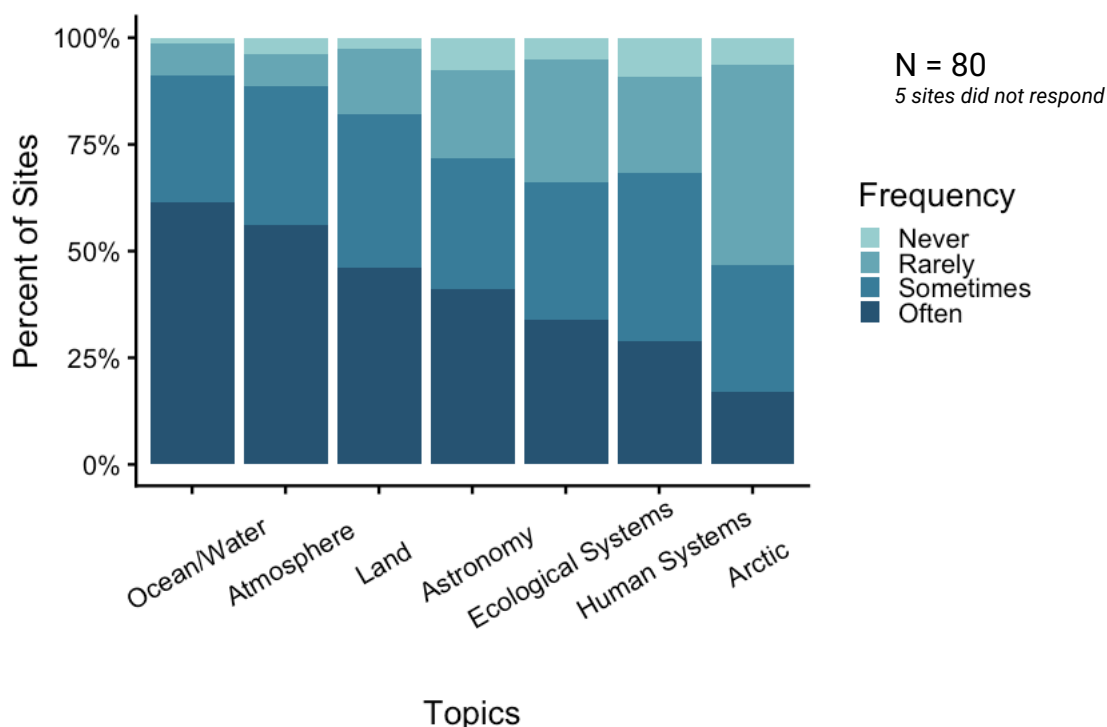


Figure 11. Content Areas in SOS and SOSx Presentations (Matrix)

## How often are sites presenting content about climate change and are they using place-based, solutions-focused framing?

Almost all sites that responded to the question about climate change programming (n = 78) used their SOS or SOSx to present about climate change at least some of the time (96%). Further, most sites reported that their SOS or SOSx programming focused on climate change impacts (87%) and future projections (73%, Figure 12). Descriptively fewer sites used their SOS or SOSx to share climate change solutions (52%), place-based and local connections (51%), or Green Jobs (15%).

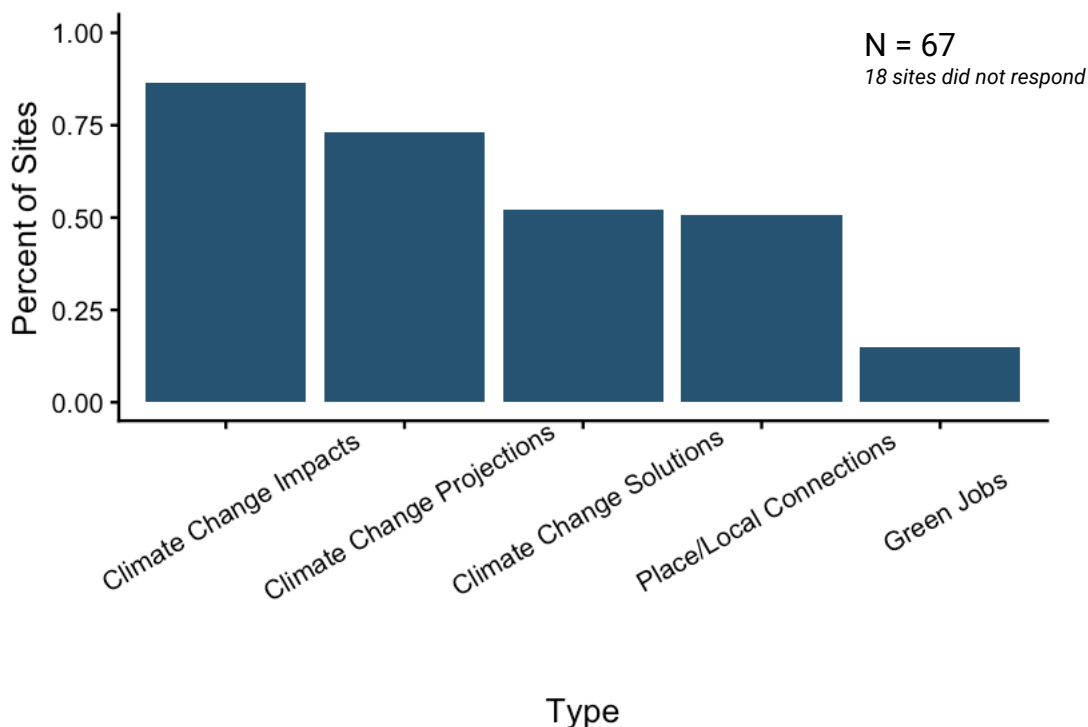


Figure 12. *Types of Climate Change Programming (Select-All)*

## What types of visualizations do sites use on SOS or SOSx?

Sites reported using a variety of visualization types with their SOS or SOSx (Figure 13). Most frequently selected are those without text or audio (96%, e.g., Blue Marble) while live programs were the least frequently selected (35%, pre-set playlists with script, e.g., Climate Change 101).

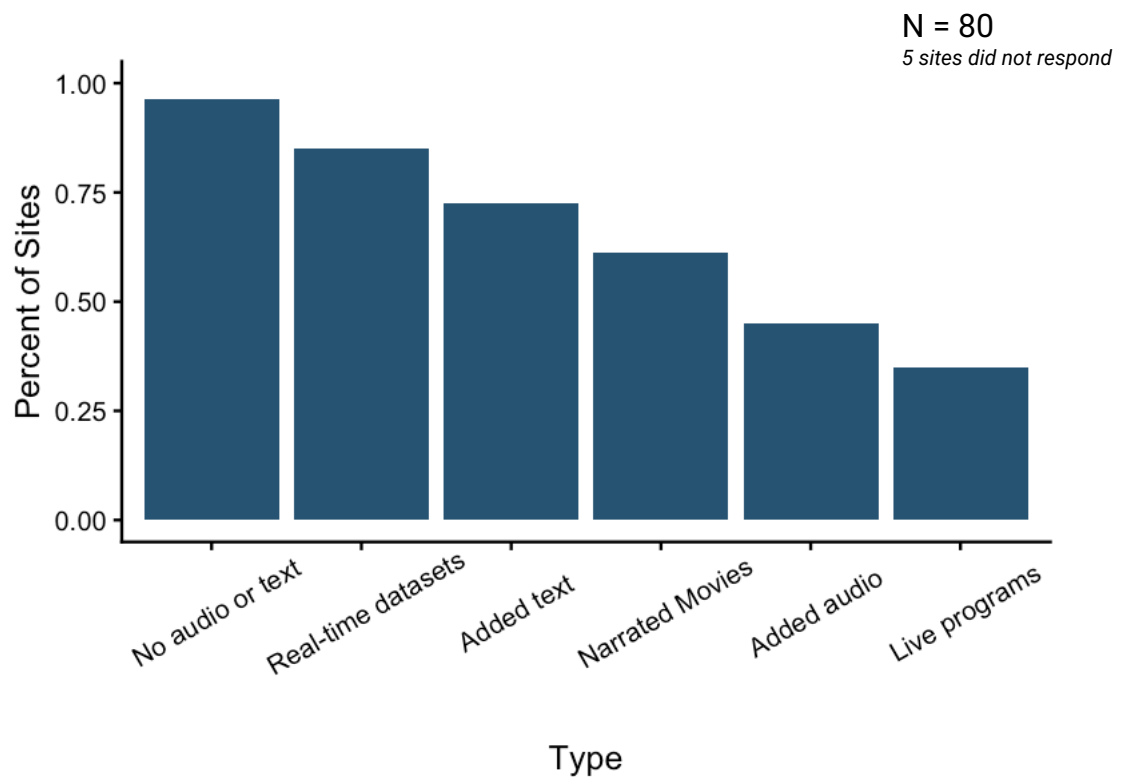


Figure 13. *Types of SOS and SOSx Visualizations (Datasets) Used (Select-All)*

We asked practitioners to explain their reasons for selecting different types of visualizations and used thematic analysis to identify five themes in their responses (Figure 14). The most frequent theme (38%) was “perceptions of audience engagement and understanding,” which identified some feature of an audience as key for determining what kind of dataset the respondent chose to use, for example, “I use real-time datasets...usually after other materials [when] I detect that the visitor “gets it”.” Next, 33% of respondents reported choosing visualizations “aligned with content that they were trying to present about,” which encompassed responses like “We use real-time datasets to teach about recent weather phenomena.” Other respondents (26%) reported choosing dataset types based on space, hardware, or presentation format constraints, which included things like selecting a dataset without audio because sound bled over from nearby exhibits in a museum, or a presenter wanting an audio description for a topic they didn’t know very much about. Finally, sometimes respondents pointed out that, due to the presentation formats used at their site, they didn’t select datasets for visitors at all (13%, e.g., in the case of a self-serve kiosk).



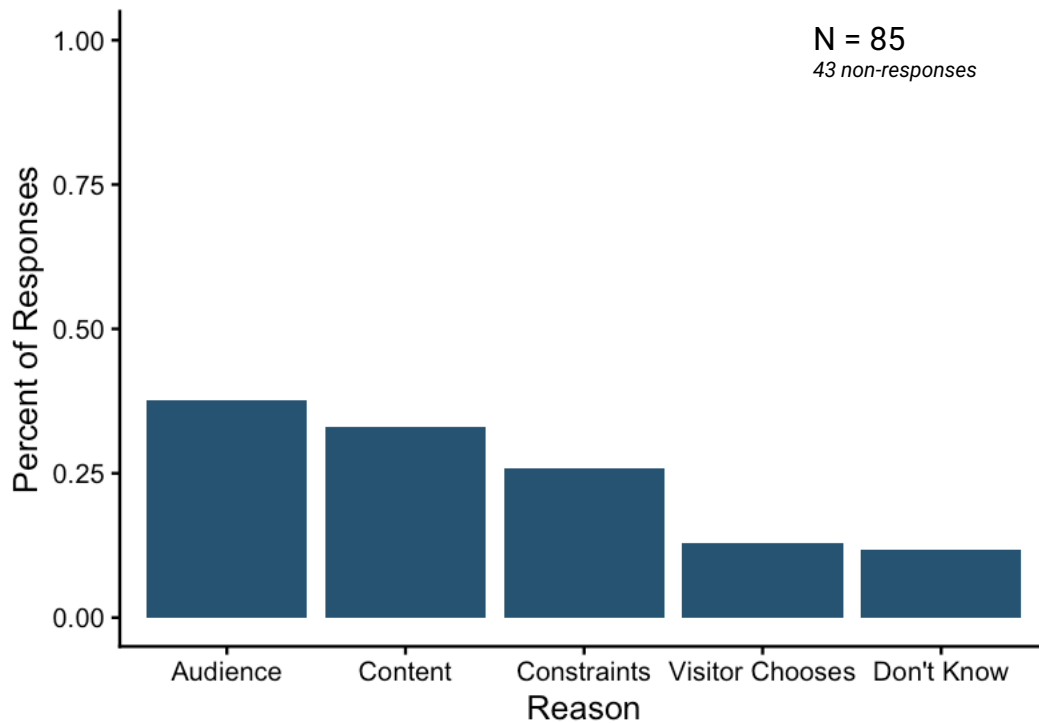


Figure 14. *Practitioners' Reasons for Choosing Each Type of Visualization (Free Response)*

*\*Note: Audience = "chose to align with audience engagement or understanding, Content = "chose to align with content they were presenting about", Constraints = "chose based on space, hardware, or modality constraints"*

Almost all sites reported using static, non-animated visualizations at least some of the time (95%). When asked to elaborate on why they selected static visualizations, a little under half of respondents reported doing so explicitly because visualizations not being animated made them fit the learning needs of their audience (43%, Figure 15). The remaining respondents reported not thinking about the static versus animated dimension when selecting visualizations (34%), selecting static visualizations only when there is no other visualization available to show a particular content area (17%), or because the visitor chooses visualizations (2%, e.g., from a kiosk).

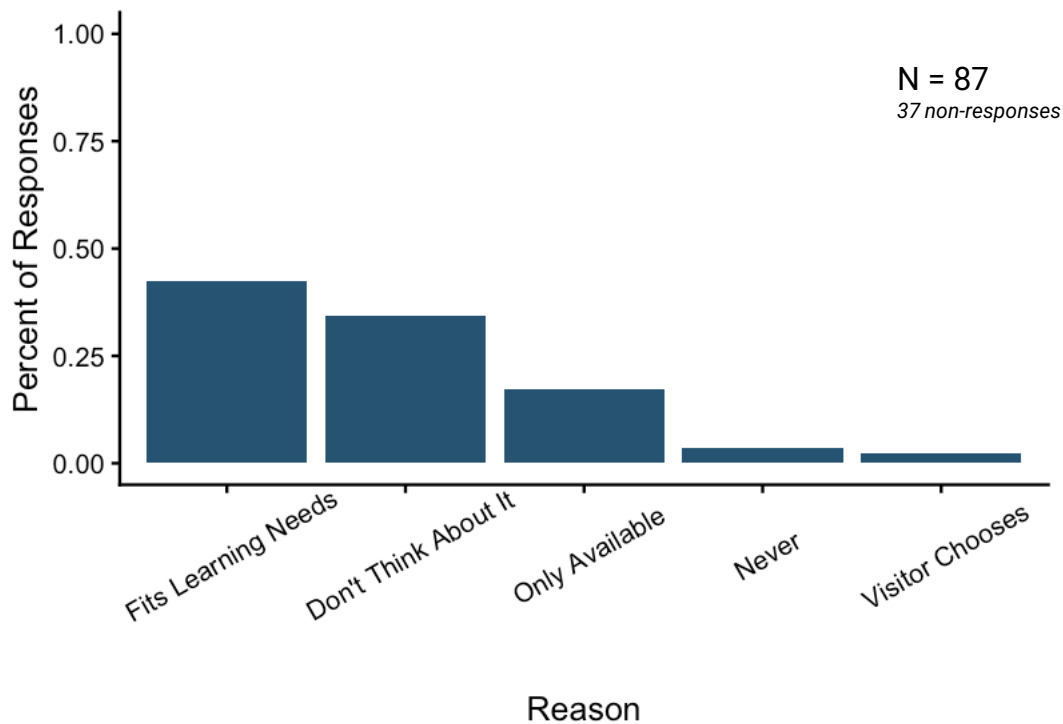


Figure 15. *Practitioners' Reasons for Choosing Static Visualizations (Free Response)*

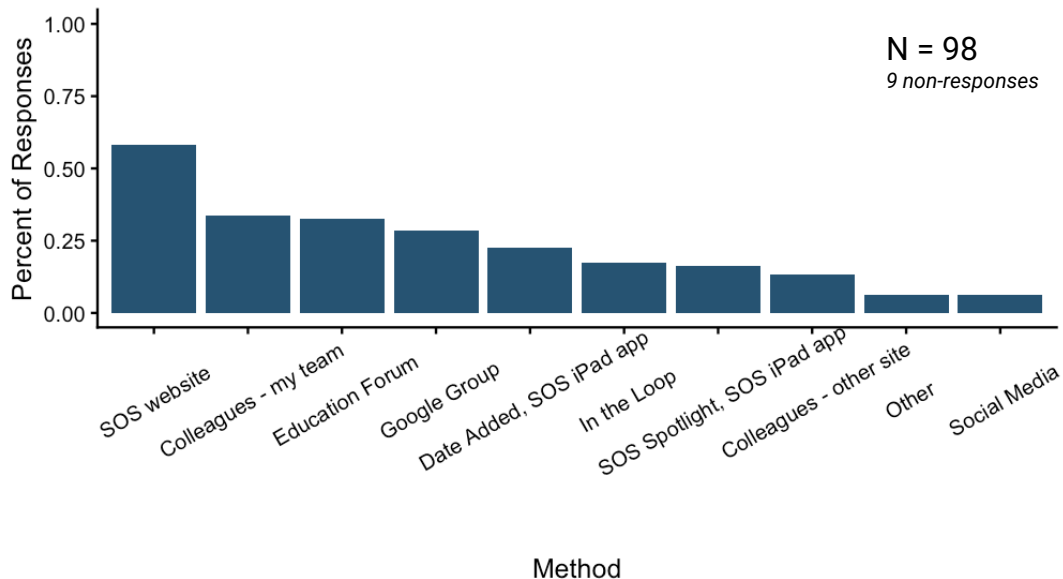
*\*Note: Fits Learning Needs = "choose static visualizations because they fit learning needs", Don't Think About It = "do not think about the static/animated dimension when choosing visualizations", Only Available = "choose static visualizations if they are the only ones available", Never = "never chooses static visualizations"*

## How do sites find and, if relevant, customize content for their SOS or SOSx exhibit?

Across both SOS and SOSx users, the most frequent avenue for finding out about new visualizations was the SOS Data Catalog website (SOS: 58%; SOSx: 52%; Figure 16). Very few users found new datasets from the SOS Program's social media accounts (SOS: 6%, SOSx: 4%). Within-site communication about new SOS and SOSx visualizations occurred (SOS: 34%, SOSx: 20%), but across-site communication was less frequent (SOS: 13%, SOSx: 8%). We note that it is a little challenging to compare across SOS and SOSx users for this question because the established methods of communicating across the SOS and SOSx communities are different. For example, the SOS Education Forum, a monthly virtual community meeting disseminated through the SOS Google Group listserv, is a key way that respondents from SOS sites found out about new datasets to use at their sites. As another example, the SOS iPad app allows users to sort by the date visualizations were added to the catalog to find new visualizations and includes the "Spotlight" feature, which periodically highlights a

visualization for users. SOSx users do not have a similar email list and regular meeting, and the SOSx app does not provide a way to sort the datasets by date added. There were four SOS respondents and seven SOSx respondents who gave “other” responses, including responses like “I don’t really learn about new datasets”, “I am involved in the making of new datasets”, “[I] note them when automatically loaded”.

#### A. SOS



#### B. SOSx

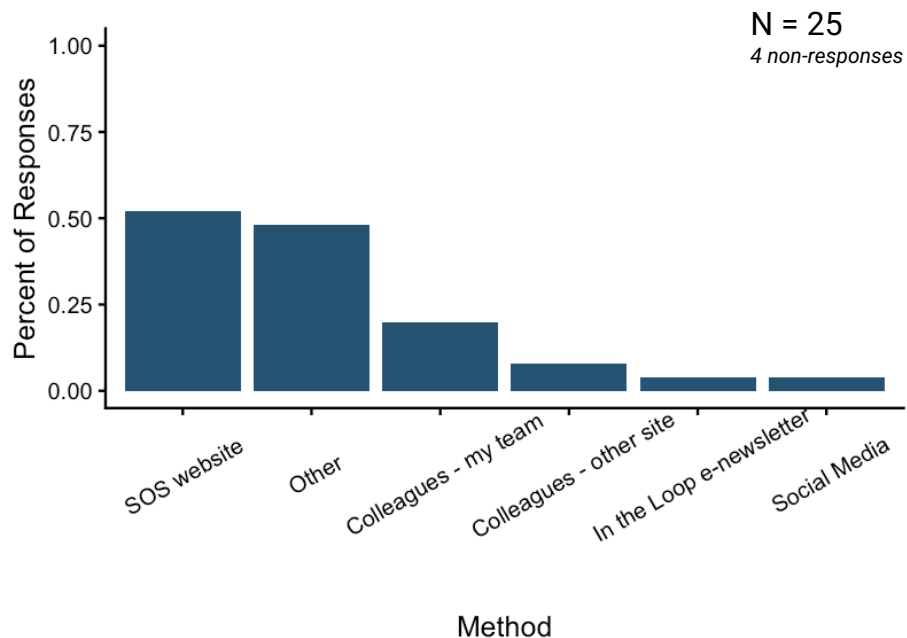


Figure 16. *How SOS and SOSx Sites Find Out About New Visualizations (Select-All)*

## How common is it for sites to use unaltered content from the SOS Data Catalog, augmented content, or create entirely site-custom material?

