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# Summative Evaluation

BEYOND SPACESHIP EARTH



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## Executive Summary

*Beyond Spaceship Earth* (BSE) opened at The Children's Museum of Indianapolis in June 2016 as a permanent (20-year) experience for children and families. The multi-faceted project includes an immersive permanent exhibit that features the International Space Station and an Indiana Astronaut Wall of Fame, the Schaefer Planetarium and Space Object Theater currently featuring the Liberty Bell 7, museum theater and facilitated programs throughout the exhibit galleries, complementary programming for schools and families in the STEMLab, and a freely available unit of study for classroom teachers of 3rd-8th grades. The project was funded through major grants from NASA[1], Lilly Endowment Inc., and Eli Lilly and Company, as well as numerous private donations. From 2016-17, the Museum's Research and Evaluation Department designed and implemented the summative evaluation of the project using qualitative and quantitative methods in the form of tracking and timing, program observations, exit interviews, post-visit/experience surveys, and student product review. The evaluation focused on the primary audiences of families, teachers, and students.

**Key Findings by Evaluation Question:**

What are the visitation patterns in the ISS exhibit and Space Object Theater?

- The ISS exhibit's average stay time (14 minutes) compares favorably with other Museum galleries when square footage is accounted for; its Sweep Rate Index is virtually identical to *Playscape* in terms of favorable stay time per square foot.
- Visitors typically enter and exit the gallery through opposite doors, so the majority of visitors do walk through the entire exhibit.
    - When using the main entrance, more than half of groups made their first stop at the Lower Your Visor displays, and over three-quarters stopped somewhere in the first "room."
- The two main areas of the gallery (ISS interior and ISS exterior) are extremely well-visited by families, with 98% of all families stopping in them and the average number of stops corresponding to half of the elements.
    - All other exhibit areas (the Planetarium vestibule; Planetarium dome; and IN Astronaut Wall of Fame) were also visited by 40-50% of families.

**Families stayed in the ISS exhibit for 14 minutes on average, a long time given the gallery's very small square footage.**

**Most families visit the main gallery areas thoroughly; all areas are visited by at least 40%.**

[1] NASA award NNX14AD06A did not fund any part of the Schaefer Planetarium and Space Object Theater or the Indiana Astronaut Wall of Fame.

- Experiential elements (i.e., Weightlifting, Glove Boxes) or those that allowed for extended pretend play (i.e., the Truss, the Soyuz capsule) attracted the highest percentages of families.
- Elements with the longest stay times tended to be pretend-play environments and high-tech interactives.
- The exhibit hosted 1.1 million visitors during its first year of operation, indicating that close to 90% of all Museum visitors went to the exhibit.
- Attendance data indicate that 14% of all museum visitors watched shows in the Space Object Theater during the first year of operation, which is higher than typical annual visitation to the SpaceQuest Planetarium.

To what extent do family groups engage in the intended family learning behaviors in the ISS exhibit, interpretation programs, and lab programs?

- At a gallery level, the ISS exhibit compares to other Museum galleries in its distribution of the three high-level categories of Family Learning, 1) Participation, 2) Collaboration and Problem-Solving and 3) Enhancement.
- Families averaged a total of 41 family learning behaviors during their exhibit visit. This is on par with *Take Me There: China* (TMTC), at 43 family learning behaviors, and higher than *Playscape* (35).
- Typical family learning behaviors in the gallery were focusing on an element together (a measure of basic Participation, ALFIE code A or B), providing information or directions related to an element (including reading/summarizing labels out loud, code P), and calling attention or pointing to an element (codes Z and EE). Collaboration behaviors were less frequent overall but did include scaffolding and working together.
- The ISS exhibit had a higher incidence of children using elements alone than did TMTC, but this appears to be related to the small footprint of the gallery, which makes it very easy for family members to be standing next to each other but focusing on different elements. Despite this trend, when adults and children were focused on the same element, they demonstrated a high number of observable family learning behaviors.
- The evaluation of Interpretation programs in the ISS exhibit found that all programs were delivered with consistency and accuracy, a particularly important finding with regards to the use of "informal" programming in the gallery. The successful use of loosely scripted programs delivered by both actor-interpreters and facilitators builds on the success of TMTC programming and demonstrates the flexibility of this type of programming to enhance galleries with little to no space for formal, large group programming.
- Overall, Interpretation programs were found to support family learning outcomes; the planned family learning behaviors surpassed goal metrics in most programs. Other key findings include:

**High-tech elements and pretend play areas drew high numbers of families and had long stay times.**

**Families averaged two Family Learning behaviors per stop, equal to the level seen in TMTC.**

**Interpretation is working to ensure that adults are invited to participate throughout all offered programs.**

**Family learning goals are being met across gallery and STEMLab programs, regardless of the formality or flexibility of the format.**

- Primary program goals and objectives were achieved at rates of over 80%.
    - Improvement was made in staff inclusion of adults *throughout* interactions. Staff plan to apply these strategies to increase adult involvement in other programs.
    - All of the programs were extremely successful at prompting the family learning behavior related to making comparisons (FF), which is typically a challenge; it appears that this type of conversation was much more successful in the context of discussing ways that life in space differs from life on earth.
- Programming in the STEMLab also fostered family learning behaviors at high rates (usually above 80%).
- Observations of STEMLab engineering challenge workshops across a range of content topics revealed that programs in which family groups naturally work together to build a single prototype result in more consistent and higher levels of adult-child collaboration.

To what extent do the project components increase participant interest in STEM topics?

- The majority of families who visited the ISS exhibit and Space Object Theater (66%) reported that their group's interest in the space program had increased from the experience.
    - Two-thirds of groups who completed surveys one week after their visit described having additional conversations or even taking actions to extend the experience beyond their visit.
- Families who participated in a robotics coding program in the STEMLab indicated that 38% of children had increased interest in robotics, and 47% of adults were more interested in robotics. Adults reported that an additional 44% of children already had a high interest in robotics.
    - Nearly half of families (45%) reported that they had had a conversation or done an activity related to robotics within the week following their visit.
- Two-thirds of children who participated in the *Out of this World Engineering* program in the STEMLab reported that their interest in both engineering and space had **increased** as a result of the program.
- According to surveys, over half of students who experienced the BSE unit of study in their classrooms (56%) are now more interested in space and NASA. Furthermore, 44% of students reported that their current career interest [when they grow up] is STEM-related.

To what extent do visitors and students have a better understanding of daily life and work aboard the ISS, including research activities, as a result of project components?

**Key aspects that are predictive of family collaboration during open-ended engineering workshops have been identified to assist in future planning.**

**☑ The majority of families who visit the exhibit and participate in STEMLab programs report an increase in STEM interest.**

- After visiting the ISS exhibit, 25% of visitors reported that the main thing they learned from the exhibit was about daily life on the ISS (including eating and sleeping), 15% gave answers related to work on the ISS (including research activities), and 11% mentioned the necessity or way that astronauts exercise daily.
    - When asked specifically about whether they learned about research happening on the ISS, 30% of visitors interviewed reported learning about plant and cell research, the main types of research presented in the exhibit.
- Students who completed the unit of study also reported learning about similar aspects of daily life: exercise, sleep, food consumption.
- The unit of study was quite successful in introducing students to research aboard the ISS: 56% of students reported learning about experiments, and 25% of students described that it is valuable to send astronauts to live in space so that they can do scientific experiments.

To what extent do families and students have a better understanding of the variety of STEM fields and careers that contribute to NASA's space program?

- Most families who were known to have interacted with the Indiana Astronaut Wall of Fame element in the exhibit (87%) reported learning about the diversity of backgrounds among astronauts.
- Among the children who participated in the *Out of This World Engineering* family program in the STEMLab, half (52%) gained a more nuanced understanding of engineering through the program.
- Almost all students who completed the unit of study in their classroom (96%) reported learning about careers in the space program beyond astronaut; common examples given included engineer, designer, scientist, mathematician, and mission control.
- Most teachers of students who participated in the *Coding with Robonaut* program in the STEMLab (82%) believed that the program was effective in introducing students to new careers.

To what extent do project components foster positive attitudes towards engineering?

- Among families interviewed after participating in the *Out of This World Engineering* program in the STEMLab, half of families (48%) indicated that they are more likely to pursue future engineering experiences.
    - Among the 27 groups interviewed, only 1 included a child who described their prior understanding of engineering using a positive adjective, while children in 10 groups (37%) described their perception of engineering using positive adjectives after the program.