Over 80% of respondents reported that their site used datasets from the SOS Catalog without changing them (83%, Figure 17). Respondents also reported making new custom datasets (53%) and “augmenting” existing datasets from the SOS catalog (41%, e.g., adding captions or a “picture in picture” (PIPs) on top of an existing visualization). Few sites made custom narrated movies (18%). Seventeen responded “other”, which encompassed responses indicating lack of knowledge about how to customize (n=2), as well as responses like “we create ways to stream in live information using the webcam to augment topics or content engagement”, and “we have auxiliary PowerPoint slides for content.”

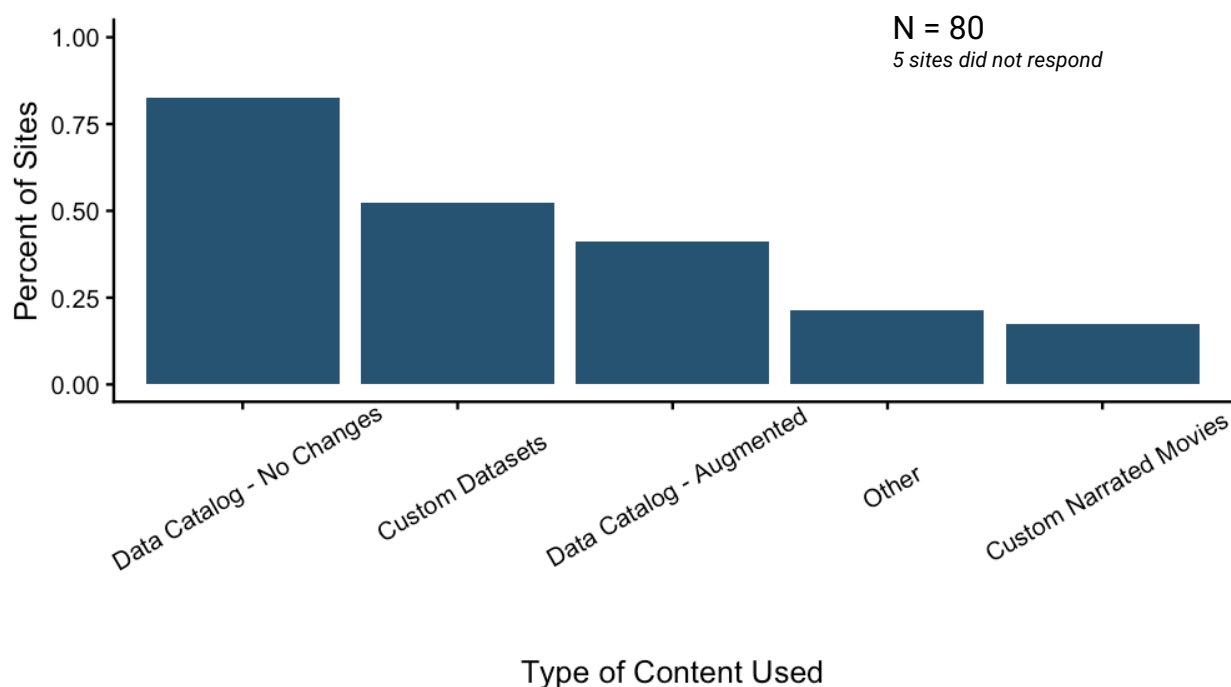


Figure 17. *Do Sites Create Custom Content? (Select-All)*

We next asked respondents who reported that their site augmented datasets from the SOS catalog to tell us what kinds of customizations they were making (Figure 18). Knowledge of customization options was high (81-93% knew about features), though sites did not necessarily use all of the customization options. Image/movie PIPs and text PIPs were the most frequently used customizations.

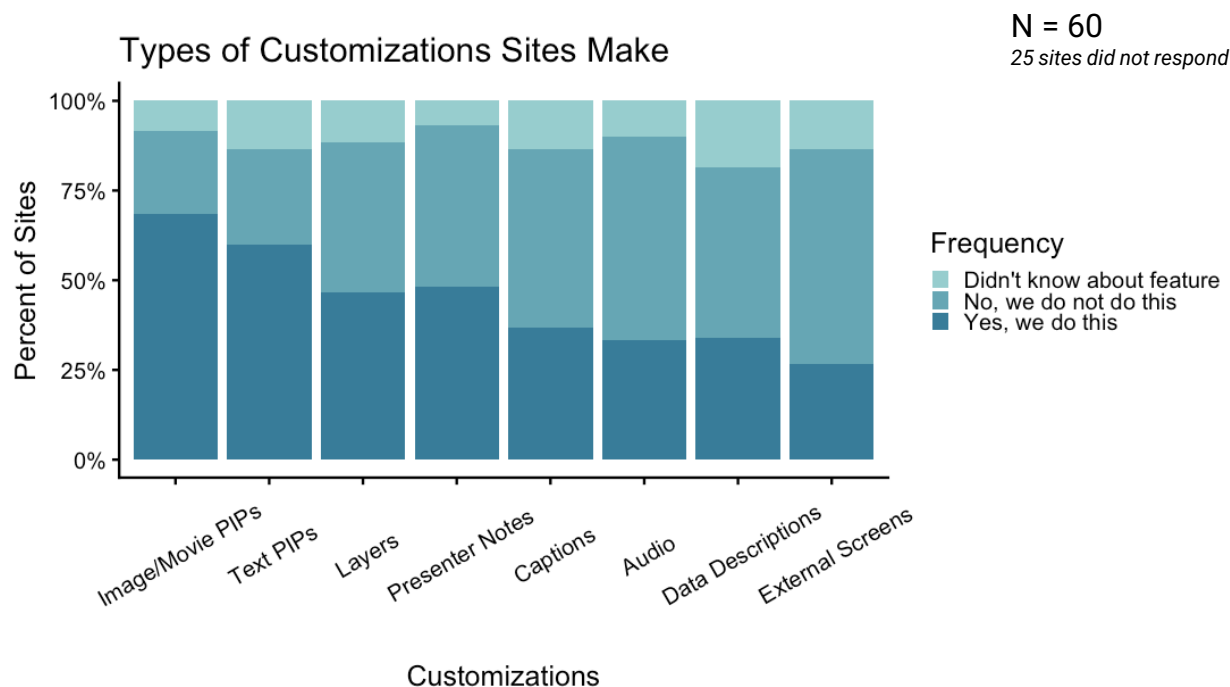


Figure 18. Which Customizations Sites Make to Visualizations (Matrix)

## Presentation Format

### Which SOS platforms and modalities are sites using? Do sites ever use platforms together?

Seven sites reported having both SOS and SOSx installations and four said that visitors can view both simultaneously in their space. Only two sites said that they use their SOS and SOSx together for educational purposes.

Respondents from both SOS and SOSx sites reported using a mixture of modalities with their installations (Figure 19). SOS sites often had formal presentations (52%), or an educator available (49%) daily or weekly, and 66% reported using their SOS in autorun mode “always” or “daily”. Over half the surveyed SOS sites (68%) and SOSx sites (62%) reported “always” using a kiosk. The pattern of use for SOSx sites was less clear given a smaller number of respondents, but 25% of SOSx sites had formal presentations “always” or “weekly”, 50% had an educator available “always” or “weekly”, and 50% used autorun mode “always” or “weekly”.

We asked respondents to elaborate on the modalities in which their institution used their SOS and SOSx and again used thematic analysis to identify patterns (n=60). When presentations with the SOS were not occurring, an equal number of sites had their SOS

on autorun (50%) or had an interactive kiosk available (50%). Only two sites reported turning their SOS off when it was not being used for presentations. For SOSx sites, the pattern was slightly different: most SOSx sites reported having a kiosk available (78%) when the SOSx was not being used for a presentation, 17% had their SOSx on autorun, and one reported that they turn their SOSx off when not presenting with it.

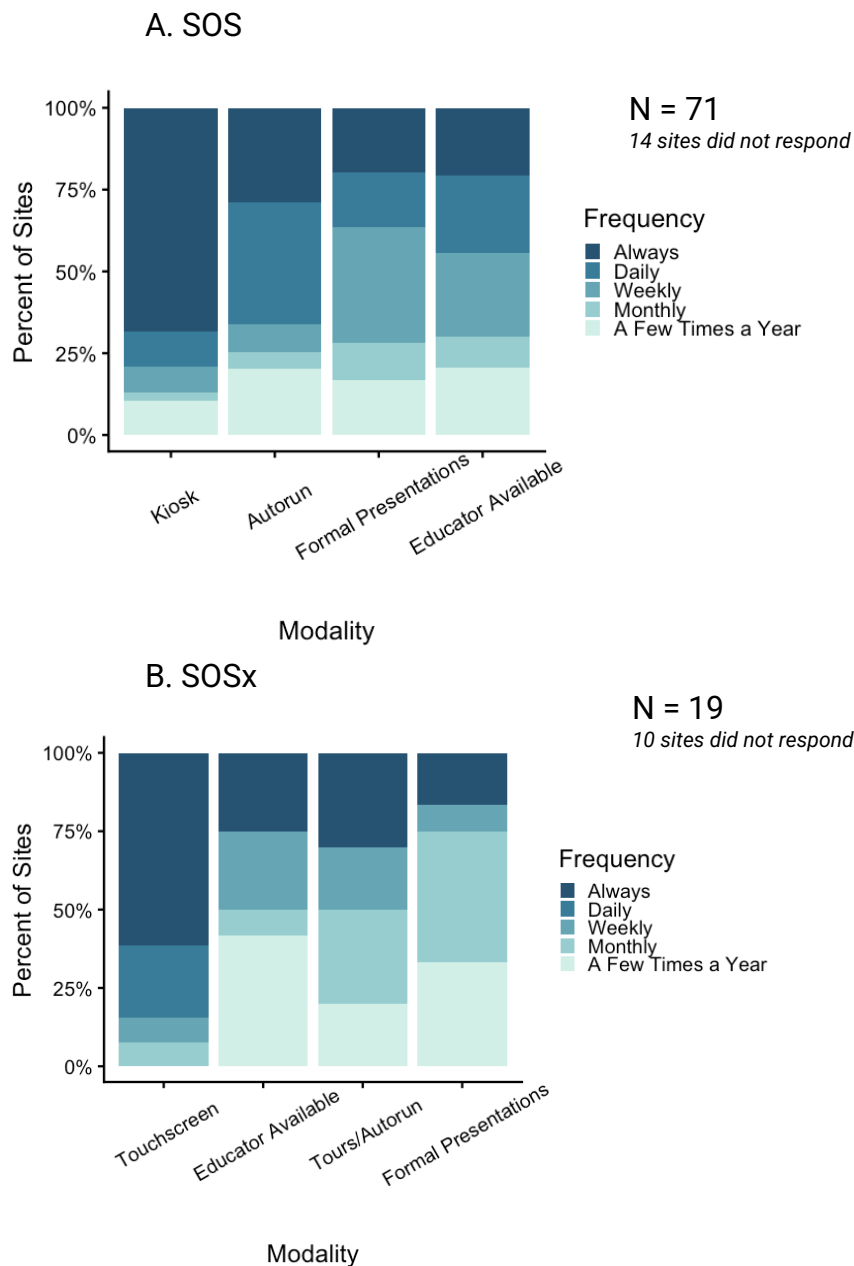
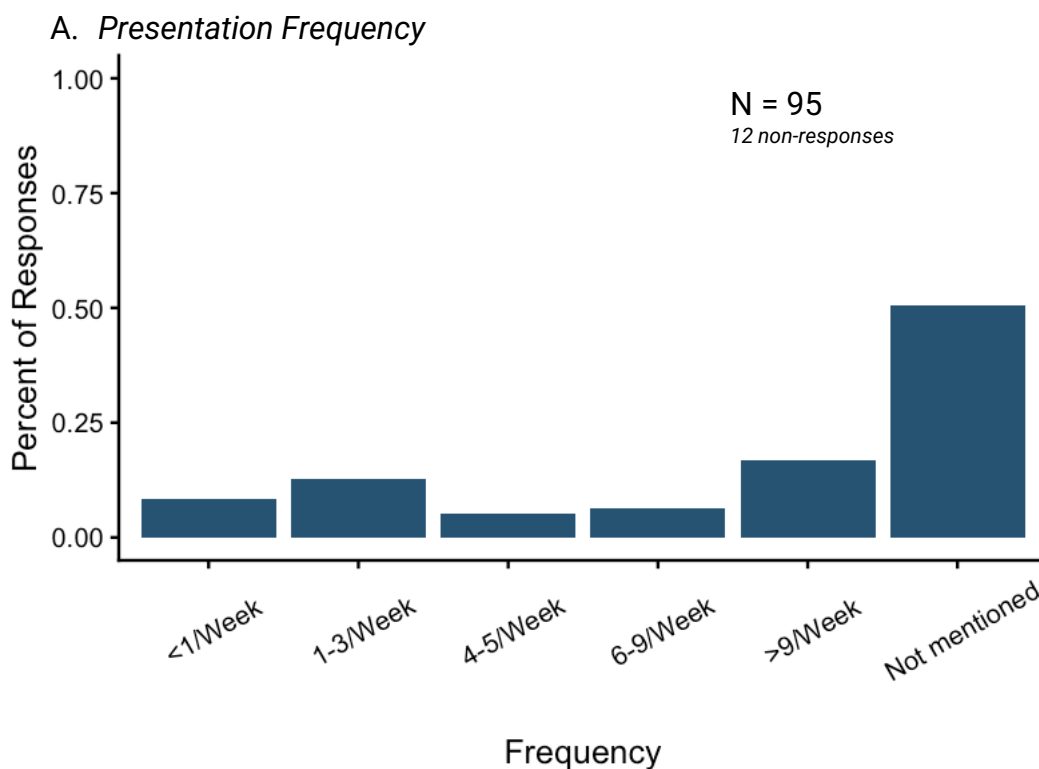


Figure 19. Frequency of SOS and SOSx Modalities (Matrix)

About half of respondents from SOS sites mentioned the frequency of presentations in their free response; most of those who did were from sites with one or more presentation per week (41%; Figure 20, A). Most SOSx respondents did not mention frequency of presentations in their responses (n=1 <1 per week, n=1 4-5 per week, n=2 >9 per week). Most SOS sites did not report day or time patterns for presentations (n=5 weekends and weekdays are different; n=2 daytime and evenings are different). None of the respondents from SOSx sites included day or time patterns in their responses. Thirty-five percent of SOS respondents reported using presentations either sometimes or always for field trips (e.g., for school groups as opposed for other audiences; Figure 20, B). Most SOSx respondents did not mention presentations being used for field trips (n=3 some presentations for field trips; n=1 all presentations for field trips).





## B. Field Trips

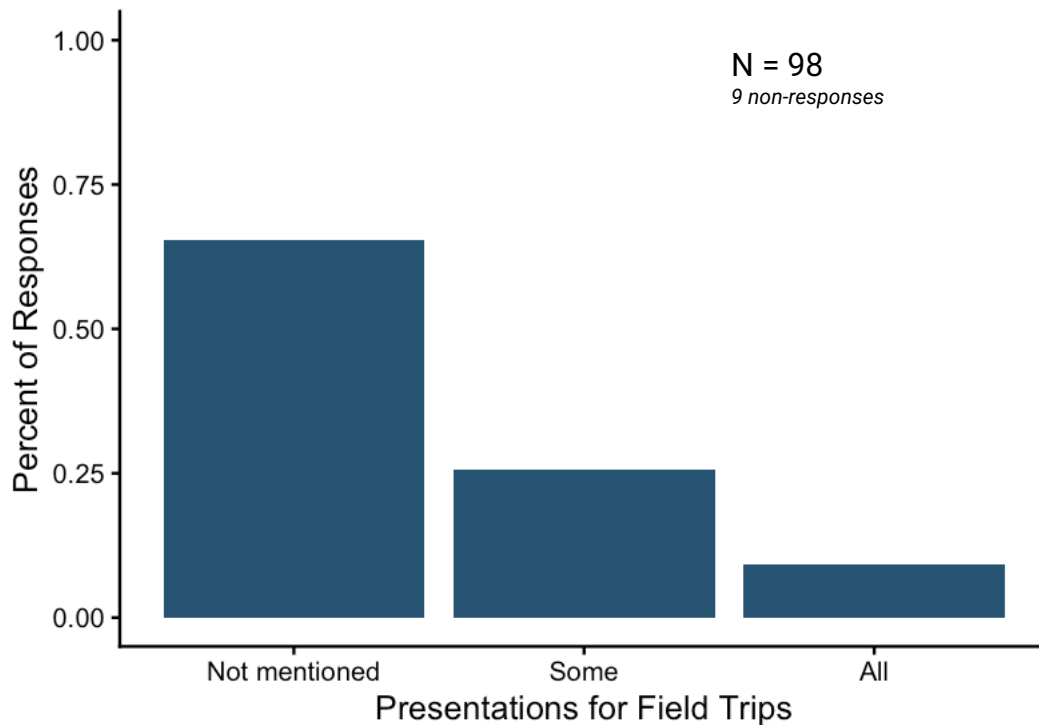


Figure 20. Frequency and Field Trip Patterns in SOS Presentations (Free Response)

For sites that have facilitators, who are they, and how are they trained? Do facilitators use active learning techniques or props when presenting?

Across SOS and SOSx sites, facilitators were most frequently paid staff (75%) and educators (70%, Figure 21). We note that we did not define these categories for respondents, so “paid staff” and “educators” could be overlapping. Sites reported having volunteers and subject-matter experts as presenters less often. Six sites reported “other” presenters; these included undergraduate or graduate student employees, seasonal student interns, AmeriCorps volunteers, science facilitators, and the respondent themselves.

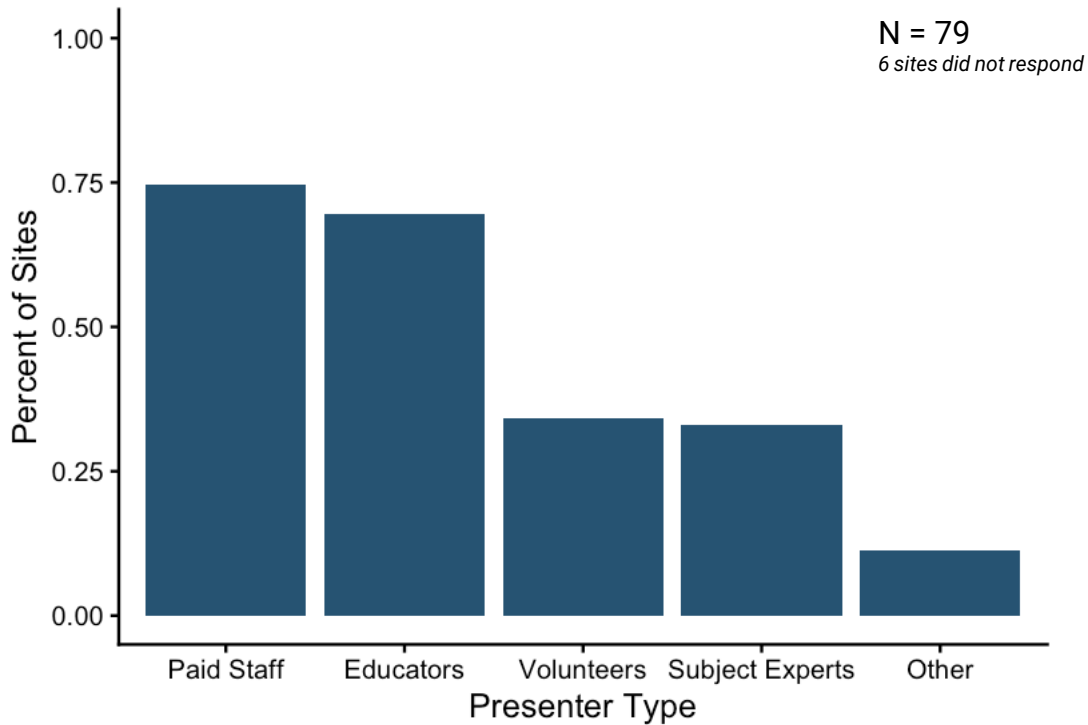
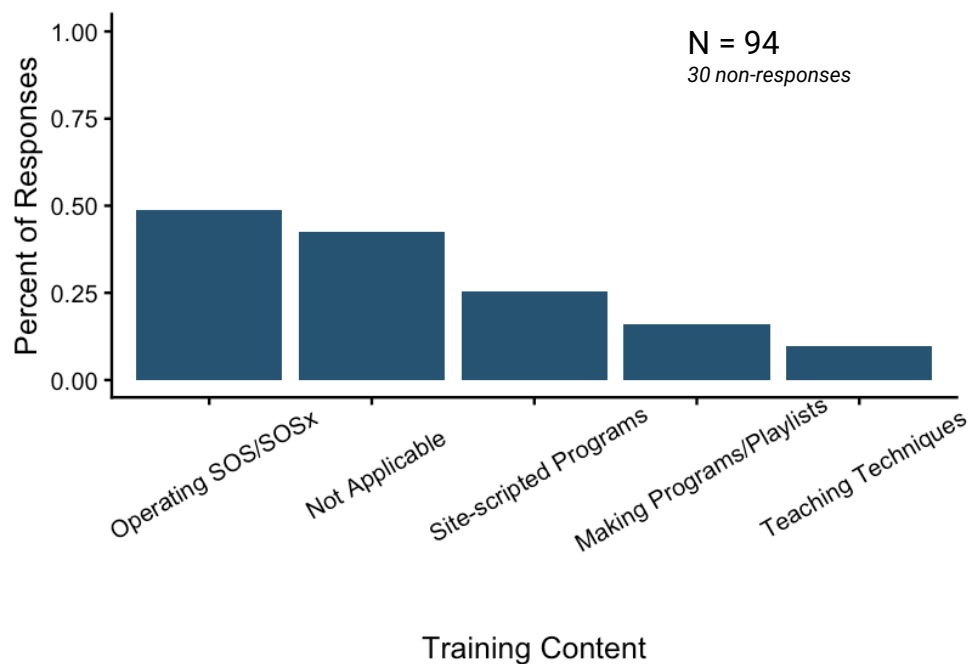


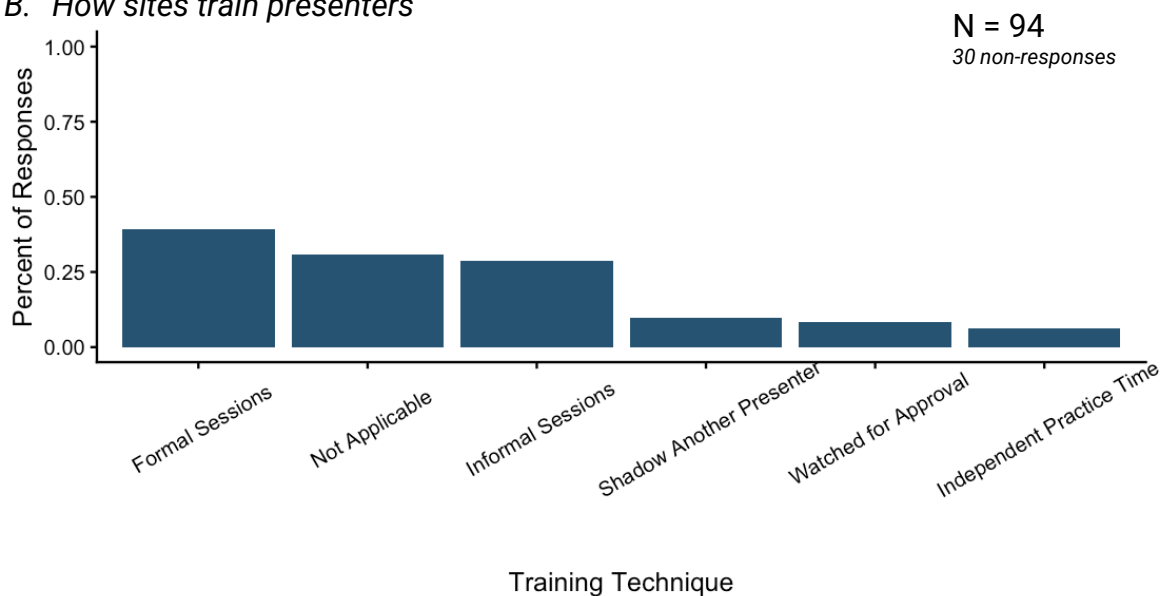
Figure 21. *Types of Presenters at SOS and SOSx Sites (Select-All)*

Most respondents reported that their site offered training to SOS or SOSx presenters (76%), while an additional 17 respondents said that their site did not offer training and six said that they did not know. Next, respondents described the training, and we identified two themes in their responses: what sites trained presenters to do (Figure 22 A) and how they structured their trainings (Figure 22 B). About half of sites taught presenters how to operate SOS/SOSx (49%), 26% taught presenters site-scripted programs or playlists, 16% taught presenters how to make their own programs or playlists, and only 10% taught presenters teaching techniques. Respondents reported that their sites use both formal (39%) and informal (29%) learning sessions to teach SOS and SOSx presenters. Few sites reported steps like shadowing another SOS or SOSx presenter (10%), having an experienced presenter watch a new presenter and give feedback (9%), or having independent practice time with the sphere (6%).

### A. What sites train presenters to do



### B. How sites train presenters



Note: In this item, the category "Not Applicable" includes both respondents who answered that their site did not have trainings in the preceding question, as well as respondents who answered that their site did have trainings but provided no information about what was included in those trainings or how they were done.

Figure 22. SOS and SOSx Site Presenter Training: What and How (Free Response)

When asked about what kind of guidance was provided around visualization choice and content for presentations, a little under half of sites either did not use scripts or the respondent from the site did not know if they used scripts (45%; Figure 23). Of sites that reported using scripts, the type of script varied: 59% reported that each presenter created their own script, 37% reported site-wide scripts, and 13% reported that they used SOS Live Program scripts, which are created by the SOS Program and are available through the SOS iPad app.

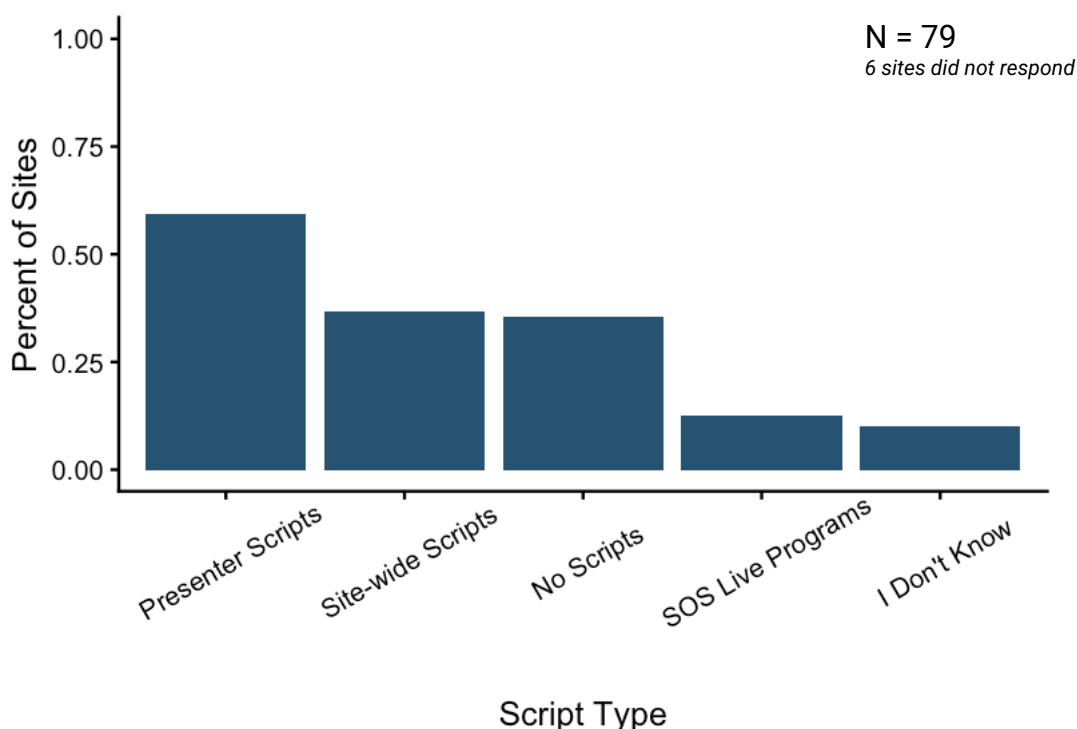


Figure 23. *Extent to Which Sites Use Scripts for SOS and SOSx Presentations (Select-All)*

Of the active learning techniques queried, respondents shared that facilitators most frequently asked visitors to ask or answer questions (93%) or make observations (91%; Figure 24). Other active learning techniques SOS and SOSx facilitators reported using were: asking visitors to make predictions (66%), imagine a scenario (53%), gesture or move (42%), think/pair/share (23%), use a clicker to answer questions (8%) and to draw (7%). Some respondents elaborated with “other” responses, including “we do dances around the Earth to represent the Moon’s tidal locking”, “have used worksheets that require students to use projected data to answer a research question”, “nearpod quizzes and games, graphing on miniature white boards”.

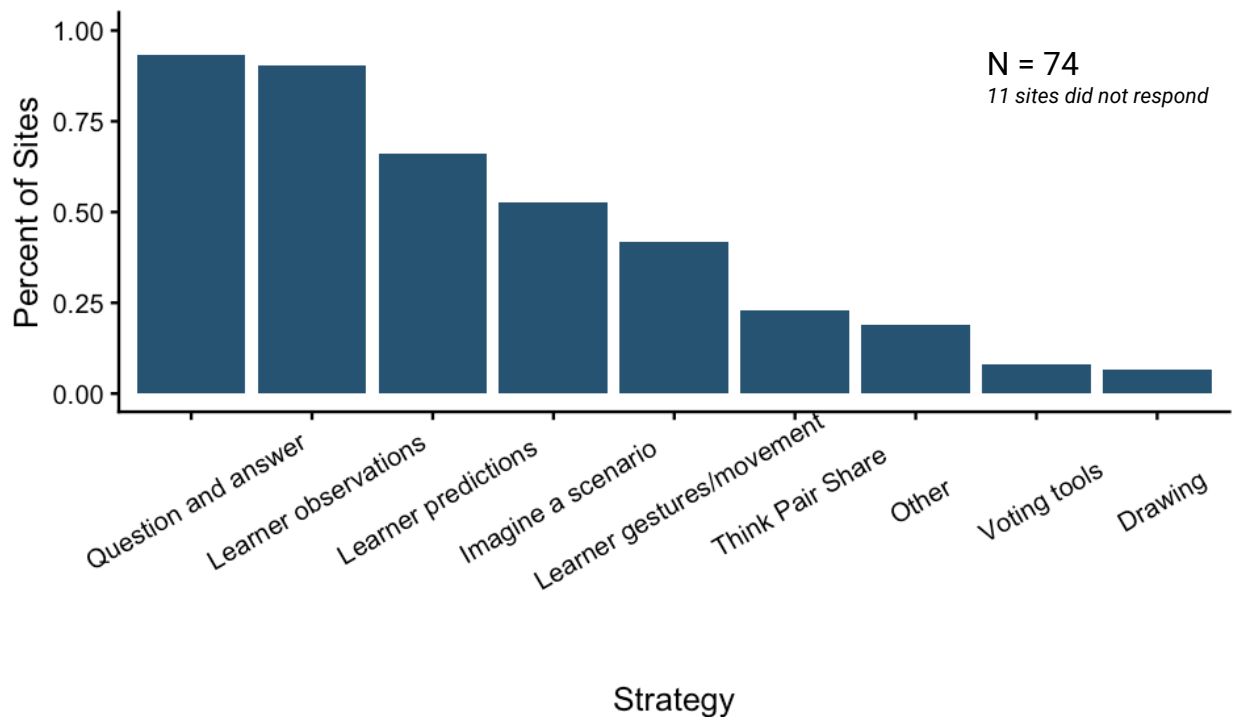


Figure 24. Sites' Use of Active Learning Strategies in Presentations (Select-All)

A little over half of sites reported not using props with their SOS or SOSx (57%; Figure 25). The remaining sites reported a variety of contexts for using props, including using them to represent objects or processes off of the sphere (e.g., how Earth moves around the sun, 32%), to show relative distances or scale (32%), to represent physical artifacts from Earth (e.g., a piece of coral, a rock, animal bones, 29%), to represent abstract ideas or processes (e.g., magnetic fields around Earth, 15%), or to show how data presented on the sphere are collected (e.g., a buoy, 11%). Some sites reported using "other props", including "activity sheets and colored pencils when completing an observational activity", "[having a] discovery lab hands-on", "using props to represent physical processes that occur on Earth", and "using props to represent satellite orbits". A further two sites reported previously, but not currently, using props, and one reported using props in parts of their program before SOS.

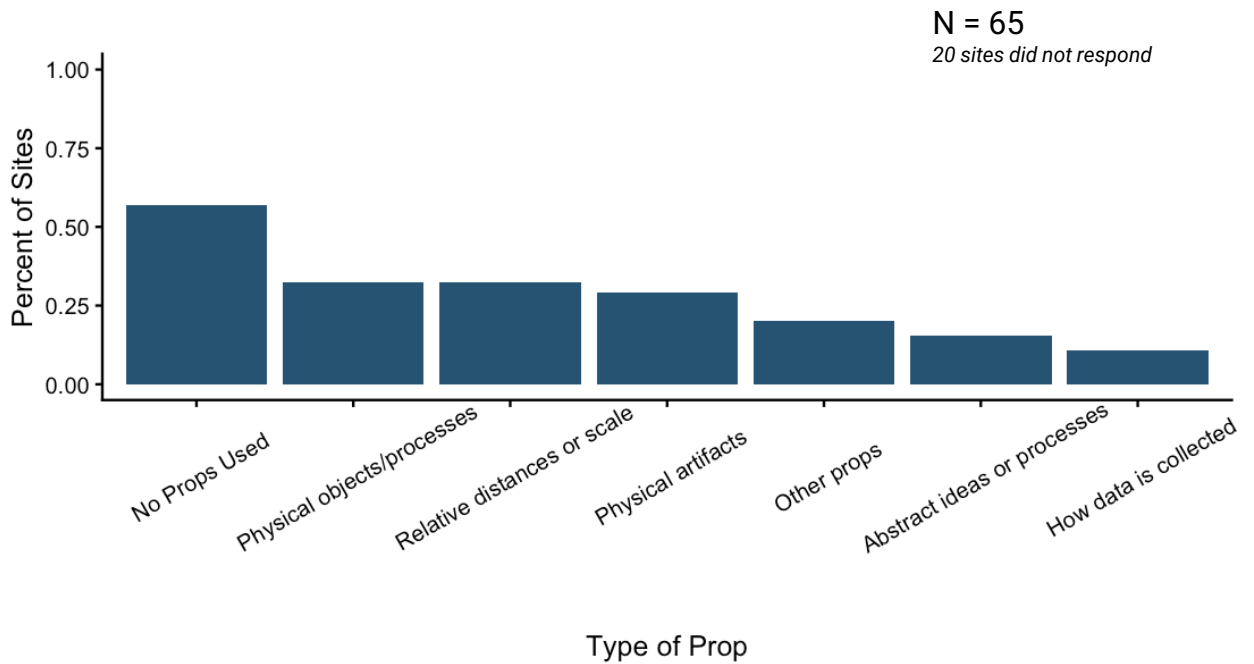


Figure 25. SOS Sites' Use of Props (Select-All)

### Does content, platform, modality (including presenter type and training), or teaching strategies systematically vary based on type of institution?

Next, we explored whether patterns of SOS and SOSx use differed or were similar based on type of institution. Because there were relatively small numbers of some institution types (see Table 1), we collapsed them into three categories: Educational Facilities (Higher Ed, K-12, n=22), Government Facilities (Government Facilities, n=11), and Informal Learning Institutions, or ILIs (Museums, Planetariums, Visitor Centers, Zoo/Aquariums, n=52). Given the unequal number of respondents within each institution type, we caution against overinterpreting directional differences between categories.

First, there were similar patterns in modality use across all three site types, with higher levels of “always” or “daily” kiosk or touchscreen use compared with other modalities (Figure 26).

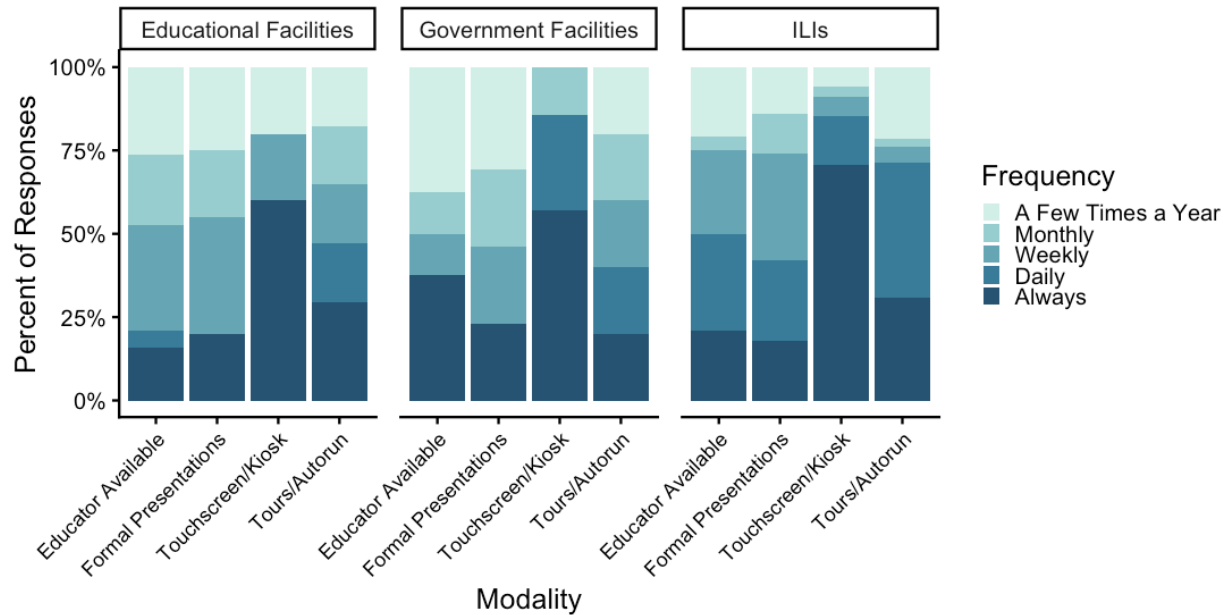


Figure 26. *Frequency of SOS and SOSx Modalities by Site Type (Matrix)*

There were both commonalities and differing patterns in the type of presenters across institution type (Figure 27). Paid staff were the most frequent presenters at government facilities (38%) and ILIs (37%), while educators were the most frequent presenters at educational facilities (39%). Volunteers made up a relatively low percentage of presenters at government facilities (12%) and educational facilities (11%). Subject experts were most common at government facilities (27%), followed by educational facilities (20%), and were least common at ILIs (9%).