**☑ The unit of study increases student interest in space and STEM-related careers.**

**☑ One-third to one half of families and students who experience different BSE activities learn about daily life on the ISS.**

**☑ Families and students are learning about the variety of careers that contribute to the space program through a particular exhibit element, on-site programming, and the unit of study.**

- The majority of teachers who taught or reviewed the unit of study (63%) agreed that the unit experiences promote a positive attitude toward engineering.
- Among students who completed the unit of study in their classrooms, and therefore participated in an engineering design challenge, the majority (65%) reported that they would be quite interested in doing another similar project.

To what extent do families and students practice STEM process skills while participating in project components?

- Almost ALL families observed during the *Out of this World Engineering* program in the STEMLab demonstrated the STEM skills of identifying a problem with an object, brainstorming possible solutions to that problem, and building a prototype of the re-engineered object.
- Most families observed in other open-ended engineering challenge programs in the STEMLab displayed persistence while testing and refining their prototypes (85%).
- Almost all students observed during the *Coding with Robonaut* program in the STEMLab (96%) practiced the skills of writing, testing, and rewriting code to direct a robot to complete a task.
- Teachers reported that the unit of study activities in their classrooms fostered the STEM process skills of analyzing and interpreting data, identifying a problem, designing a solution, and critical thinking.
- Three-quarters of student projects completed during the unit of study in their classrooms provided a reasonable solution to their selected challenge of living and working in space.

**Report Summary**

*Beyond Spaceship Earth* is successful in supporting family learning and meeting project goals for both families and students. Observational data demonstrate that the exhibit has a long stay time given its relatively small square footage. The analysis of family learning data shows the gallery supports a wide range of family learning behaviors, including adult-child participation, collaboration, and conversations focused on using elements and reading labels.

Data from interviews and surveys with families and students reveal that the exhibit, gallery and STEMLab programming, and unit of study support the following outcomes:

- content acquisition focused on awareness of living and working in space and STEM careers
- provided positive experiences with engineering
- supported and increased interest in the space program and STEM in general

**☑ Engineering-focused programs and the unit of study are successful in fostering positive attitudes towards engineering and increasing interest in pursuing additional engineering experiences.**

**☑ Engineering-focused programs and the unit of study are highly successful in prompting families and students to practice STEM process skills.**

# Introduction

*Beyond Spaceship Earth* (BSE) opened in June 2016 as a permanent exhibit. The multi-faceted project includes an immersive permanent exhibit that features the International Space Station and an Indiana Astronaut Wall of Fame, the Schaefer Planetarium and Space Object Theater currently featuring the Liberty Bell 7, museum theater and facilitated programs throughout the exhibit galleries, complementary programming for schools and families in the STEMLab, and a freely available unit of study for classroom teachers of 3rd-8th grade. The experience features an immersive environment to feature everyday life and research on the ISS and planetarium dome technology to create an enhanced multisensory object experience. The project was funded through major grants from NASA, Lilly Endowment Inc., and Eli Lilly and Company, as well as numerous private donations. The following main messages guided the project's development:

<u>Big Idea</u>:
The work of NASA scientists plays a vital role in making human space exploration and research possible.

<u>Main Messages</u>:

- Humans require specialized technology to live and work safely in space.
- The ISS allows us to do scientific research and conduct experiments that would be impossible on earth.
- Science and technology skills help us create innovative solutions to solve complex problems.

This document reports the summative evaluation findings for BSE with a dual focus on family learning and the content and attitudinal outcomes outlined in the NASA grant proposal. The report's findings are organized by project activity/product (e.g., exhibit, programming, unit of study) beginning on page 13. The study used a combination of methods including timing and tracking, program observations, exit interviews, post-visit/experience surveys, and student product review. Data collection for the summative evaluation occurred from October 2016-October 2017. Select findings from the remedial evaluation study of the gallery are also referenced in this document. Please see *Beyond Spaceship Earth Remedial Memo* (Thoma Emmons 2016) for the complete remedial evaluation findings.