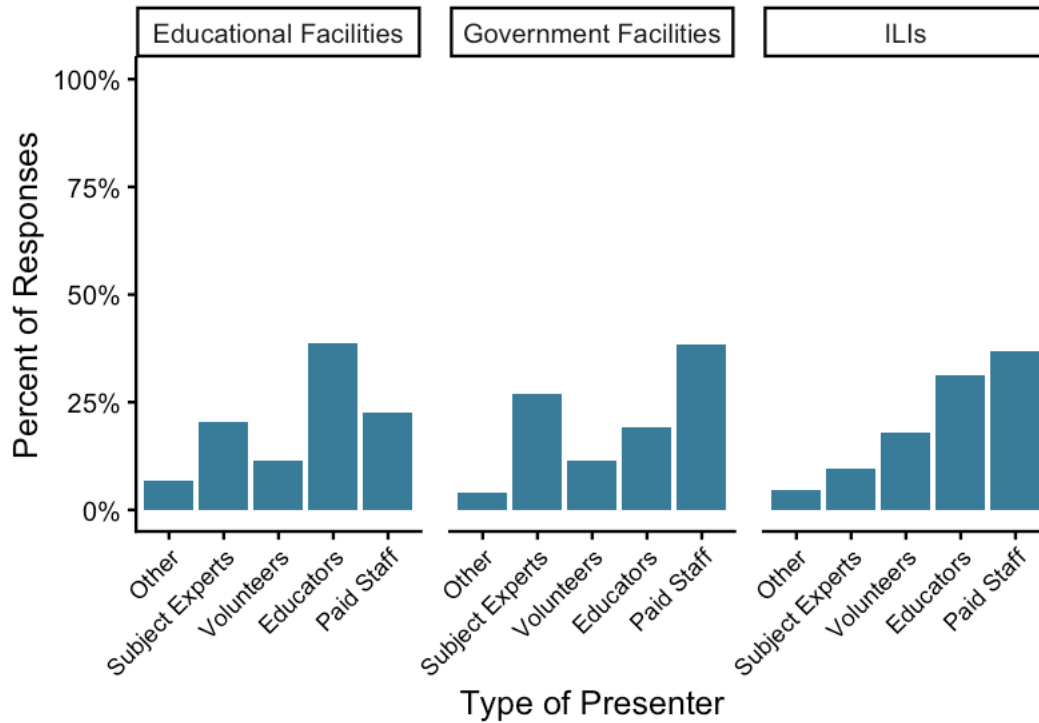


Figure 27. *Types of Presenters by Institution Type (Select-All)*

Several patterns in script use emerged (Figure 28). Educational facilities (41%) and government facilities (43%) were more likely to report not having scripts compared with ILIs (14%). All institution types reported similar levels of presenter-made scripts (educational facilities 41%, government facilities 36%, ILIs 38%). ILIs had a higher percentage of site-wide scripts (35%) compared with the other two site types (educational facilities 4%, government facilities 0%).

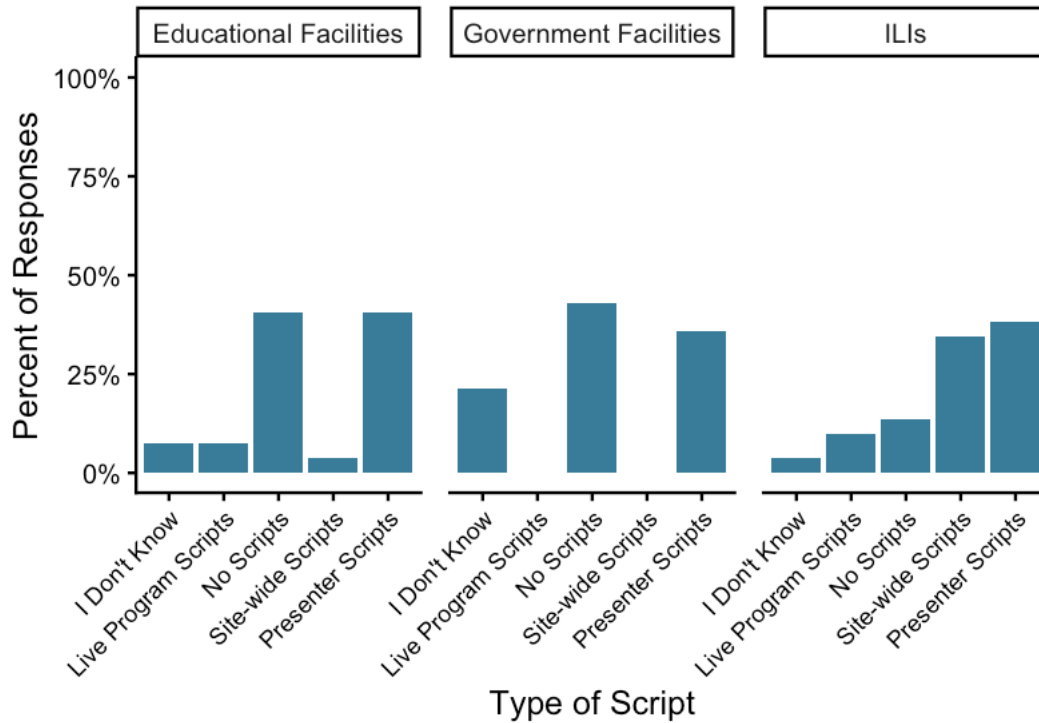
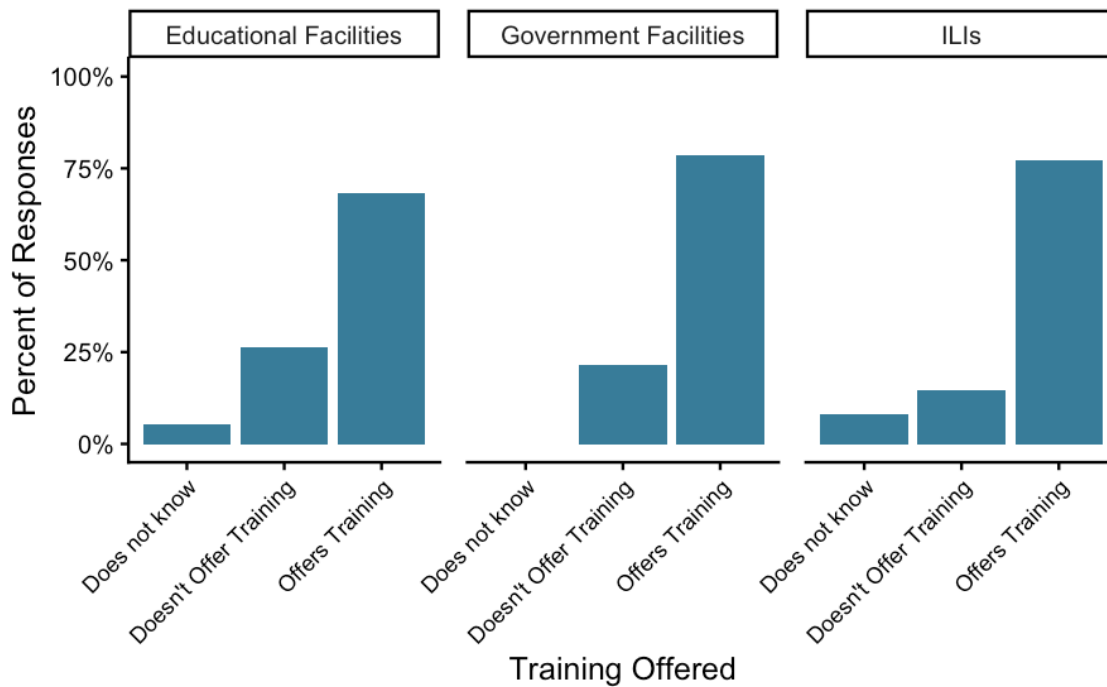


Figure 28. *SOS and SOSx Sites' Use of Scripts by Institution Type (Select-All)*

The rate of offering trainings was similar across site types (68-79%; Figure 29 A). However, thematic analysis revealed that respondents from different types of institutions included different content in their trainings (Figure 29 B). A portion of responses from each type of institution did not specify what was included in trainings at their site (government facilities: 32%, ILIs: 21%, educational facilities: 74%). Of those who did, the most frequent response was “how to operate SOS/SOSx” (government facilities: 37%, ILIs: 35%, educational facilities: 26%). Few sites include teaching techniques in their trainings (government facilities: 5%, ILIs: 8%, educational facilities: 0%).

### A. Is Training Offered?



### B. What Content is Trained?

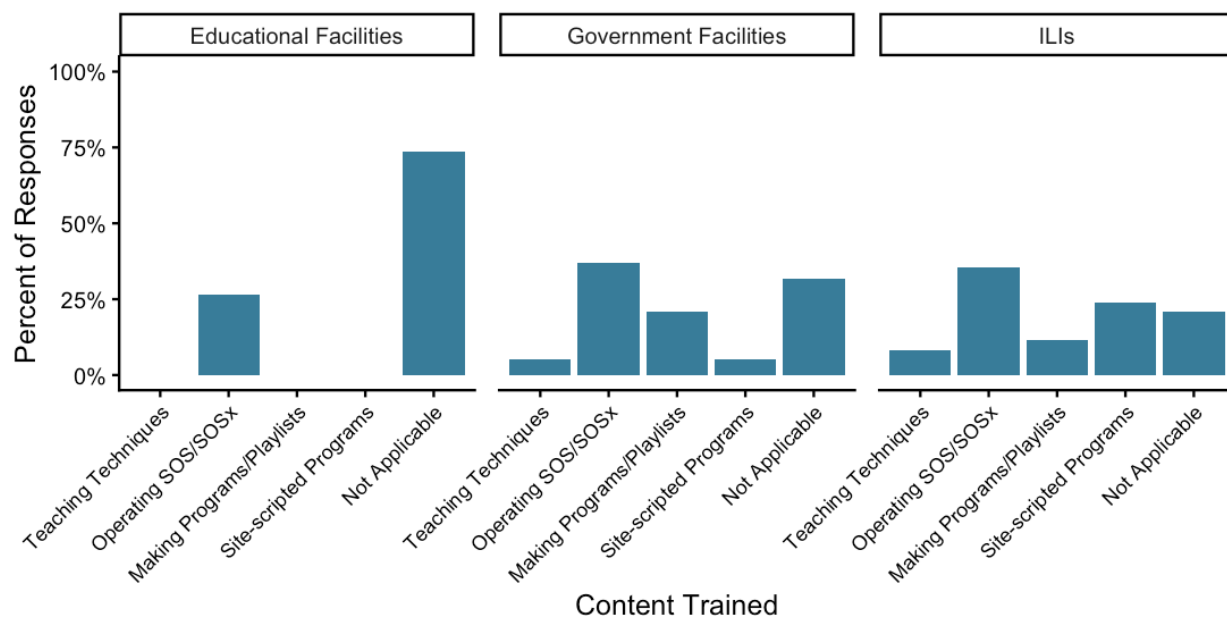


Figure 29. SOS and SOSx Sites' Training by Institution Type (Free Response)

The pattern of active learning strategies used across types of institutions was similar (Figure 30). For all institution types, “open question and answer” (22-29%) and “asking visitors to make an observation” (22-26%) were the most common strategies used. Similarly, asking visitors to draw was not a common strategy at any institution type (0-3%).

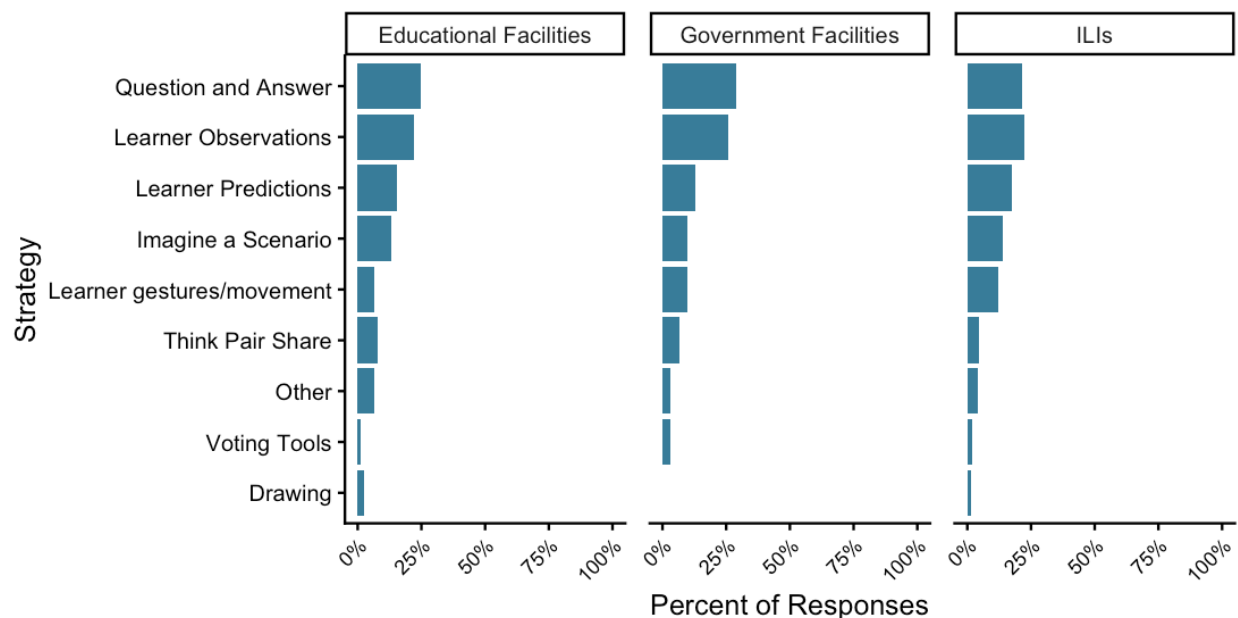


Figure 30. *Active Learning Strategies Used by Institution Type (Select-All)*

ILIs were most likely to report using props (46% of government facilities, 39% educational facilities, and 24% of ILIs report not using props; Figure 31). Within ILIs, the most frequent types of props used were those used to show physical objects or processes happening “off the sphere” (20%) and relative distances or scale (18%).

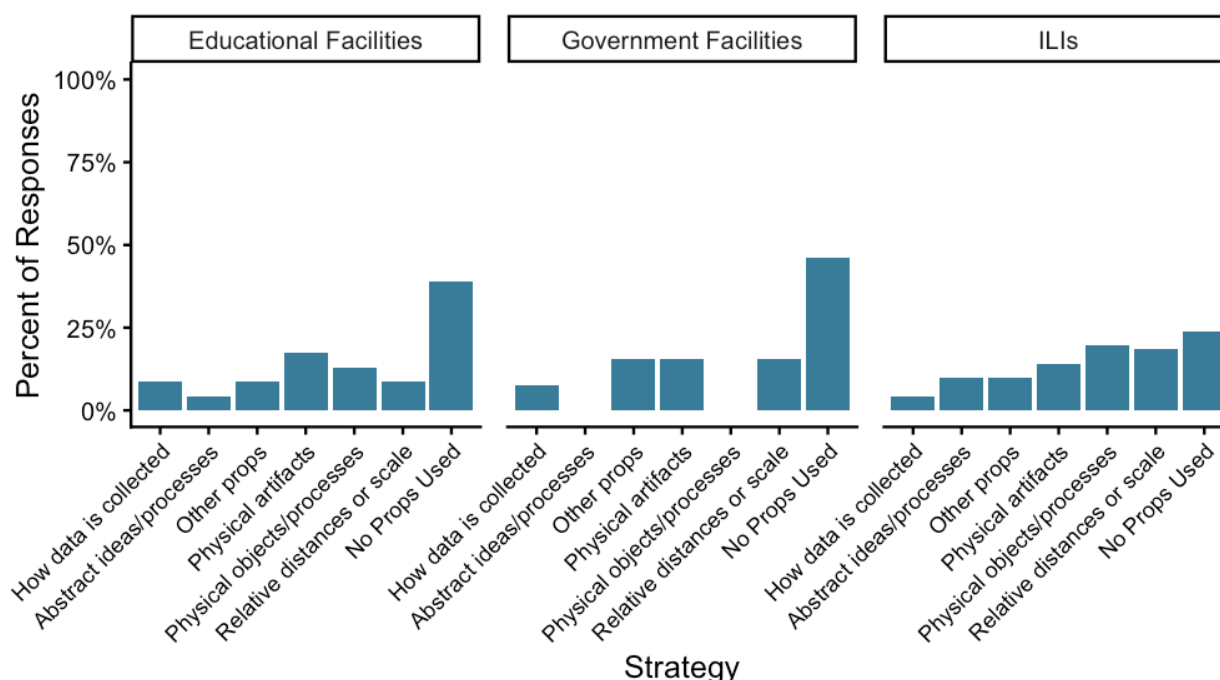


Figure 31. SOS Sites' Use of Props by Institution Type (Select All)

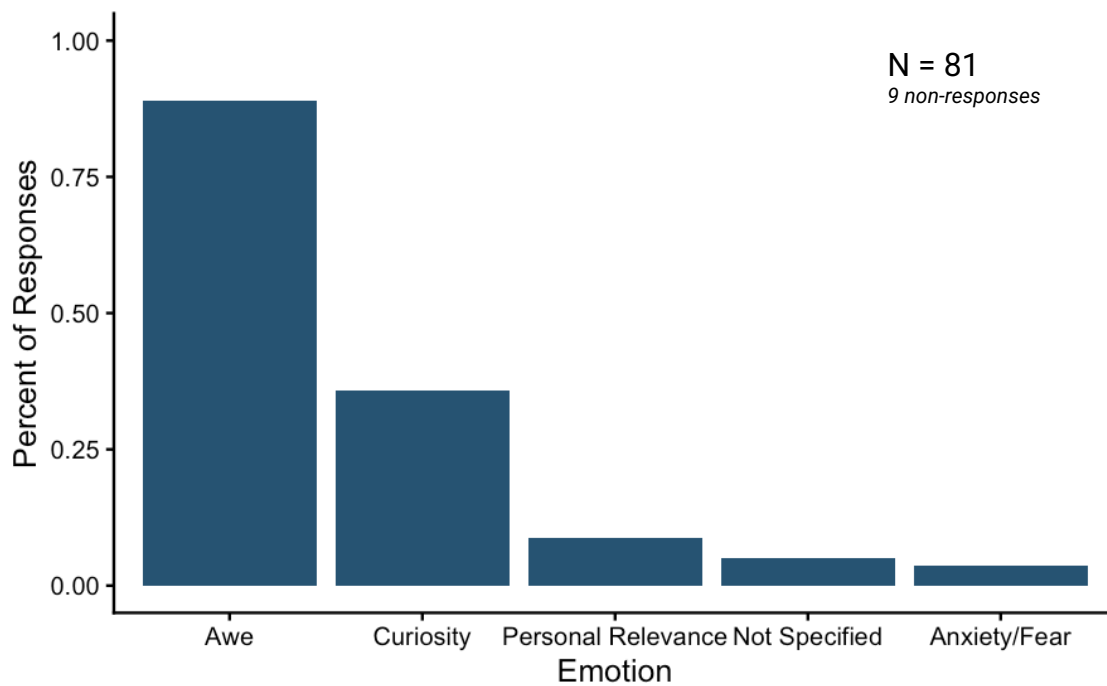
## Visitor Behavior and Reactions to SOS and SOSx

What do practitioners notice about visitor engagement with the sphere (e.g., age differences, movement around the sphere, responses to size and scale, engagement with the kiosk)?

### *Emotions, Size, and Scale Reactions to SOS and SOSx*

Practitioners reported patterns of visitor reactions to SOS and SOSx similar to prior evaluations. Almost all practitioners (98%) reported that visitors are sometimes or always surprised by the relative size or location of things on SOS/SOSx. Most practitioners reported “awe” as the emotion elicited by SOS or SOSx (89%, Figure 32, A.), but also identified curiosity (36%), personal relevance (9%) and anxiety or fear (e.g., when thinking about the effects of climate change on Earth, 4%). A little under half of respondents did not include a specific part of SOS or SOSx that elicited an emotional response, but 38% identified content presented and 33% identified the technology of SOS/SOSx as eliciting the emotional response (Figure 32, B.).

A. *Emotion Elicited*



B. *What Elicits Emotion?*

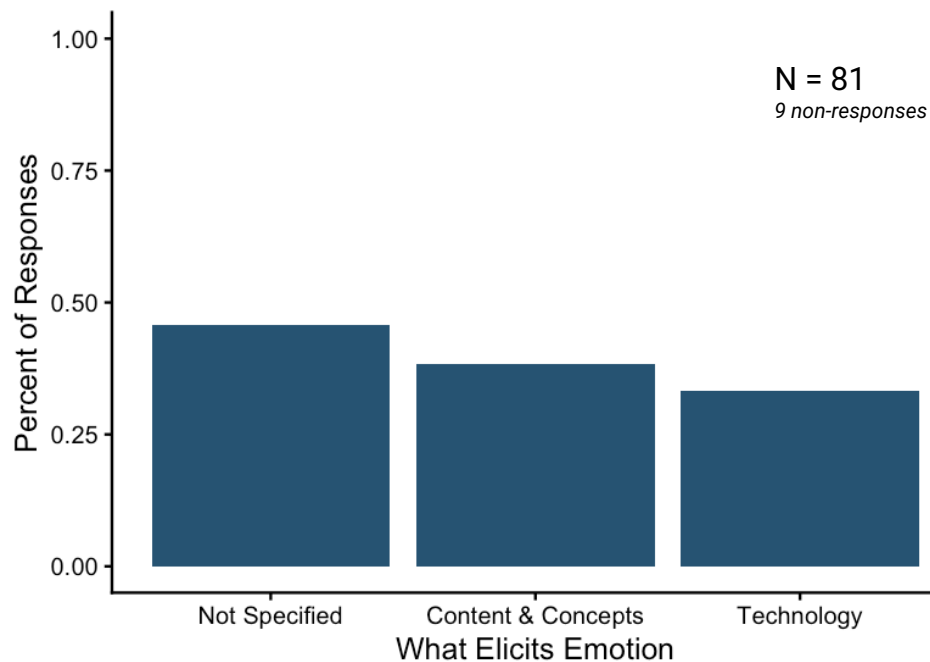


Figure 32. *Practitioners' Report of Visitors' Emotional Responses to SOS/SOSx (Free Response)*

### *Movement Around SOS*

About half of respondents said that presenters at their site asked visitors to move around the sphere sometimes or every time a presentation is given (49%, Figure 33). Twenty respondents selected “other”, highlighting features of the physical space in which their SOS is installed, such as “we have seating, so it is counter-intuitive to have them [visitors] get up from the seating and move around”, or “our SOS is displayed as a hemisphere on the wall [so it is not possible to walk around it]”. Other responses highlighted variation by the specific presenter using SOS.

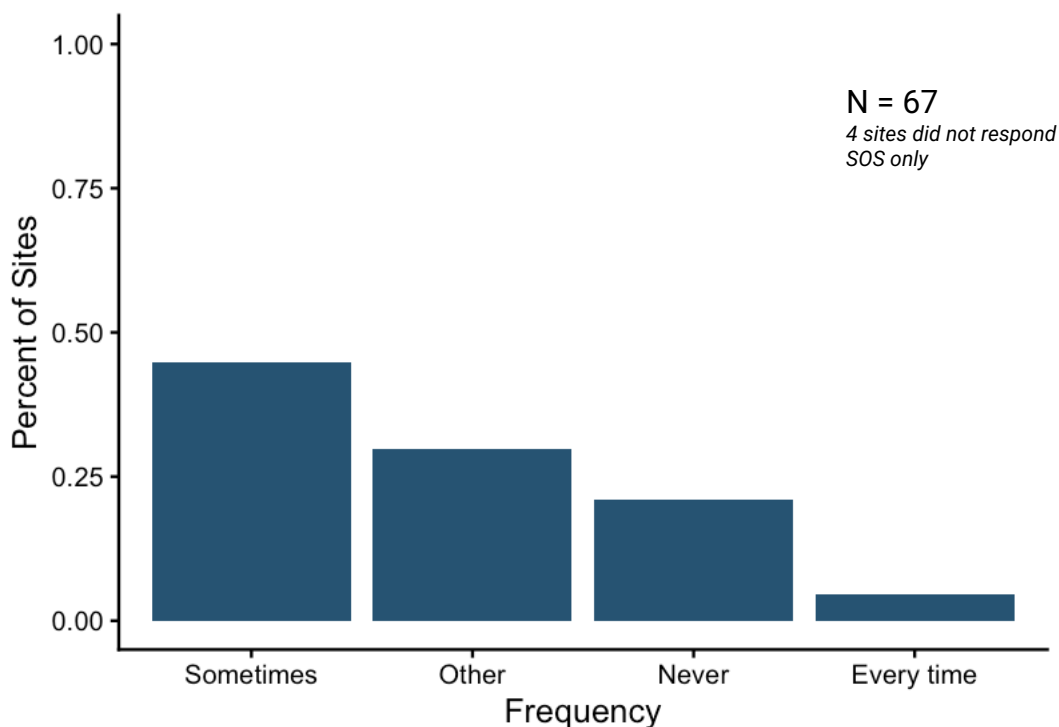


Figure 33. *How Often Do Presenters Ask Visitors to Move Around Sphere? (SOS only)*



#### Observations about SOS Kiosk and SOSx Touchscreen

Next, we asked respondents about their observations of visitors' interactions with the SOS kiosk or SOSx touchscreen (Figure 34). About a quarter of respondents said that they did not have a kiosk or touchscreen at their site (24%). Of those that did have an SOS or SOSx kiosk, the most frequent theme was a belief that the kiosk allowed increased visitor choice (34%). However, the second most frequent theme (21%) was that using SOS or SOSx with a kiosk led to challenges within their site context (e.g., a visitor selects a movie, sits down, and other visitors unwittingly override their selection). Other themes that emerged were observations about specific content visitors select (18%), software challenges (11%), age differences in kiosk use (9%), and increased visitor collaboration facilitated by the kiosk (9%).

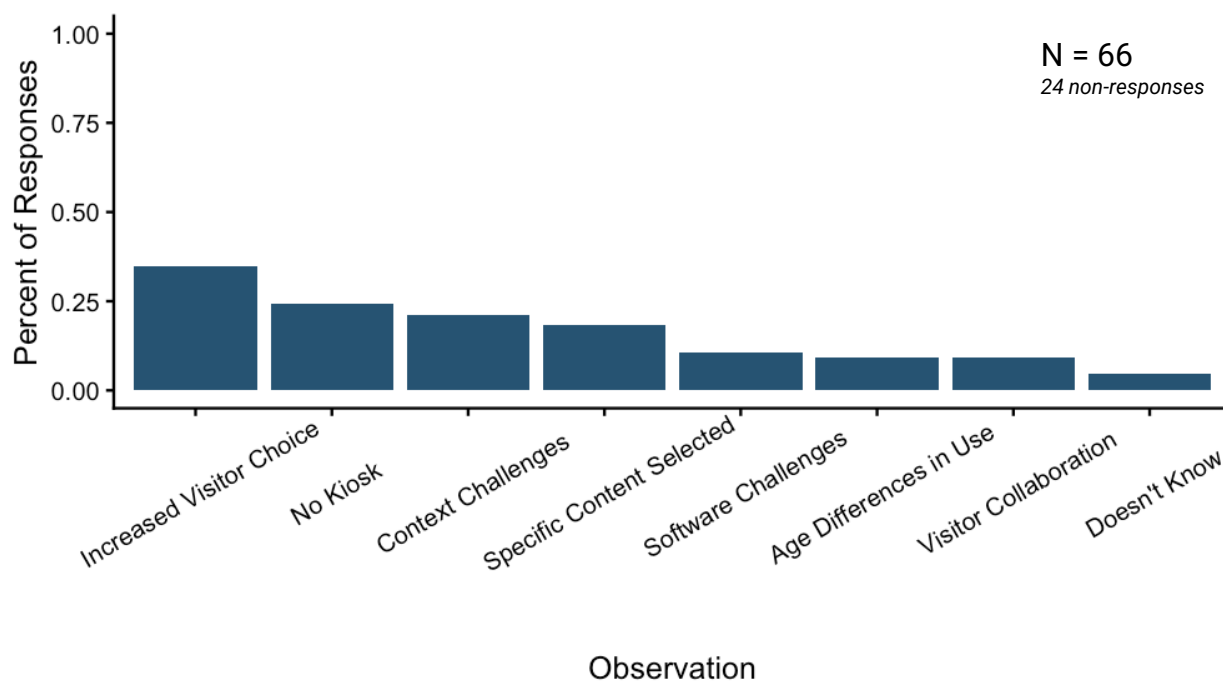


Figure 34. *Practitioners' Observations About Visitor-Kiosk Interactions (Free Response)*

#### Age Differences in SOS/SOSx Interactions

Next, respondents explained how children and adults interacted with SOS and SOSx (Figure 35). A little over a quarter of respondents reported no differences between children and adults' patterns of engagement with SOS or SOSx (32%). For respondents who did identify age differences in interaction with SOS and SOSx, seven categories of responses emerged: differences in attention and engagement (22%), interest in content or concepts versus the technology of SOS/SOSx (20%), question-asking (16%),

preferences for different modalities (15%), content understanding (15%), movement around the sphere (6%) and variation depending on child age (6%).

For each of these themes, we further identified directional patterns. Most respondents who identified age differences in attention and engagement said adults had longer attention span and greater engagement than children (83%, n=15). Further, 58% (n=11) said children are more interested in the technology that makes SOS/SOSx work than the content or concepts being displayed, while 26% (n=5) said adults were more interested in content or concepts than technology. Twelve participants identified age differences in question-asking (83% said children asked more questions than adults), content understanding (92% said adults had better content understanding than children), and use-case preferences (54% said children prefer kiosks, 31% said adults prefer presentations). Finally, only five respondents mentioned age differences in visitors' likelihood of moving around the sphere. All said children were more likely to move around the sphere than adults. We caution against over-interpretation of these directional patterns given the small number of respondents in each category.

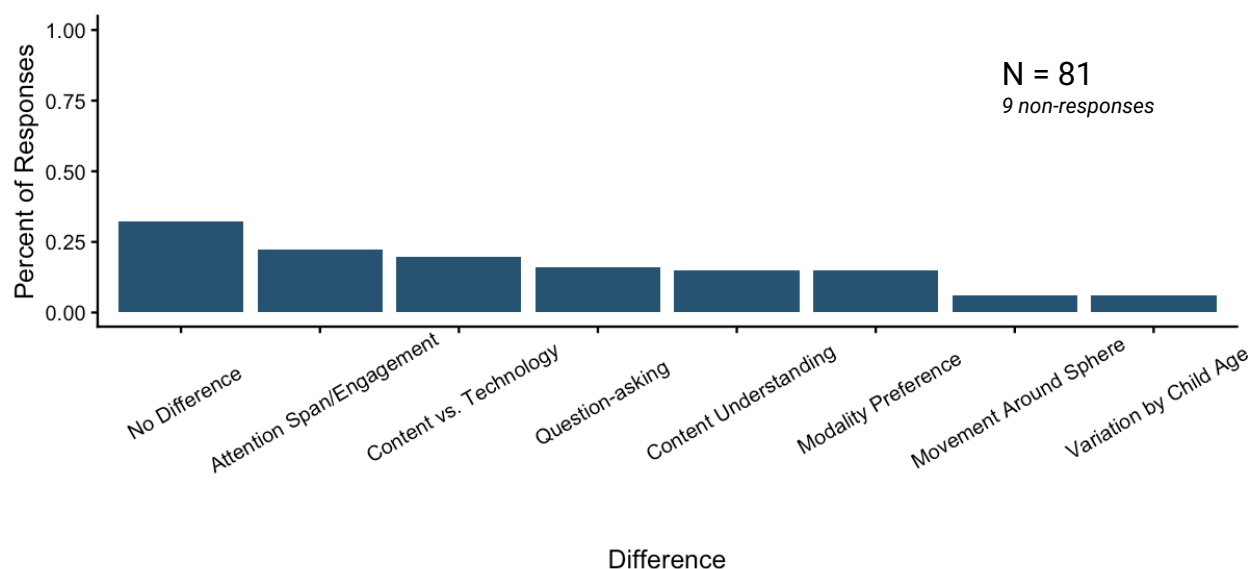


Figure 35. *Practitioners' Observations of Age Differences in Interaction with SOS and SOSx (Free Response)*

#### *What Makes SOS/SOSx Engaging*

When asked about what makes SOS and SOSx most engaging for visitors, respondents (n=79) identified the content that can be shown with these technologies (42%), the different modalities available for using SOS/SOSx (41%, e.g., presentations, kiosk, auto-run), the novelty of SOS/SOSx (34%), and specific types of visualizations that can be shown on these technologies (30%, e.g., real-time datasets).

Within each of these engagement categories, sub-themes emerged. Within “content” (n=35 respondents), 63% referenced global context, 20% referenced place connections, and 17% referenced other aspects of content as the reasons SOS/SOSx’s content was engaging. Within “modality” (n=33), 61% identified kiosks as most engaging, 27% identified formal presentations as most engaging, and 12% identified informal presentations as most engaging. Within visualization type (n=25), 56% said real-time datasets, 20% said films and movies, 24% said animated movies, and none mentioned live programs or tours.

#### *Challenges to Using SOS/SOSx as an Educational Tool*

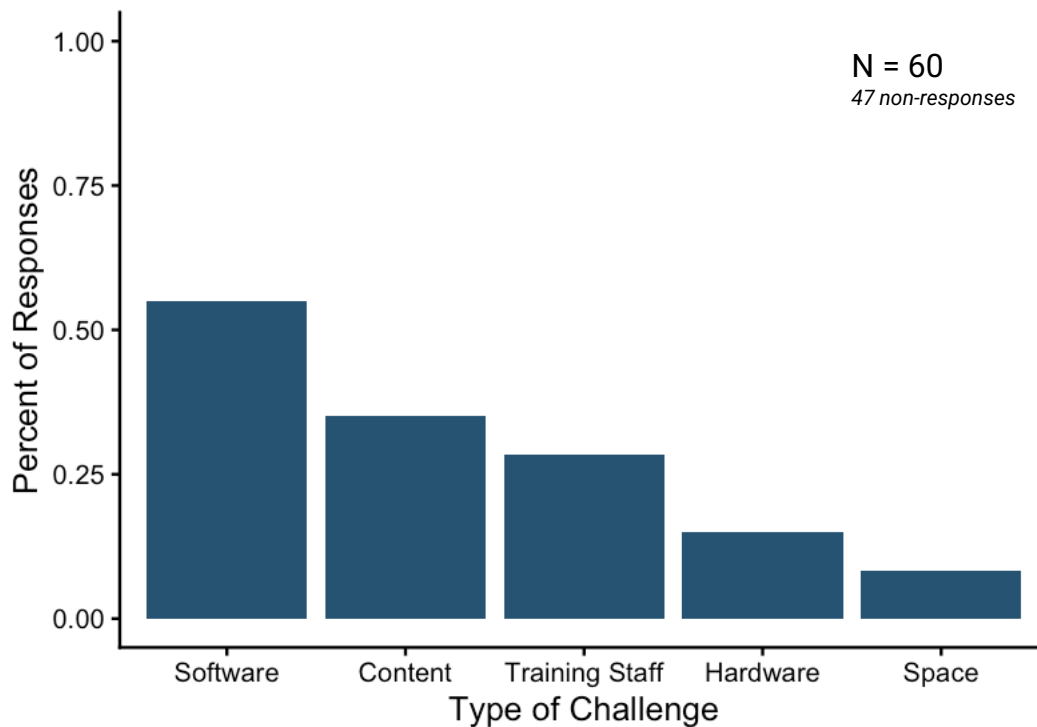
In addition to identifying features of SOS and SOSx that are engaging for visitors, respondents also identified challenges that they have encountered when using SOSx as an educational tool. We first asked respondents to answer a multiple-choice question about challenges. Seventy-three respondents from SOS sites and 25 respondents from SOSx sites responded to this item: 36% of respondents from SOSx sites reported “no challenges”, all respondents from SOS sites reported experiencing a challenge. Challenges included “it is hard to train and retain presenters” (SOS: 40%, SOSx: 8%), “it is hard to use the SOS hardware” (SOS: 25%, SOSx: 12%), “it is hard to use the SOS software” (SOS: 25%, SOSx: 12%), and “SOS content produced by NOAA does not fit our needs” (SOS: 18%, SOSx: 12%). Many respondents selected “other” to describe the challenges they experienced with their SOS or SOSx installation (SOS n=48, 66%; SOSx n=15, 60%).

As a result, we conducted thematic analysis of these “other” responses together with a separate free response question about challenges (n=60 SOS, n=16 SOSx). When we did so, the pattern across SOS and SOSx sites was similar (Figure 36 A and B). For both, respondents reported challenges with software (SOS: n=33, 55%; SOSx: n=8, 50%), content (SOS: n=21, 35%; SOSx: n=5, 31%), training staff (SOS: n=17, 28%; SOSx: n=2, 13%), and hardware (SOS: n=9, 15%; SOSx: n=2, 13%). For SOS, space constraints emerged as an additional category of response that was not included in the multiple-choice item (n=5, 8%) (Figure 36 A).

When we examined responses that mentioned SOS or SOSx software challenges, we found that these were not necessarily about the software itself, but instead about connectivity issues (SOS: n=14, 39%; SOSx: n=3, 33%), staff knowledge of how the software worked (SOS: n=12, 33%; SOSx: n=4, 44%), or suggestions of additional software features that respondents wanted to see in the future (SOS: n=10, 28%; SOSx: n=2, 22%). Next, for SOS, we found that many “content” responses highlighted that content was not aligned with their sites’ needs (SOS: n=14, 64%; SOSx: n=5) or that the site wanted to make their own custom content but did not have sufficient resources to

do so (SOS: n=6, 28%); a further two sites noted that teaching about climate change can be controversial at their site (SOS: n=2, 9%). Finally, responses touched on several reasons why training people to use SOS or SOSx can be challenging: lack of confidence presenting (SOS: n=6, 35%; SOSx: n=1), staff turnover (SOS: n=5, 29%), lack of confidence creating datasets (SOS: n=4, 24%; SOSx: n=1), and training presenters to use effective teaching techniques (SOS: n=2, 12%).

#### A. SOS



## B. SOSx

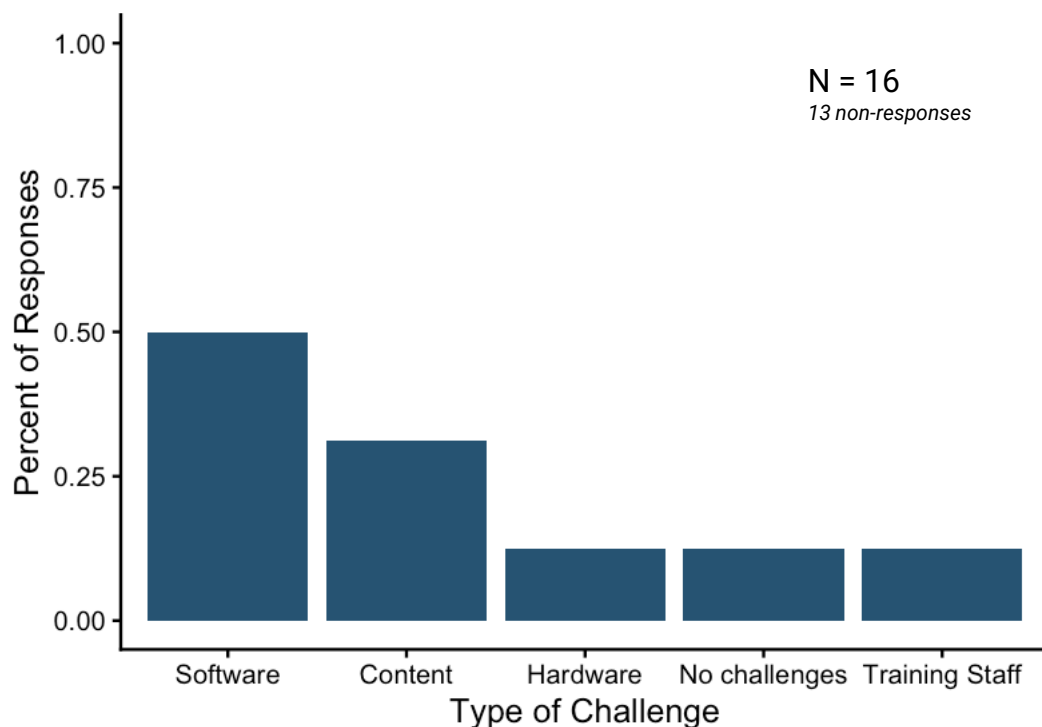


Figure 36. *Practitioners' Challenges Using SOS and SOSx as an Education Tool (Free Response)*

### *Practitioners' Research Questions*

Finally, practitioners shared research questions that they would like to see answered about SOS or SOSx (Figure 37). Practitioners' responses most frequently included questions about whether and how SOS and SOSx can be used for learning content or concepts (34%, e.g., "Are there content areas people struggle with?"; "Does dataset [visualization] type change learning?"). A similar number of respondents (34%) gave responses like "I don't understand the question". Respondents' other research questions included how learner features (e.g., age, disability status, prior STEM experience) affect learning from SOS/SOSx (21%), effectiveness of different modalities for learning (16%), how SOS or SOSx technology features affect learning (15%), extending existing SOS/SOSx capabilities or contexts (6%), investigating emotional responses to SOS/SOSx (4%), and whether SOS/SOSx can spur behavior change (e.g., around climate change, 4%).