## Family Learning Framework and Evaluation Questions

The framework that underlies the summative evaluation of all Museum galleries is the theory of family learning as conceptualized by the Museum. This family learning framework is recognized as having eight dimensions, all of which may be supported by a learning experience, including a museum visit:

1. **Interests**: Developing new interests or pursing existing interests
2. **Knowledge**: Gaining new knowledge or reinforcing existing knowledge
3. **Skills**: Building new skills or practicing existing skills
4. **Attitudes**: Gaining a new perspective on something or reinforcing an existing perspective
5. **Learning about your family**: Gaining a new awareness of your family or reinforcing what you already know about your family
6. **Interacting with others outside of your family**: Interacting with other children, adults, or museum staff.
7. **Learning how to learn at the museum**: Knowing how to use the museum as a learning resource
8. **Reinforcing your family's values**: Practicing values that are important to your family

At the Museum, these dimensions of family learning are "activated" by planning and designing experiences that intentionally foster:

- Inclusion of all family members
- Collaboration by family members
- Communication between family members
- Inspiration of family members to learn, try, or "take it home"
- Connection to personal experiences

In addition to the family learning framework, this project's development was also guided by content and attitudinal outcomes outlined in the original NASA grant proposal and in subsequent grant reporting documents. These included:

- Understanding daily life on the ISS, including sleeping, eating, and exercising
- Awareness of STEM careers associated with the space program
- Awareness of science research aboard the ISS
- Understanding of challenges to living in space and ways those challenges have been overcome
- Supporting and increasing interest in STEM topics, STEM careers, and the space program
- Fostering positive attitudes towards engineering
- Practicing STEM process skills

The summative evaluation was designed to provide evidence of the degree to which various components of the BSE project 1) achieve outcomes, and 2) use strategies to promote family learning. The evaluation was designed to address seven evaluation questions reflective of the goals for the project:

1. What are the visitation patterns in the ISS exhibit and Space Object Theater?
2. To what extent do family groups engage in the intended family learning behaviors in the ISS exhibit, interpretation programs, and lab programs?
3. To what extent do the project components increase participant interest in STEM topics?
4. To what extent do visitors and students have a better understanding of daily life and work aboard the ISS, including research activities, as a result of project components?
5. To what extent do families and students have a better understanding of the variety of STEM fields and careers that contribute to NASA's space program?
6. To what extent do project components foster positive attitudes towards engineering?
7. To what extent do families and students practice STEM process skills while participating in project components?

By answering these evaluation questions, the Museum is able to:

- Describe what is occurring in the gallery and corresponding programming
- Reveal how the project components align with and impact participants' perceptions of STEM topics, including space exploration
- Measure family learning behaviors across project components

# Methods

The study used a combination of methods including tracking and timing, program observation, exit interviews, post-visit/experience surveys, and student product review. The table below provides an overview of the methods used, audience groups, and sample sizes. A more detailed description of the methods including timing of data collection and sample descriptions can be found in Appendix A.

**Table 1. Methods and Sample Sizes for the BSE Summative Evaluation**

| Method | Audience and Sample Size |
|---|---|
| Tracking and timing | Family groups, n=51 |
| Program observations | Family groups:<br>• Exhibit programs, n=91<br>• Lab programs, n=85<br>School groups:<br>• Robotics Lab program, n=24 classes; 625 students |
| Feedback wall | Family members, n=136 responses |
| Exit interviews | Family groups with at least one child over 4 years:<br>• ISS exhibit, n=50<br>• ISS awareness, n=56<br>• Actor Lab program, n=27 |
| Post surveys | Family groups:<br>• Planetarium & Exhibit, n=110<br>• Robotics Lab program, n=35<br>Teachers:<br>• Robotics Lab program, n=14<br>• Space Object Theater show, n=20<br>• Unit of Study, n=36<br>Students:<br>• Unit of Study in classroom, n=324 |
| Student engineering design project review | Student groups, n=78 |

# International Space Station Exhibit Use and Outcomes

This section focuses on the following evaluation questions:

1. What are the visitation patterns in the ISS exhibit?
2. To what extent do family groups engage in the intended family learning behaviors in the ISS exhibit?
3. To what extent do the project components increase participant interest in STEM topics?
4. To what extent do visitors and students have a better understanding of daily life and work aboard the ISS, including research activities, as a result of project components?
5. To what extent do families and students have a better understanding of the variety of STEM fields and careers that contribute to NASA's space program?

The findings for this section draw on data collected through tracking and timing observations, gallery exit interviews, follow-up surveys, and counters at the gallery entrance. Timing and tracking observations were conducted between September and October 2016, during a range of visitation periods including peak days (weekends and fall break) and off-peak days (weekdays in September). Interview demographics reveal a diverse sampling of visitors, representing first-time visitors as well as members who are already familiar with the gallery. All interviewees visited the gallery in a family group with at least one child between the ages of 4 and 18 years old. For more details on the samples, see Appendix A.