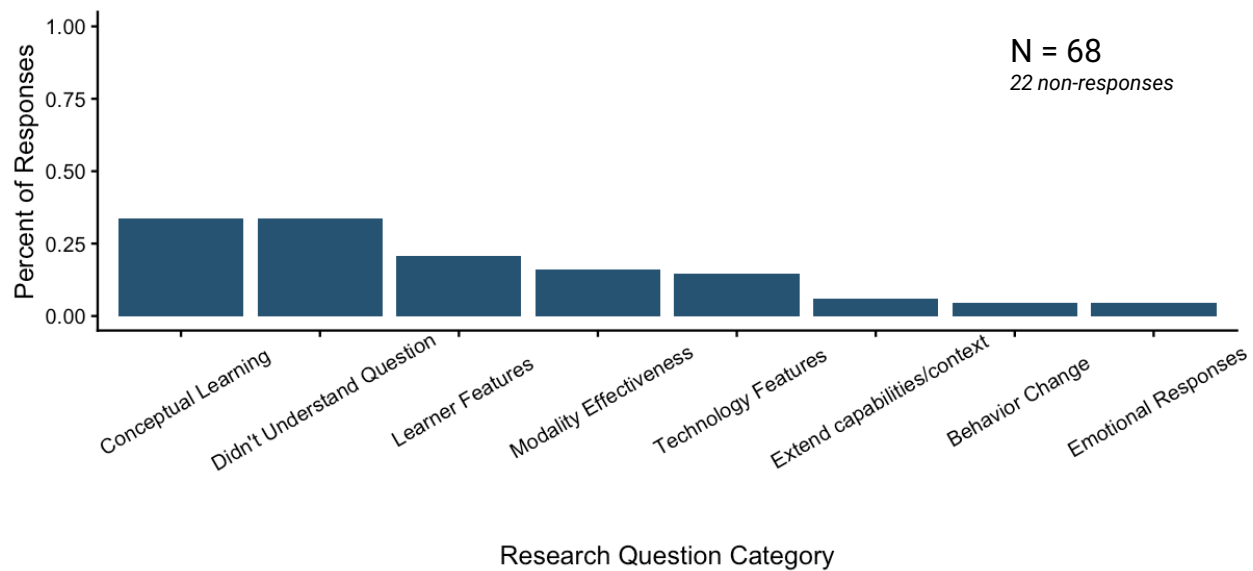


Figure 37. *Practitioners' Research Questions about SOS and SOSx (Free Response)*

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## Appendix A.

### Inactive Sites' Reports of Why They No Longer Use Their SOS Exhibit

Site	Current State of SOS/SOSx Exhibit	Why Site No Longer Uses Exhibit	Theme
1	"We need approximately \$60k for equipment upgrade, installation and training. Operating system out of date with no funding to update the software, computers, lightbulbs for projectors. It is turned off, and cranked up to the ceiling."	"We don't have personnel on staff to maintain and upgrade the equipment. Disinterest by leadership, lack of funding to update OS / computers / bulbs for projectors, and lack of a "champion" on staff. The staff who loved SOS were elevated to other positions, and scolded by their new supervisors not to spend time on programming. There is still deep interest in the SOS in town since we ran teacher in-services several times, teaching teachers how to use it, and giving them the iPad to manipulate it, even one of our staff had made lots of datasets, such as the entry of countries into WWII over a span of time (countries would light up), or voyages of early European explorers to Alaska (these show up like "spilled yarn" on the sphere!), and even datasets replicating spherical objects from our collection onto the sphere, such as Eskimo high-kick balls (for the northern sport). It's a shame, really, since we constructed the new SOS gallery specifically for the Sphere, good audience participation, and	Funding, administrative priorities

		had used the Sphere to do lots of programs about climate change. Our leadership is unwilling to seek NOAA help on this, and feels that grant funding is needed for so many other more pressing needs than resurrecting our SOS."	
2	"It is decommissioned. There are several new media products being discussed for production to contribute to the SOS Network, but they are not yet in queue."	"GSFC decided to convert the exhibit space it was using to a more traditional multi-use theater space. I am unclear about how decisions were made about our traveling sphere."	Administrative priorities, space
3	"We now run footage from our wildlife cameras onto the tv instead of SOSx."	"It was always frozen, not updated, or otherwise not working."	Technical issues
4	"At the moment due to changes in our School administration, the SOSx is not in use. We hope to have it up and running again soon."	"Changes in management resulted in physical relocation of personnel responsible for SOSx."	Administrative priorities, personnel
5	"It is in transition. We are converting it to a kiosk interactive version."	"Our SOSx exhibit has been taken offline for exhibit renovations. It will be reinstalled in the near future."	Temporary, renovations
6	"Our SOS is currently in storage."	"We are currently undergoing a 2-3 yr expansion project to build a brand new building. During this process, several exhibits will be going on/off-line during different phases."	Temporary, renovations

Note – site names are removed.

## Appendix B.

### Number of Respondents, Location, and Platforms at All Responding Sites

Site Name	Number of Respondents	Location	Platforms	Active?	Type
Museum of Natural History, Nova Scotia Museum	1	Halifax, Nova Scotia, Canada	SOS		Museum
Florida Air Museum: Aerospace Museum of Excellence	2	Lakeland, FL, USA	SOS		Museum
Alaska State Museum	2	Juneau, AK, USA	SOS	No	Museum
Aldo Leopold Nature Center	1	Monona, WI, USA	SOS		Museum
Museum of the Southwest: Blakemore Planetarium	1	Midland, TX, USA	SOS		Museum
Buttonwood Park Zoo	2	New Bedford, MA, USA	SOS		Zoo/Aquarium
Central Weather Administration: Taiwan	1	Taipei, Taiwan	SOS		Government Facility
Clark Planetarium	1	Salt Lake City, UT, USA	SOS		Planetarium

Colorado College	1	Colorado Springs, CO, USA	SOSx		Higher Ed
Conservancy of Southwest Florida (Dalton Discovery Center)	2	Naples, FL, USA	SOS, SOSx		Museum
Dayton Society of Natural History (Boonshoft Museum of Discovery)	1	Dayton, OH, USA	SOS		Museum
Denver Museum of Nature and Science	2	Denver, CO, USA	SOS		Museum
Discovery Cube Los Angeles	2	Sylmar, CA, USA	SOS		Museum
Discovery Cube Orange County	1	Santa Ana, CA, USA	SOS		Museum
University of Colorado Boulder: Fiske Planetarium and Science Center	1	Boulder, CO, USA	SOS		Higher Ed
Florida State University: Earth Ocean and Atmospheric Sciences	1	Tallahassee, FL, USA	SOS		Higher Ed
Griffin Museum of Science and Industry	1	Chicago, IL, USA	SOS		Museum

IMAG History and Science Center	2	Fort Myers, FL, USA	SOS, SOSx		Museum
Imiloa Astronomy Center of Hawaii	1	Hilo, HI, USA	SOS		Museum
International Museum of Art & Science	2	McAllen, TX, USA	SOS		Museum
Kalamazoo Valley Museum	2	Kalamazoo, MI, USA	SOS		Museum
Kitt Peak National Observatory/ NSF NOIRLab	3	Tucson, AZ, USA	SOS		Planetarium
Michigan State University Museum	1	East Lansing, MI, USA	SOS		Higher Ed
Papahānaumokuākea Marine National Monument: Mokupāpapa Discovery Center	1	Hilo, HI, USA	SOSx		Government Facility
Museu da Vida Fiocruz	2	Rio de Janeiro, Brazil	SOSx		Visitor Center
The Museum of Arts and Sciences	3	Macon, GA, USA	SOS		Museum
Museum of Life and Science	4	Durham, NC, USA	SOS		Museum
NASA Goddard Space Flight Visitor Center	1	Greenbelt, MD, USA	SOS	No	Government Facility



NASA Wallops Flight Facility Visitor Center	1	Wallops Island, VA, USA	SOS		Government Facility
NOAA Headquarters (Silver Spring)	1	Silver Springs, MD, USA	SOS, SOSx		Government Facility
Ted Stevens Marine Research Institute: NOAA Alaska Fisheries Science Center	1	Seattle, WA, USA	SOS		Government Facility
National Center for Weather and Climate Prediction: NOAA Betty Petersen Memorial Library	1	College Park, MD, USA	SOS		Government Facility
NOAA Earth System Research Laboratory	2	Boulder, CO, USA	SOS, SOSx		Government Facility
NOAA Inouye Regional Center	2	Honolulu, HI, USA	SOS		Government Facility
Northern Illinois University	1	Dekalb, IL, USA	SOS		Higher Ed
The Nurture Nature Center	2	Easton, PA, USA	SOS, SOSx		Museum
Olympic Coast National Marine Sanctuary	3	Port Angeles, WA, USA	SOSx		Government Facility
Oregon Museum of Science and Industry	1	Portland, OR, USA	SOS, SOSx		Museum

Pacific Science Center	1	Seattle, WA, USA	SOS		Museum
Palmyra Cove Nature Park/Institute for Earth Observations	1	Palmyra, NJ, USA	SOSx		Museum
Queensland Museum	1	South Brisbane, Australia	SOS		Museum
Rookery Bay Research Reserve	1	Naples, FL, USA	SOSx	No	Government Facility
Royal Saskatchewan Museum	3	Regina, Saskatchewan, Canada	SOS		Museum
Science Central	2	Fort Wayne, IN, USA	SOS		Museum
Science City at Union Station	2	Kansas City, MO, USA	SOS		Museum
Science Museum of Virginia	1	Richmond, VA, USA	SOS		Museum
SHU Discover Science Center and Planetarium	2	Bridgeport, CT, USA	SOS		Higher Ed
Smithsonian National Museum of Natural History	1	Washington, DC, USA	SOS		Museum
Snow College	1	Ephraim, UT, USA	SOSx		Higher Ed

Space Foundation Discovery Center	2	Colorado Springs, CO, USA	SOS		Museum
Tauese P.F. Sunia Ocean Center	3	Fagatogo, American Samoa	SOS, SOSx		Government Facility
Tel Aviv University	1	Tel Aviv, Israel	SOSx	No	Higher Ed
The Wild Center	3	Tupper Lake, NY, USA	SOS		Museum
Trinity University	1	San Antonio, TX, USA	SOSx		Higher Ed
UC Davis Tahoe Environmental Research Center	1	Incline Village, NV, USA	SOSx		Higher Ed
State University of New York - University at Albany	1	Albany, NY, USA	SOS		Higher Ed
University of Southern Mississippi Marine Education Center	3	Ocean Springs, MS, USA	SOS		Higher Ed
Virginia Commonwealth University <sup>7</sup>	1	Richmond, VA, USA	SOS		Higher Ed
Columbia River Maritime Museum	1	Astoria, OR, USA	SOSx	No	Museum

Cox Science Center and Aquarium (South Florida Science Center and Aquarium)	1	West Palm Beach, FL, USA	SOS, SOSx	No	Museum
CU Boulder Sustainability, Energy and Environment Community (SEEC)	1	Boulder, CO, USA	SOSx		Higher Ed
Danville Science Center	1	Danville, VA, USA	SOS		Museum
Detroit Zoological Society	1	Royal Oak, MI, USA	SOS		Zoo/Aquarium
E.O. Wilson Biophilia Center	1	Freeport, FL, USA	SOS		Museum
EcoExploratorio: Museo de Ciencias de Puerto Rico	1	San Juan, Puerto Rico	SOSx		Museum
Eugene Science Center	1	Eugene, OR, USA	SOSx		Museum
Florida International University	1	Miami, FL, USA	SOSx		Higher Ed
Fort Worth Museum of Science and Industry	1	Fort Worth, TX, USA	SOS		Museum
Galaxy E3 Elementary School	1	Boynton Beach, FL, USA	SOS		K-12

Modesto Junior College: Great Valley Museum and Planetarium	1	Modesto, CA, USA	SOS		Higher Ed
Gwangju National Science Museum	1	Gwangju, South Korea	SOS		Museum
Indiana University: Cyberinfrastructure Building	2	Bloomington, IN, USA	SOS		Higher Ed
Instituto Oceanografico da Universidade de Sao Paulo		Sao Paulo, Brazil	SOS		Higher Ed
James E. Richmond Science Center, Charles County Public Schools	1	Waldorf, MD, USA	SOS		K-12
Metropolitan Community College	2	Omaha, NE, USA	SOS		Higher Ed
Mote Marine Laboratory and Aquarium	1	Sarasota, FL, USA	SOSx		Museum
MUSE – Museo delle Scienze	1	Trento, Italy	SOS		Museum
National Maritime Museum of the Gulf of Mexico (GulfQuest)	1	Mobile, AL, USA	SOS		Museum

North Carolina Aquarium on Roanoke Island	2	Manteo, NC, USA	SOS		Zoo/Aquarium
Planetarium – Silesian Science Park	1	Chorzow, Poland	SOS		Planetarium
Public Institution Papuk Nature Park	1	Croatia	SOS		Museum
Rochester Museum and Science Center	1	Rochester, NY, USA	SOS		Museum
Santa Fe Community College	2	Santa Fe, NM, USA	SOS		Higher Ed
Science Center Heureka	2	Vantaa, Finland	SOS		Museum
Snow King Observatory and Planetarium	1	Jackson, WY, USA	SOS		Planetarium
St. Paul's School	1	Concord, NH, USA	SOS		K-12
Thunder Bay National Marine Sanctuary: Great Lakes Maritime Heritage Center	1	Lake Huron, MI, USA	SOS		Government Facility
Visit Sheboygan	1	Sheboygan, WI, USA	SOS		Visitor Center
Wings of Eagles Discovery Center	1	Horseheads, NY, USA	SOS		Museum

Aquarium of the Pacific	2	Long Beach, CA, USA	SOS		Zoo/Aquarium
Bishop Museum	1	Honolulu, HI, USA	SOS		Museum

# Appendix C.

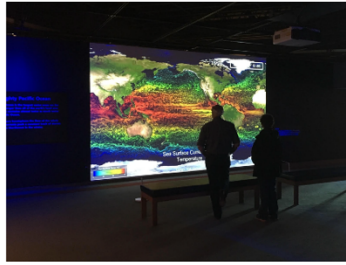
## Survey Instrument

The “SOS PLATFORMS” and “SOS USE OPTIONS” appeared as rollover options in the Qualtrics survey for relevant questions.

SOS PLATFORMS:



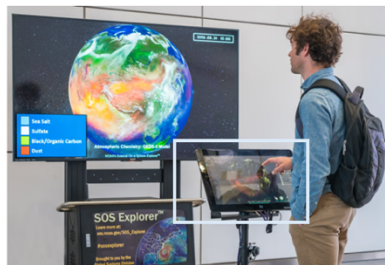
Science On a Sphere  
(SOS)  
(big ball sphere)



SOS Explorer Exhibit  
(SOSx)  
(flat screen)



SOS  
with Kiosk



SOS Explorer Exhibit with  
dual screen set up

SOS USE OPTIONS:

**“Autorun” datasets or narrated movies:** an automated playlist of datasets or movies that plays in a loop on the sphere

**Presentations by docents or other educators:** a formal presentation to a live audience

**Docent or educator available to display datasets and answer questions on demand:** someone is available at the SOS exhibit to show datasets and answer visitor questions

**Visitor-led exploration with kiosk:** visitors can directly interact with a kiosk to choose what content is displayed on SOS

**PARTICIPANTS (EVERYONE)**



Thank you for responding to this survey.

We are hoping to receive two responses for every site with a Science on a Sphere or SOS Explorer exhibit. We encourage two separate responses from the following team members:

- 1) an SOS/SOSx program manager, and
- 2) someone who frequently interacts with SOS/SOSx exhibit visitors.

We recognize that sites vary. For some sites, this might be the same person! Please respond based on what you feel you can answer confidently about your site. You'll have the opportunity to indicate in which capacity you are responding in the survey.

If your site has both an SOS and an SOSx exhibit, every respondent will be asked questions about both.

-----

1. What is your role at your institution? [Free Response]
2. What is the name of your institution? [Free Response]
3. Approximately how many people visited your institution in the last year?
  - a. <50,000 visitors
  - b. 50,001 – 150,000 visitors
  - c. 150,001 – 250,000 visitors
  - d. 250,001 – 350,000 visitors
  - e. > 350,001 visitors
4. What SOS platforms exist as exhibits at your institution? Select all that apply.
  - a) Science on a Sphere (SOS - big ball sphere)
  - b) SOS Explorer (SOSx - flat screen)
  - c) We used to have SOS but it is no longer installed, is not functional, or is not being used
  - d) We used to have SOS Explorer (SOSx) but it is no longer installed, is not functional, or is not being used

### **PARTICIPANTS (NO SITE)**

*(branching logic – if answered c or d for 4.)*

5. Please describe the current state of your SOS or SOSx exhibit. [Free Response]
6. Please explain why your institution no longer uses your SOS or SOSx exhibit.  
[Free Response]

*(then branching logic to take participants who said they no longer have SOS to the end of the survey)*

---

## **PARTICIPANTS (STILL HAVE SITE)**

*(branching logic - if they select 4 a. SOS)*

7. What best describes your role with regards to the SOS located at your site?  
Please check all that apply.
- a. Present to visitors using the SOS
  - b. Create SOS playlists
  - c. Create custom SOS datasets
  - d. Maintain or troubleshoot SOS software/hardware
  - e. Develop overall program/education programs for your SOS exhibit
  - f. Other [free response]
- 

*(branching logic - if they select 4 b. SOSx)*

8. What best describes your role with regards to the SOSx located at your site?  
Please check all that apply
- b. Present to visitors using the SOSx
  - c. Create SOSx tours
  - d. Create custom SOSx datasets
  - e. Maintain or troubleshoot SOSx software/hardware
  - f. Develop overall program/education programs for your SOSx exhibit
  - g. Other [free response]
- 

9. How long have you been involved with SOS or SOSx at your institution?
- a. Less than a year
  - b. Between 1-3 years
  - c. Between 4-7 years
  - d. Between 8-15 years
  - e. Greater than 15 years
10. Have you directly led an SOS or SOSx presentation, served as a docent with SOS or SOSx, or otherwise guided visitors' use of your SOS or SOSx exhibit?
- a. Yes
  - b. No
- 

*(branching logic, if they answer 10 a. Yes)*

11. When was the last time you led an SOS or SOSx presentation or guided visitors' use of your SOS or SOSx exhibit?
- a. In the last week
  - b. In the last month
  - c. In the last six months
  - d. In the last year
  - e. In the last five years
  - f. More than five years ago
12. How frequently do you give presentations or guide visitors' use of your SOS or SOSx exhibit?
- a. Multiple times a week
  - b. About once a week
  - c. About once a month
  - d. About once every six months
  - e. About once a year
  - f. Less than once a year
- 

### MANAGER SELF SELECT

The next set of questions is for SOS or SOSx program managers.

We will ask about the content you show on your sphere, whether and how you customize it, and details about the physical setup of your SOS or SOSx exhibit.