## Capture Rate

The BSE exhibit hosted 1.1 million visitors during its first year of operation, indicating that close to 90% of all Museum visitors went to the exhibit. This is an extremely high capture rate suggesting a very high level of interest among all visitors, regardless of age. By way of comparison, *Dinosphere* is the only other Museum exhibit that regularly attracts 90% or more of visitors; other favorable capture rates fall in the 60-75% range. It is possible that the capture rate for BSE is slightly inflated due to the fact that one of the entrances borders the Lilly Theater Lobby and is likely subject to some amount of cross-traffic, or visitors walking "out" of the exhibit and then back "in" and being counted twice. Even if this were the case, it is safe to conclude that BSE has the second highest capture rate of the Museum's permanent exhibits.

## Length of Exhibit Visit

Drawing on a combination of the tracking and timing data and card timing data, the average time spent in just the ISS exhibit by families in the study was 14 minutes, with a range of 4 minutes to 49 minutes (n=73). The average time spent when a space object theater show was also watched by the group was 44 minutes (n=57). The difference in stay times correlates nicely with the actual length of most shows, which is 20 minutes. While the stay time for just the exhibit is the lowest of all permanent galleries (see Table 2), this exhibit is also by far the smallest of all permanent galleries, so the Sweep Rate Index provides a fairer basis for comparison (see Table 3).

**Table 2. Average Visit Duration Across Museum Exhibits**

| Exhibit (date of data collection) | Average Exhibit Visit Duration (in minutes)[a] |
|---|---|
| Playscape (2013-2014) | 44 |
| Dinosphere (2006-2008) | 33 |
| Take Me There: China (2015) | 29 |
| Scienceworks (2017) | 26 |
| Take Me There: Egypt (2009 & 2010) | 26 |
| Power of Children (2008-2009) | 23 |
| Treasures of the Earth ( 2011 & 2012) | 16 |
| **Beyond Spaceship Earth ISS Exhibit (2016)** | **14*** |

[a] Family visitors only. *Average time for groups who also watched space object theater shows was 30 minutes longer.

A common metric that is used to compare stay times in galleries of different sizes is the Sweep Rate Index or SRI. SRI is calculated by dividing the square footage of an exhibit by the average stay time and was first defined by Beverly Serrell in her book *Paying Attention: Visitors and Museum Exhibitions* (1998). It can be thought of as "square feet covered per minute." According to Serrell, a lower SRI indicates visitors spent more time per unit of area, so a lower SRI is thought to be "better" than a higher SRI. When using the metric of SRI, BSE tops the list for the Museum's galleries with a SRI of 175 (Table 3). This indicates that visitors are spending a long time in the exhibit given its small footprint.

**Table 3. Sweep Rate Index across Permanent Exhibits**

| Exhibit (date of data collection) | Sweep Rate Index (SRI)[a] |
|---|---|
| Playscape (2013-2014) | 173 |
| **Beyond Spaceship Earth ISS Exhibit (2016)** | **175** |
| Take Me There: China (2015) | 287 |
| Scienceworks (2017) | 318 |
| Take Me There: Egypt (2009 & 2010) | 308 |
| Dinosphere (2006-2008) | 341 |
| Treasures of the Earth ( 2011 & 2012) | 365 |
| Power of Children (2008-2009) | 481 |

*Visitors are actually staying in BSE for a long time given its small footprint.*

[a] SRI is calculated by dividing the square footage of an exhibit by the average stay time.

## Typical Entry and Exit Patterns

There was a small concern prior to opening that visitors who entered on the Lilly Theater side of the exhibit may not visit the entire exhibit if they encountered a bottleneck upon trying to enter the ISS interior. Data from card timing, which intercepted equal numbers of groups entering from either side of the exhibit showed that 90% of groups exited the exhibit opposite of where they entered, meaning that the vast majority walked through the entire exhibit. For timing and tracking, the decision was made to only intercept visitors at the intended entrance of the gallery (next to the ramp entrance and the *Flight Adventures* display). This allowed evaluators to document movement through the gallery from the intended starting point and to reliably observe whether visitors stopped at the Indiana Astronaut Wall of Fame, which is located beyond the footprint of the main exhibit.

From the main entrance, many groups (55%) first stopped at the Lower Your Visor displays, and the majority (78%) stopped somewhere in the very first "room." Next stops commonly included the Staying Fit in Space video, the Weightlifting activity, and the What's for Dinner display. As seen with the card timing data set, almost all tracked families exited on the opposite side, with nearly half (47%) stopping at the Wall of Fame, usually as their last stop.