If you feel confident answering these kinds of questions, please select "yes". If you do not feel confident answering these kinds of questions, please select "no".

- a. Yes, I can answer these program manager questions
- b. No, I cannot answer these program manager questions

### CONTENT (SOS & SOSx – MANAGERS)

13. Who are the main audiences for your SOS exhibit? Select all that apply.
- a. Public audience
  - b. K-12 student groups
  - c. University student groups
  - d. Professional groups
  - e. Other (please elaborate)
14. How frequently do SOS or SOSx presentations at your site cover the following topics? (matrix)
- d. Ocean or Water [often, sometimes, rarely, never]
  - e. Astronomy [often, sometimes, rarely, never]

- f. Atmosphere [often, sometimes, rarely, never]
  - g. Land [often, sometimes, rarely, never]
  - h. Arctic [often, sometimes, rarely, never]
  - i. Ecological systems (including animals) [often, sometimes, rarely, never]
  - i. Human systems [often, sometimes, rarely, never]
  - k. Other [please elaborate]
15. Approximately how much of your SOS or SOSx programming focuses on climate change?
- a. None
  - b. Some
  - c. About half
  - d. More than half
  - e. All
  - f. N/A

*(branching – if they answer b-e for 42.)*

16. Does SOS or SOSx programming at your site include any of the following? Select all that apply.
- a. Climate change solutions
  - b. Place-based or local connections
  - c. Careers related to climate or Green jobs
  - d. Climate change impacts or challenges
  - c. Climate change projections
17. What type of datasets does your site currently use? Select all that apply.
- a. Dataset with neither audio nor text (other than legends) (e.g., Blue Marble)
  - b. Datasets with added text only (e.g., Solar Eclipse Paths and Cloud Fractions)
  - c. Dataset with audio description only (e.g., Carbon Dioxide Concentration: GEOS-5 Model)
  - d. Dataset that is a narrated movie (e.g., Frozen, Largest)
  - e. Live programs (pre-set playlists with script; e.g., Climate Change 101)
  - f. Real-time datasets (e.g. [Clouds – Real-time](#))
  - g. I don't know
18. Please elaborate on the reasons why your site selects these datasets. [Free Response]
19. Does your site create custom content to show on your SOS or SOSx? Select all that apply.
- a. We use content from the SOS Data Catalog without changing it
  - b. We use content we've augmented from the SOS Data Catalog
  - c. We create new custom datasets
  - d. We create new custom narrated movies

e. Other [text box]

*[branching logic – display only if responded b, c, d or e for prior question]*

20. Does anyone at your site customize datasets or movies?

- b. Customization by adding audio
- c. Customization by adding captions
- d. Customization by adding image or movie PIPs (picture in picture)
- e. Customization by adding Text PIPs
- g. Customization by adding custom dataset descriptions that show up in the iPad
- j. We add information by adding presenter notes (to the iPad app)
- l. Customization by displaying information on a screen nearby while using SOS
- m. Customization in other way (please elaborate)

21. Do you turn “on” the built-in movie captions on SOS datasets?

- a. Yes, we use captions in English
- b. Yes, we use captions in another language [textbox]
- c. No, we do not use captions
- c. No, I didn’t know about this feature

22. Do you translate any of the following SOS or SOSx content? Select all that apply.

- a. Yes, we translate dataset titles and/or descriptions
- b. Yes, we translate user interfaces (e.g., kiosks)
- c. Yes, we translate audio or captions on movies
- d. No, we do not translate any SOS content
- e. Other (please elaborate)

*[branching logic – only if they select 46 b. or do not select 47 d.]*

23. Which languages do you translate SOS or SOSx content into? [drop down box]

### EDUCATOR SELF SELECT

The next set of questions is for people who interact frequently with SOS or SOSx visitors. We will ask you about your observations of how visitors interact with SOS or SOSx and about SOS or SOSx presentations, if applicable.

We recognize that SOS and SOSx sites vary, so this could be an education lead, an educator, a long-time volunteer docent, or a program manager.

If you feel confident answering these kinds of questions about your site, please select

"yes,". If you do not feel confident answering these kinds of questions, please select "no".

- a. Yes, I can answer these educator questions
- b. No, I cannot answer these educator questions

*[branching logic – respondents will see either 1) SOS, 2) SOSx, 3) 2 questions relevant to SOS + SOSx sites depending on how they responded to Q3 above “What SOS platforms exist as exhibits at your institution?”]*

### **SET UP (SOS ONLY - EDUCATORS)**

- 24. Does your SOS exhibit include a kiosk that allows visitors to directly control SOS?
  - a. Yes
  - b. No
  - c. I don't know
- 25. Does the display location of your site's SOS exhibit include seating?
  - a. Yes
  - b. No
  - c. I don't know
- 26. Does the placement of your site's SOS exhibit allow using audio?
  - a. Yes
  - b. No
  - c. I don't know
- 27. How do you find out about new SOS datasets? Select all that apply.
  - a. SOS Google Group emails
  - b. SOS “In the Loop” e-newsletter
  - c. SOS social media
  - d. SOS Education Forum webinars
  - e. I go to the SOS website to discover new datasets
  - f. I sort by Date Added on the SOS Remote iPad app
  - g. I use the SOS Spotlight feature on the SOS Remote iPad app
  - h. Others from my team tell me about new datasets
  - i. Colleagues from another site tell me about new datasets
  - j. Other [please explain – text box]

*[branching logic – if they select e., go to this question]*

- 28. Do you use the “Next Generation Science Standards (NGSS)” filter to search the SOS Data Catalog?
  - a. Yes

- b. No
- c. No, I didn't know it existed

29. In which ways do you use SOS at your site currently? (**matrix question**)

- a. "Autorun" of datasets or narrated movies  
(always, daily, weekly, monthly, a few times a year, N/A)
- b. Presentations by docents or educators  
(always, daily, weekly, monthly, a few times a year, N/A)
- c. Docent or educator available to display datasets and answer questions on demand  
(always, daily, weekly, monthly, a few times a year, N/A)
- d. Visitor-led exploration with kiosk  
(always, daily, weekly, monthly, a few times a year, N/A)
- e. Other [Please describe:]

30. Please describe how your institution generally uses SOS with visitors? (For example, *"Our site has two docent-led presentations per day, and the rest of the time we have auto-run datasets and videos on the sphere."* Or *"Our site only uses presentations by educators or docents"*)

[Free Response]

31. Please describe any challenges when using SOS as an educational tool. Select all that apply.

- a. SOS content produced by NOAA does not fit our needs
- b. It is hard to train and retain presenters
- c. It is hard to use the SOS software
- d. It is hard to use the SOS hardware
- d. Other (please elaborate)

32. Please elaborate on challenges when using SOS as an educational tool: [free response]

### SET UP (SOSx ONLY EDUCATORS)

33. Does your SOSx exhibit include a touchscreen that allows visitors to directly control SOSx?

- b. Yes
- c. No
- d. I don't know

34. Does the display location of your site's SOSx exhibit include seating?

- a. Yes
  - b. No
  - c. I don't know
35. Does the placement of your site's SOSx exhibit allow using audio?
- d. Yes
  - e. No
  - f. I don't know
36. How do you find out about new SOSx datasets? Select all that apply.
- b. SOS "In the Loop" e-newsletter
  - k. SOS social media
  - l. I go to the SOS website to discover new datasets
  - m. Others from my team tell me about new datasets
  - n. Colleagues from another site tell me about new datasets
  - o. Other [please explain – text box]

(display logic – if they select l. for preceding question)

37. Do you use the "Next Generation Science Standards (NGSS)" filter to search the SOS Data Catalog?
- a. Yes
  - b. No
  - c. No, I didn't know it existed
38. In which ways do you use SOSx at your site currently? (**matrix question**)
- b. Tours of datasets or narrated movies on repeat  
(always, daily, weekly, monthly, a few times a year, N/A)
  - c. Presentations by docents or educators  
(always, daily, weekly, monthly, a few times a year, N/A)
  - d. Docent or educator available to display datasets and answer questions on demand  
(always, daily, weekly, monthly, a few times a year, N/A)
  - e. Visitor-led exploration with touchscreen  
(always, daily, weekly, monthly, a few times a year, N/A)
  - f. Other [Please describe:]
39. Please describe how your institution generally uses SOSx with visitors? (For example, "Our site has two docent-led presentations per day, and the rest of the time we have auto-run datasets and videos on SOSx." Or "Our site only uses presentations by educators or docents")



[Free Response]

40. Please describe any challenges when using SOSx as an educational tool. Select all that apply.
- b. SOSx content produced by NOAA does not fit our needs
  - c. It is hard to train and retain presenters
  - e. It is hard to use the SOSx software
  - f. It is hard to use the SOSx hardware
  - e. Other (please elaborate)
41. Please elaborate on challenges when using SOSx as an educational tool: [free response]

### SET UP (SOS & SOSx EDUCATORS)

*(branching logic – if answered that they have both an SOS and SOSx at their site.)*

42. How are your SOS and SOSx located in relation to each other?
- a. In the same room – visitors can view both simultaneously
  - b. In the same room – visitors cannot view both simultaneously
  - c. In separate rooms
43. Do you ever use your original SOS and SOSx together for educational purposes?
- a. Yes (please elaborate)
  - b. No
  - c. I don't know

### VISITOR OBSERVATIONS (SOS & SOSx - EDUCATORS)

44. Have you observed visitors being surprised at the size or relative location of things they see on SOS or SOSx?
- a. Never
  - b. Sometimes
  - c. Always
45. What emotional responses to the sphere, if any, have you noticed in your visitors?
46. Do you observe any differences in interactions with SOS or SOSx when comparing children to adult visitors?
- (branching logic – only if they say they have an SOS kiosk or SOSx touchscreen above)*
47. Please describe any observations you have had about how visitors interact with the SOS kiosk or SOSx touchscreen at your site (e.g., datasets selected, time spent, collaboration with other visitors)?

## **PRESENTERS (SOS & SOSx – EDUCATORS)**

[branching logic – educators will only see this if they selected anything other than n/a for q 17 (about how their site uses SOS or SOSx)]

48. Which of the following best describes presenters at your site? Select all that apply.
- a. Volunteers
  - b. Paid staff
  - c. Educators
  - d. Subject-matter experts
  - e. Other (please elaborate)
49. Do SOS presenters at your site use presenter scripts? Select all that apply.
- a. Yes, presenters make their own scripts
  - b. Yes, we have site-wide scripts
  - c. Yes, we use scripts from SOS Live Programs
  - d. No (please elaborate)
  - e. I don't know
50. Please describe the training you offer to SOS presenters at your site:  
[Free Response]
51. Do presenters at your site incorporate the following techniques into SOS presentations? Select all that apply.
- a. Asking visitors to make a prediction
  - b. Asking visitors to make an observation
  - c. Clicker or other voting tool questions
  - d. Asking visitors to draw
  - e. Open Question and Answer
  - f. Asking visitors to imagine a scenario
  - g. Think pair share (asking visitors to talk with a neighbor and then share with the group)
  - h. Asking visitors to make gestures or other movement
  - i. Other (please elaborate)
  - j. None of the above
52. How often does your site use static, non-animated datasets in presentations?
- a. Never
  - b. Sometimes
  - c. Regularly
53. When do you choose to use static versus animated datasets?

## **PRESENTERS (SOS ONLY – EDUCATORS)**

*[branching logic – will only see this if they indicate they have an SOS on question 4]*

54. How often do presenters at your site ask visitors to move around the sphere when presenting with SOS?
- a. Every time a presenter gives an SOS program
  - b. Sometimes when presenters give an SOS program
  - c. Presenters never ask visitors to move around the sphere
  - d. Other (please elaborate)
55. Do presenters at your site use props when presenting with SOS? Select all that apply.
- a. We do not use props
  - b. We use props to represent physical artifacts from the Earth (e.g., a piece of coral, a rock, animal bones)
  - c. We use props to represent physical objects or processes that happen “off of the sphere” (e.g., how the Earth moves around the Sun)
  - d. We use props to show relative distances or scale
  - e. We use props to represent abstract ideas or processes (e.g., magnetic fields around earth)
  - f. We use props to show how data presented on the sphere are collected (e.g., a buoy)
  - g. We use props in a different way. Please elaborate.

## **FINAL QUESTIONS (everyone)**

56. What appears to be most engaging about the SOS or SOSx exhibit for visitors at your site? Please elaborate and provide examples.  
[Free Response]

57. If you were to suggest a research topic, what questions do you have about how visitors learn from SOS or SOSx?

[Free Response]

*(branching if they consented to images in the consent form)*

58. Please upload picture(s) of all SOS or SOSx exhibits at your institution, including any kiosks

# Appendix D.

## Qualitative Coding Scheme for Free Response Survey Items

### **A few notes to keep in mind:**

Please note that some codes are NOT mutually exclusive. If an item is marked as being mutually exclusive, select only one code. If an item is not marked as being mutually exclusive, and you feel that 2 codes apply to a response, please write both in the excel sheet with a comma separating them.

Some items were presented after a multiple-choice item (Q18, Q30/39, Q32/41, Q53). Please be sure to read the prompts for the preceding item (included here). They will help you understand the item you are coding.

Some items have both a primary code and one or more subcodes. Each will be its own column the excel sheet. You will assign a code for each of the subcodes.

Some items are the same, except one was asked about SOS (big ball sphere) and one was asked about SOSx (flatscreen). In these cases, you will apply the same coding scheme to both questions.

## Free Response Items

Q17: What type of datasets does your site currently use? Select all that apply.

- h. Dataset with neither audio nor text (other than legends) (e.g., Blue Marble)
- i. Datasets with added text only (e.g., Solar Eclipse Paths and Cloud Fractions)
- j. Dataset with audio description only (e.g., Carbon Dioxide Concentration: GEOS-5 Model)
- k. Dataset that is a narrated movie (e.g., Frozen, Largest)
- l. Live programs (pre-set playlists with script; e.g., Climate Change 101)
- m. Real-time datasets (e.g. [Clouds – Real-time](#))
- n. I don't know

Q18: Please elaborate on the reasons why your site selects these datasets. [Free Response]

### Q18\_dataset

Dataset Type Reason	Code	Example
Visitor chooses (not respondent)	1	Site uses kiosk, so visitors choose which dataset types to look at – this can also be true if the response says that the visitor chooses (even without including kiosk) <i>*If respondent mentions that there is a kiosk in their response to this item– we will add a 1 code*</i>
Space, hardware, presentation format constraints	2	sound bleeding from other galleries, language barrier for movies, disconnected audio system, educators giving a presentation don't want audio from SOS playing over them, educators use audio for topics they don't know much about
Align with content they are trying to present about	3	real-time datasets for recent weather phenomena; "our system is used in the classroom to project datasets specific to the course being taught"
Perceptions of audience engagement or understanding	4	"I use real-time datasets...usually after other materials and I detect that the visitor "gets it"; "in our elementary school, primary to Grade 6 programs"; "we want to give our guests a diverse list of datasets to show the versatility of SOS"

Don't know or non-responsive	777	"in some senses the sphere is a news source"; "they were chosen before I became involved with the program" <i>*really only use this one if there is not something we could interpret!</i>
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Note: these items should be coded the same way – one is about SOS and one is about SOSx

**Q29/38.** In which ways do you use SOS at your site currently?

- c. "Autorun" of datasets or narrated movies  
(always, daily, weekly, monthly, a few times a year, N/A)
- d. Presentations by docents or educators  
(always, daily, weekly, monthly, a few times a year, N/A)
- e. Docent or educator available to display datasets and answer questions on demand  
(always, daily, weekly, monthly, a few times a year, N/A)
- f. Visitor-led exploration with kiosk  
(always, daily, weekly, monthly, a few times a year, N/A)
- g. Other [Please describe:]

**Q30/39.** Please describe how your institution generally uses SOS with visitors? (For example, "Our site has two docent-led presentations per day, and the rest of the time we have auto-run datasets and videos on the sphere." Or "Our site only uses presentations by educators or docents")

#### Primary code

Q30\_notpres/Q39\_notpres

What is the use of SOS/SOSx when presentations are not happening	Code	Example
Not clear from response	777	"Faculty led discussions for students and visitors."
SOS/SOSx is turned off	0	"Our room is multipurpose, so we do not have the sphere on auto run ever"
Datasets or movies are played in autorun	1	"When an educator is not in SOS or is on break, we have a series of videos playing back-to-back on loop for the public to enjoy."
Kiosk is available	2	"Our site has three part-time presenters who present lessons to students that meet their science education standards. <b>We also use the kiosk without auto-play mode</b> most of the time in order to collect data on visitor interest and use it to guide our customization of kiosk datasets."

Q30\_pres/Q39\_pres

Presentation Details	Code	Example
Frequency	1	Does the response explicitly mention how frequently presentations are done?
Day or Time	2	Does the response mention day of the week or time of day patterns (e.g., weekday v. weekend; daytime v. evening)
Fieldtrips	3	Does the response mention field trips? (e.g., "field trips", "school groups", "visiting students")
Special audiences	4	Does the response mention SOS/SOSx being used for other specific audiences (e.g., , paid participants, "special events or guests", "VIPs")
No presentations	777	If they mention no presentations being done with their SOS/SOSx at all!

### Subcodes

#### Q30\_freq/Q39\_freq

Frequency of Presentations	Code	Example
Frequency not mentioned	777	"We have interpretation and planetarium staff that will utilize SOS when they are doing in-person presentations otherwise the unit is self-guided experience from the kiosks."; "Docent programs happen regularly, don't know how often but our educator answering the survey will."
<1x per week	1	"We very, very occasionally have docent-led interactions (almost always me)."; "Docent led presentations on certain occasions about once a month."
1-3x per week	2	"We usually have a ~8 hour runs a few SOS shows every week for general visitors."
4-5x per week	3	"We have one presentation a day Tuesday-Friday"
6-9x per week	4	"We have a docent-led presentation twice a day."
10+ x per week	5	"The SOS serves as one of the exhibits in the Solar Telescope facility. We have a 2-4 SOS presentations per day."

\*note that for this subcode, you may need to calculate – e.g., if a site is open 5 days per week, and there are 2 presentations per day, that would be 10+ times per week. If a site



does not include the number of days per week (e.g., “we have docent-led presentations twice a day”, please use 5 as our baseline.

\*added 3/11: if there is ambiguity, use the \*minimum number\*. For example, if a site says “we have educator presentations during the week with students, and one presentation per day on the weekend”, put a code of 2 (“1-3x per week”), because we do not know from their response how many presentations are happening during the week. Further, please mark responses that have this kind of ambiguity.

#### Q30\_time/Q39\_time

Day/Time pattern of presentations	Code	Example
No day or time pattern mentioned	777	“Every group has docent-led presentations”
Weekends and weekdays are different	1	“Field trip programs integrated into activities with school groups and open presentations to the public on weekends when a volunteer is available”; “Kiosk for public use all day. Two docent-led presentations per day on weekends. School tour presentations for anyone from 10 to 50 students per tour one to four times a day Tuesdays thru Fridays.”
Daytime and evenings are different	2	“We typically offer the SOS kiosk and sphere during the day for university students, K12 groups, and public audiences to use. At night, we have our student employees available to present SOS content to public audiences.”

#### Q30\_trips/Q39\_trips

Field Trips mentioned	Code	Example
Presentations for field trips are not mentioned	777	“The setup allows visitors to control it from a panel, or facilitator from an iPad”
Some presentations are for field trips	1	“We have different school programs that integrate the SOS as part of the program. These school programs are staff-led presentations...During the weekend we have staff-led presentations once per day as well as docent-volunteers available to answer questions from visitors.”

		-> presentations for <b>both</b> school programs and general visitors mentioned; could use language like "workshop"
All presentations are for field trips	2	"Our site has three part-time presenters who present lessons to students that meet their science education standards."