Upon entering the gallery, children tended to lead their adult through the gallery choosing when to leave an element and what to visit next without much conversation about the decision. An adult was only observed prompting a child to end an activity in 2% of stops, much less frequently than in either *Playscape* or *Take Me There: China* (TMTC) (in both of those galleries, adults prompted an end to the element interaction 27% of the time). These instances were almost always at pretend play elements, including the EVA area, Chores crawlspace, and Soyuz capsule. Drawing on the narrative of the tracking and timing observations, the selection of the next element was typically left up to the child as well, often without a verbal exchange.

## Time Spent in Gallery Areas

The BSE exhibit was divided into 5 main areas for this timing and tracking analysis (See Table 4 for the area list and Appendix B for the full list of areas and elements). The two main sections of the exhibit, the ISS Interior and the Exterior/Spacewalk were both visited by almost 100% of families. Further, the average number of stops compared to the total available elements in those areas was roughly half, indicating thorough use of both areas. The Planetarium vestibule and Indiana Astronaut Wall of Fame both had stops from about half of all families. 45% of all observed families watched space object theater shows. Overall, there was no area in this exhibit that was poorly visited.

**Table 4. Family Visitation Patterns by BSE Area**

| Exhibit Area | Number of families stopping in area (n=51) | Percentage of families stopping in area | Average stay time in area (in minutes) | Ratio of average number of stops/total elements in area |
|---|---|---|---|---|
| ISS Interior | 50 | 98% | 6 | 10/21 |
| ISS Exterior/Spacewalk | 50 | 98% | 6.5 | 6/10 |
| Planetarium Vestibule | 27 | 53% | 2 | 3/3 |
| Indiana Astronaut Wall of Fame | 24 | 47% | 2 | 1/3 |
| Planetarium Dome Displays | 21 | 41% | 6 | 4/5 |

## Stop Patterns at Elements

The average number of elements in the BSE exhibit that a family stopped at was 20, with a range from 4 stops to 46 stops (n=51 families). The study allowed for the identification of elements in the gallery that were most attractive to families (Figure 1 and Table 5). Many of the elements that had the highest capture rates were the large, full-body interactives like the Truss, the Chores crawlspace, and the Soyuz capsule. Experiential interactives, like the Weightlifting activity and Glove Boxes also had some of the highest usage.

**Figure 1. The elements that attracted the highest percentage of families tended to be pretend play or experiential interactives. The combination of artifact cases with audio/visual media at "h"-What's for Dinner? and "n"-Indiana Astronaut Wall of Fame was also successful in attracting visitors (Letters correspond to Table 5).**