Note: these items should be coded the same way – one is about SOS and one is about SOSx

**31/40.** Please describe any challenges when using SOS as an educational tool. Select all that apply.

- c. SOS content produced by NOAA does not fit our needs
- d. It is hard to train and retain presenters
- g. It is hard to use the SOS software
- h. It is hard to use the SOS hardware
- f. Other (please elaborate)

32/41. Please elaborate on challenges when using SOS as an educational tool: [free response]

**Please also look at column Q31\_5\_TEXT and Q40\_5\_TEXT – some respondents answered in that "other" text box!**

**Primary Code:31**

**Q32\_challenge/Q41\_challenge**

Type of Challenge	Code	Example
No challenges	0	"We currently do not have challenges in using SOS as an educational tool."
Software	1	"Using the software to add new tools is difficult and not obvious. Finding the correct dataset is sometimes difficult."; "The technology we are using to run our SOS is incredibly outdated, but there is no one at my facility who knows enough about it to make

		the changes that need to be made to update it at this time."
Hardware	2	Age of hardware, video card issues, "Crestson" <i>*note: there is no sub-code for hardware problems</i>
Content	3	"Sometimes the provided datasets don't fit our needs or we have to find creative ways to use them."
Training Staff	4	"It is difficult to train our demonstrators not only on using the system but to look up and create their own datasets. It is intimidating to them."; "Education team has low retention rate, so training new staff takes time we do not always have."
Space	5	"At least in our exhibit, I feel if the space was bigger, it would be better for the audience."; "Any challenges I have are more specific to my own work and site (ex. our gallery is really loud when other people are in the building in nearby galleries, so I really need a sound dampening door!)"

### Subcodes:

#### Q32\_software/Q41\_software

Software	Code	Example
Not a software challenge	777	<i>*add this if you gave a code for Q32/41_challenge but it was not 1 - software</i>
Connectivity issues	1	Ipad touchscreen issues, lagging, freezing
Staff knowledge of software	2	Lack of staff knowledge to make updates, challenges navigating tools, challenging to update software, presenter interface too complicated, challenges making/curating playlists, operating system (e.g., Linux) is unfamiliar
Software feature suggestion	3	Keypad display when kiosk is locked is distracting to visitors

#### Q32\_content/Q41\_content

Content	Code	Example
Not content challenge	777	<i>*add this if you gave a code for Q31/42_challenge but it was not 3 - content</i>

Content doesn't align with site needs/audiences	1	Non-science datasets, curriculum aligned content, reading level is too high for visitors to understand
Don't have enough resources to make the custom content they want	2	Staff knowledge, money, time; "those who want to use it can't/won't make their own content and we lack manpower to put out custom content quickly"
Climate change is controversial	3	"Another challenge is not about SOS exhibit, but the challenge is we are in a time when Climate change is often considered a controversial topic and navigating the best way to educate about the changing planet due to human impact."

### Q32\_training/Q41\_training

Training Staff	Code	Example
Not training challenge	777	<i>*add this if you gave a code for Q31/42_challenge but it was not 4 – training staff</i>
Staff turnover	1	"Education team has low retention rate, so training new staff takes time we do not always have."
Lack of confidence in creating own datasets	2	"It is difficult to train our demonstrators not only on using the system but to look up and create their own datasets. It is intimidating to them."
Lack of confidence in presenting with SOS (technology or content)	3	"There are a lot of datasets available, and facilitator training is a challenge. Facilitators desire to learn about a LOT of datasets before they feel comfortable interacting with the SOS and guests."; "Staff can be intimidated by technology and hard/specific science of datasets."
Not good at presenting	4	"We have a lot of experts here but they don't always present well. So we need to do a better job of educating our presenters on best practices."

### Q32\_space/Q41\_space

Space constraints	Code	Example
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Not space constraint	777	<i>*add this if you gave a code for Q32/41_challenge but it was not 5 - space</i>
Size or location of space housing SOS	1	Too small; blocks a major thoroughfare so people can't gather for presentations; space is too bright to see SOS clearly
Seating availability	2	Don't have seating, "we have backless benches and they are hard to sit in"
Sound	3	Space is loud

**45** What emotional responses to SOS or SOSx, if any, have you noticed in your visitors?

*\*There are TWO independent codes for this item (c1 and c2)*

**Q45\_c1**

Emotion	Code	Words to look for	Example
Emotion not specified	777		
Awe	1	Surprise, shock, awe, wow, excitement, impressed, joy	"an audible shock", "wow, that's so cool", "I live to hear the gasp of 'wow'", "...very excited or impressed"
Curiosity	2		"they are always amazed and curious"; "Sometimes the child's interest gives them permission to spend time studying SOS and finding things that interest them, or things they can point out to their children." <i>*can include "confusion": "There's a little fascination, or confusion, that this technology exists."</i>
Anxiety/Fear	3		"some anxiety over climate topics"
Personal Relevance	4	Increased emotional connection to phenomena presented on sphere <i>*note that this includes comments</i>	"Discussing climate change while engaging with the sphere commonly involves a more emotive response in viewers; they seem to care more when actually seeing the effects of climate change."; "Visitors sometimes walk around and look for places that they have a

		<i>about emotional responses to climate change*</i>	connection to and talk about it with others in their group."
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#### Q45\_c2

What elicits emotion	Code	Example
Technology	0	"an audible shock when they realize they can control the spin and rotation of the image with the kiosk controls"; "for many students it's the first time seeing technology like that."
Content and Concepts	1	"Climate change also brings out an emotional response as well as any of the animal datasets"; "I also find I hear a lot of comments along the lines of "I didn't realize Africa was so big" or something else related to being surprised how sizes look on the Sphere vs the distortion on flat maps."
Unclear	777	If there is a response where it is not clear what about the SOS exhibit elicits emotion, for example "impressive"

**46** Do you observe any differences in interactions with SOS or SOSx when comparing children to adult visitors?

**Primary code**

**Q46\_age**

Age differences	Code	Example
There are no differences between adults and children	0	"I believe everyone is fascinated by SOS equally"
Adults and children differ in how much they move themselves around the sphere	1	"Children are more willing to participate in motion-based activities around the Sphere."; "Adults ... will physically walk around the sphere more often than kids with most things."
Adults and children differ in their attention span and engagement	2	"children have longer attention spans for the Sphere than adults"; "Children have a much shorter attention span and often just want to hit the buttons on our kiosk versus actually watch and learn" "Children are more engaged"
Adults and children differ in their question-asking	3	"Children tend to ask more questions"; "Adults tend to ask more questions" "adults are quieter" "kids are louder"
Adults and children differ in their preferences for presentation types	4	"Adults often end up more invested and are happier to talk longer if it is a facilitated interaction."; "if it's not facilitated children last longer" *use when responses note an age-related preference for kiosks, in this case ALSO use code 5
Adults and children differ in their interest in content/concepts or technology	5	Children are definitely more intrigued by what the SOS system is (i.e. "is that a hologram?" "is it floating?"; "Adults are more interested in the datasets and what they can learn"
Content understanding	6	"children are often confused"; "adults seem to understand more"
There is variation by child age	7	"Children have a much shorter attention span and often just want to hit the buttons on our kiosk versus actually watch and learn. Adults and <b>older children</b> often get frustrated when this happens."; "With large public groups, we ask questions that <b>the kids</b> might be able to

		answer, then <b><i>scale up questions for older students and adults.</i></b>
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## Subcodes:

### Q46\_move

#### Movement around the sphere

Movement around sphere	Code	Example
Did not mention movement around the sphere	777	<i>*add this if you gave a code for Q46_age but it was not 1 – movement around the sphere</i>
Children more likely to move around the sphere	0	“Children are more willing to participate in motion-based activities around the Sphere.”
Adults more likely to move around the sphere	1	“Adults ... will physically walk around the sphere more often than kids with most things.”

### Q46\_attn

#### Attention span and engagement

Attention span and engagement	Code	Example
Did not mention attention span or engagement	777	<i>*add this if you gave a code for Q46_age but it was not 2 – attention span</i>
Children have a longer attention span and deeper engagement	0	“children have longer attention spans for the Sphere than adults”
Adults have a longer attention span and deeper engagement	1	“Children are quick to change datasets...Adults tend to stay on a given dataset longer”; “Children mostly just tap the kiosk while adults watch the videos and are more interactive with it”; “Children have a much shorter attention span and often just want to hit the buttons on our kiosk versus actually watch and learn”

### Q46\_q

#### Question Asking

Attention span	Code	Example
Did not mention question asking	777	<i>*add this if you gave a code for Q46_age but it was not 3 – question asking</i>



Children ask more questions	0	"Children tend to ask more questions"; "Children are more likely to guess and feel like it's ok to not know the answer to a question"
Adults ask more questions	1	"adults almost always ask questions...children mostly like to look at it"
Children ask deeper questions	2	
Adults ask deeper questions	3	

### Q46\_pres

#### Presentation Type Preferences

Presentation Preferences	Code	Example
Did not mention presentation format differing between adults and children	777	<i>*add this if you gave a code for Q46_age but it was not 4 – presentation type preferences</i>
Children prefer kiosks	1	"If it is not facilitated, kids last longer."; "Children are more willing to jump in and use the kiosk"
Children prefer presentations	2	"Children need a presenter to keep them engaged"
Adults prefer kiosks	3	
Adults prefer presentations	4	"Adults often end up more invested and are happier to talk longer if it is a facilitated interaction."

### Q46\_conTech

#### Curiosity about content/concepts versus technology of SOS

Presentation Preferences	Code	Example
Did not mention differences in content/concepts versus technology of SOS	777	<i>*add this if you gave a code for Q46_age but it was not 5 – content/concepts v technology</i>
Children more interested in technology	1	"Children are definitely more intrigued by what the SOS system is (i.e. "is that a hologram?" "is it floating?"
Children more interested in content/concepts	2	"Children also (on average) tend to be more knowledgeable about our solar system than adults."

Adults more interested in technology	3	"Adults want to know about how the sphere works"
Adults more interested in content/concepts	4	"Adults are more interested in the datasets and what they can learn"

#### Q46\_understand

##### Content understanding

Content understanding	Code	Example
Did not mention differences in content understanding	777	<i>*add this if you gave a code for Q46_age but it was not 6 – content understanding</i>
Children have better content understanding than adults	0	"children are better at identifying planets and moons"
Adults have better content understanding than children	1	"adults understand the content better, whereas children are more likely to [be] confused" "children usually see details or it makes no sense to them at all"

**47** Please describe any observations you have had about how visitors interact with the SOS kiosk or SOSx touchscreen at your site (e.g., datasets selected, time spent, collaboration with other visitors)?

#### Q47\_kiosk

Observation	Code	Example
Respondent doesn't know/hasn't observed	777	"I have not observed visitors interacting with the kiosk.";
No Kiosk	0	"we don't have one" <i>*if they say they allow visitors to use this iPad, you should give this code as well.</i>
Kiosk allows increased visitor choice relative to other presentation methods	1	Visitors get to choose what they look at on the sphere; personal relevance (it's about a phenomena near me!) Allows visitors to pursue a personal interest: "In general, if someone comes to the exhibit with an existing interest (e.g. sea fishermen and ocean currents, travelers and the airplane tracks, ag producers and La Nina, etc) they'll engage in depth." <i>*note – we will use a 1 expansively – see first example in this code.</i>

Kiosk allows visitor collaboration	2	Groups use kiosk together; allows parents to facilitate interaction with their child
Challenges Using Software	3	Too many selections make the kiosk freeze; visitors don't understand how to use it; children can exit the program accidentally <i>*note that this includes responses where it is unclear if it's a software issue or a user misunderstanding ("inarticulate swiping")</i>
Challenges with Context	4	Visitor selects a movie, sits down, and other visitors unwittingly override their selection; "we have placed signs on the kiosk to help more people engage with it"
Age differences in kiosk use	5	Young children use it as a strength test; explore the technology, not the content
Content	6	Notice something about the content people tend to select on the kiosk – "we've noticed more visitors interacting [with] the Space category" <i>*is content mentioned? le: topics, space, weather</i>

**56** What appears to be most engaging about the SOS or SOSx exhibit for visitors at your site? Please elaborate and provide examples.

**Primary Code:**

**Q56\_engage**

Most Engaging	Code	Example
Content	1	Place, time, global context connections <b>or any mention of specific content being interesting to visitors (e.g., "hurricanes", "space")</b>
Dataset Type	2	Movies/videos, animated datasets, real-time datasets, Live Programs
Presentation Type	3	Presentation, exploration on kiosk, informal docent interaction
Novelty of SOS/SOSx	4	Size, scale, 3D, brightness

*\*note that these could co-occur, particularly 1 & 4*

**Subcodes:**

**Q56\_content**

Content	Code	Example
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Did not mention content	777	<i>*add this if you gave a code for Q56_engage but it was not 1 – content</i>
Place connection	1	"Northwest coast, where people are thinking about glaciers anyway"; "Used to supplement our Solar Eclipse event...people who were here to see the eclipse didn't have a clear understanding of how and why it happened"
Time connection	2	"real time datasets <b>because it relates to present time</b> "; seasonal variation, daytime/nighttime patterns
Global context	3	"visualization of 'big' topics like climate and migration", "sense of scale when talking about satellites"
Other content	4	"Storm, volcano and earthquake data sets."

#### Q56\_dataset

Dataset Type	Code	Example
Did not mention dataset type	777	<i>*add this if you gave a code for Q56_engage but it was not 2 – dataset type</i>
Films/movies	1	"people like to watch the movies", "animated datasets and <b>videos</b> appear to be the most engaging"
Animated Datasets	2	" <b>animated datasets</b> and videos appear to be the most engaging"
Real time Datasets	3	"watching hurricane movement on real time clouds, for example"; "Access to real time data global data sets. They like the idea of investigating Earth from Space." <i>*only use code 3 if they mention "real-time datasets" - this is a specific kind of SOS dataset where data is updated daily, not the same as datasets that show change over time.</i>
Live Programs or Tours	4	"visitors like live programs" "visitors like the tours on SOSx" <i>*only use code 4 if they mention "Live programs" (a type of SOS dataset, not the same as a presentation given by a "live" docent) or "SOSx Tours" (a type of SOSx dataset, not the same as a tour given by a docent)</i>

### Q56\_present

Presentation Type	Code	Example
Did not mention presentation type	777	<i>*add this if you gave a code for Q56_engage but it was not 3 – presentation type</i>
Formal, guided presentations	1	"A live presenter, either for a <b>scheduled presentation (like for a field trip)</b> " ; "For guided presentations, guests enjoy answering questions and the interactive parts such as hand motions"
Unscripted/informal presentations or interactions with docents	2	"when a staff or volunteer is in the space for an <b>impromptu</b> presentation."
Kiosk/free exploration	3	"being able to guide their own explorations", "...its accessibility by visitors through the kiosk"

### Q56\_novelty

Novelty	Code	Example
Not mentioned	777	<i>*add this if you gave a code for Q56_engage but it was not 4 - novelty</i>
Mentioned	1	Anything that talks about the size/scale, 3D nature, brightness, or novelty of SOS – "the novelty of it!", "grand scale", "they appreciate that this is the best way to see our planet accurately without the distortions of other flat earth projections", "being able to visualize the Earth in a new way"

**57** If you were to suggest a research topic, what questions do you have about how visitors learn from SOS or SOSx?

### Q57\_research

Topic	Code	Examples
Extending existing SOS capabilities or contexts	1	Interactive game experience, AI, augmented displays, integrating with fieldtrips
Content and conceptual learning	2	Do people learn from SOS? What datasets do people choose on the kiosk? Are there content areas people struggle with? Does dataset type

		change learning? Data literacy – connecting to graphs
Emotional responses	3	Do presentations change learners' climate anxiety? Do emotions elicited from SOS change visitor learning? <i>*impact is too vague, does not specify enough to include*</i>
Behavior change	4	"How likely are people to make pro-environmental decisions or engage in pro-environmental activities, after experiencing an SOS program and how long does this sort of empowerment last?"
Effectiveness of presentation types	5	Can visitors learn from an unfacilitated interaction with the sphere? Does the presence of an educator enhance comprehension of datasets on SOS? Does the level of interaction (passive v. active participation) affect visitor learning?
How do *learner features* affect learning from SOS/SOSx?	6	"what datasets are most impactful for various ages", How do people with disabilities best learn from SOS? STEM education level as a mediator of learning? Does repeat exposure to SOS change how people interact with it; the kinds of connections they make?
How do *SOS or SOSx* technology features affect learning from SOS/SOSx	7	How does spherical projection affect visitor comprehension and understanding of global systems (natural or biological) as opposed to flat projection; how to integrate small or local scale into presentations; the sos doesn't show those well; I'd love to see how captions influence their experience. I didn't know captions were a possibility.
Didn't understand question/gave non-responsive answer	777	"I don't understand the question", "how often does data get updated"

50 Please describe the training you offer to SOS presenters at your site:

**Primary Code:**

Q50\_train

Training (y/n)	Code	Examples
Yes, there is training	1	"We offer in-person training and coaching, along with some limited remote support."
No, there is not training	0	"right now it's just me learning as I go"; "self-trained"; "some time playing around with SOS" - emphasizing the guided part
Do not know/not responsive	777	"don't know"

### Subcodes:

#### Q50\_what

What is trained	Code	Examples
Not applicable	777	<i>If you coded Q50_train as 0 (no, there is not training), select 777 for this subcode</i> <i>*note you *CAN* have this if you have a 1 for primary code</i>
How to operate SOS/SOSx	1	"the training is focused on operating the sphere for presentations", "we teach presenters ... <b>how to use the iPad</b> "
Site scripted programs and playlists	2	<b>"They are given the script in advance (volunteers follow a script, and educators create and implement the scripts) and have time with SOS and the educator training them without visitors present to get practice."</b>
Teaching techniques	3	"Presenters are also shown best facilitation practices for the exhibit space"
How to make programs or playlists	4	"I encourage them to make a playlist of their favorite datasets"; "We teach presenters <b>how to make playlists...</b> "; <b>educators create</b> and implement the scripts

*\*Note – 2 refers to learning existing scripts; 4 refers to making your own playlists and/or scripts.*

#### Q50\_how

How they are trained	Code	Examples
Not applicable	777	<i>If you coded Q50_train as 0 (no, there is not training), select 777 for this subcode</i>
Shadow another presenter	1	"We have new hires shadow trained presenters to get a feel for the presentation", "I was not really trained but watched a previous staff member do some programs."
Informal learning sessions	2	"A few hands-on show and tells"; "Informal. Those of us who know how to use SOS show new education staff how it works.", "one on one training as it is needed"

Formal learning sessions	3	"All staff spend <b>2 hours in a small group setting</b> where they learn about the sphere and how to use the ipad to control it...Once they are comfortable with using the sphere as a teaching tool, they are then given <b>full group trainings on each presentation.</b> " *if 2 v 3 is unclear, using content in training (e.g., playlist building) as a way to differentiate
Have independent practice time with SOS/SOSx	4	" <b>Practicing on my own</b> or for colleagues outside of scheduled public presentation times"; "They will once again have two separate <b>1 hour sessions with the sphere (on their own) when they can practice</b> the presentation."
Are watched by experienced presenters for approval	5	"Giving a practice presentation to a manager until they approve it for public presentations"

52. How often does your site use static, non-animated datasets in presentations?

- d. Never
- e. Sometimes
- f. Regularly

53. When do you choose to use static versus animated datasets?

Q53\_static

\*EXCLUSIVE – SELECT ONE RESPONSE ONLY

Why do they choose static datasets?	Code	Examples
Never choose static	0	"Never", "all of the presentations I have been involved in have been animated"
All SOS interaction is visitor led on kiosks – respondent does not choose	1	"we don't decide – kiosk only"
Don't think about this dimension/select based on content only	2	"I have not paid attention to that", "when it's the most relevant data set available", "we choose our datasets based on how well they help us tell the story" If they say content only but don't explain *why*



If no other content is available	3	"many times static versions are only available, or the animated versions that could be adapted for spherical projection do not exist yet", "when there are not animated versions available", "When image quality is higher [in static than dynamic dataset]", "when there is no internet connection"
Use static because it better fits learning needs	4  *includes people who say they use it in tandem with dynamic	"to get students to look at details, move around the sphere", "to show less complex content", "to show a single time point versus time series", "to split into mirrored parts", "I normally use them in tandem, for example showing the Blue Marble before going into animated weather patterns to show the difference between a static and moving picture of Earth", "depends on the type of group that comes in" If they *do* explain why static supports teaching a particular content area