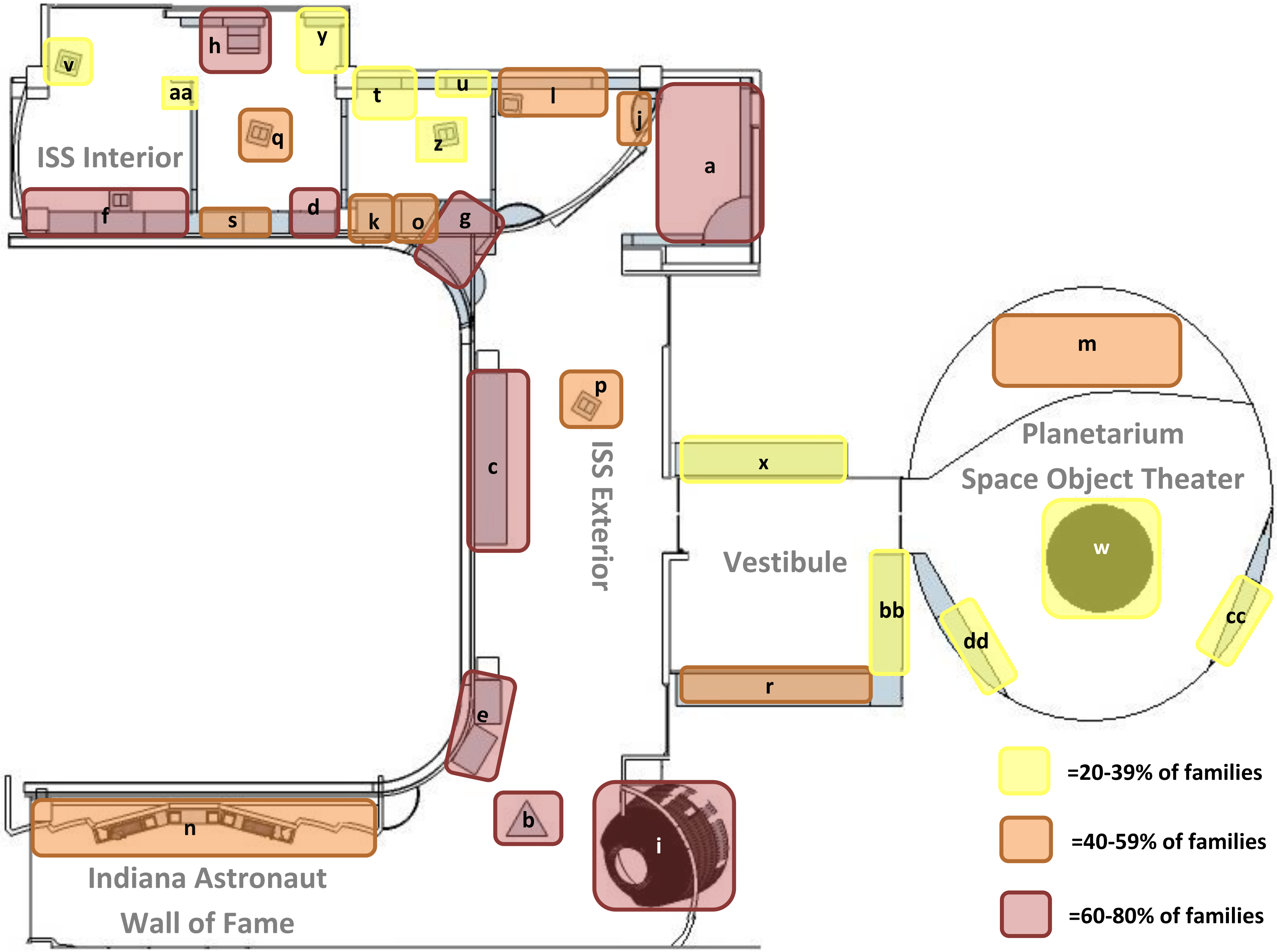

**Table 5. *Beyond Spaceship Earth* Element Capture Rates, indicating the % of families who stopped at the most visited exhibit element (n=51 families; see Appendix B for the full list of elements).**

| Element (letters correspond to Figure 1) | | Capture rate |
|---|---|---|
| a | EVA pretend play area | 78% |
| b | Canadarm game | 75% |
| c | Truss | 75% |
| d | Weightlifting label & activity | 75% |
| e | Glove boxes & labels | 73% |
| f | Lower Your Visor activity & labels | 71% |
| g | Chores label & crawlspace | 67% |
| h | What's for Dinner case & audio | 63% |
| i | Soyuz capsule | 61% |
| j | Costume hooks (cupola side) | 59% |
| k | Sleeping quarters alcove | 59% |
| l | Cupola | 55% |
| m | Space Object Theater Show* | 49% |
| n | IN Astronaut Wall of Fame | 47% |
| o | What to Wear drawers | 47% |
| p | Spacewalk iPad | 43% |
| q | Exercise iPad | 43% |
| r | Robots & Spaceships case | 41% |
| s | Staying Fit in Space video | 41% |
| t | Veggie label & activity | 39% |
| u | Bioreactor label & activity | 39% |
| v | Vacuum Up Fluids iPad | 37% |
| w | Liberty Bell 7 capsule* | 35% |
| x | Authors display case | 29% |
| y | Velcro activity | 27% |
| z | Tend the Plants iPad | 25% |
| aa | Microgravity video | 25% |
| bb | Star Trek display case | 25% |
| cc | Rocket display case* | 22% |
| dd | Grissom display case* | 20% |

*These elements were not always available because the doors to the Planetarium were closed while a space object theater show was in progress.

## Time Spent at Elements

While it is not always true that the elements which attract the greatest attention also have strong holding power, in BSE, most of the elements that attracted over 60% of groups (marked in red on Figure 1 on the previous page) also held visitors' attention for more than 40 seconds (marked in orange and red on Figure 2). In BSE several of the elements with the longest stay times were high-tech interactives, in addition to pretend-play environments.

**Figure 2. Beyond the space object theater shows, the elements where families spent the most time include pretend play areas and high- and low-tech interactives (Letters correspond to Table 6).**

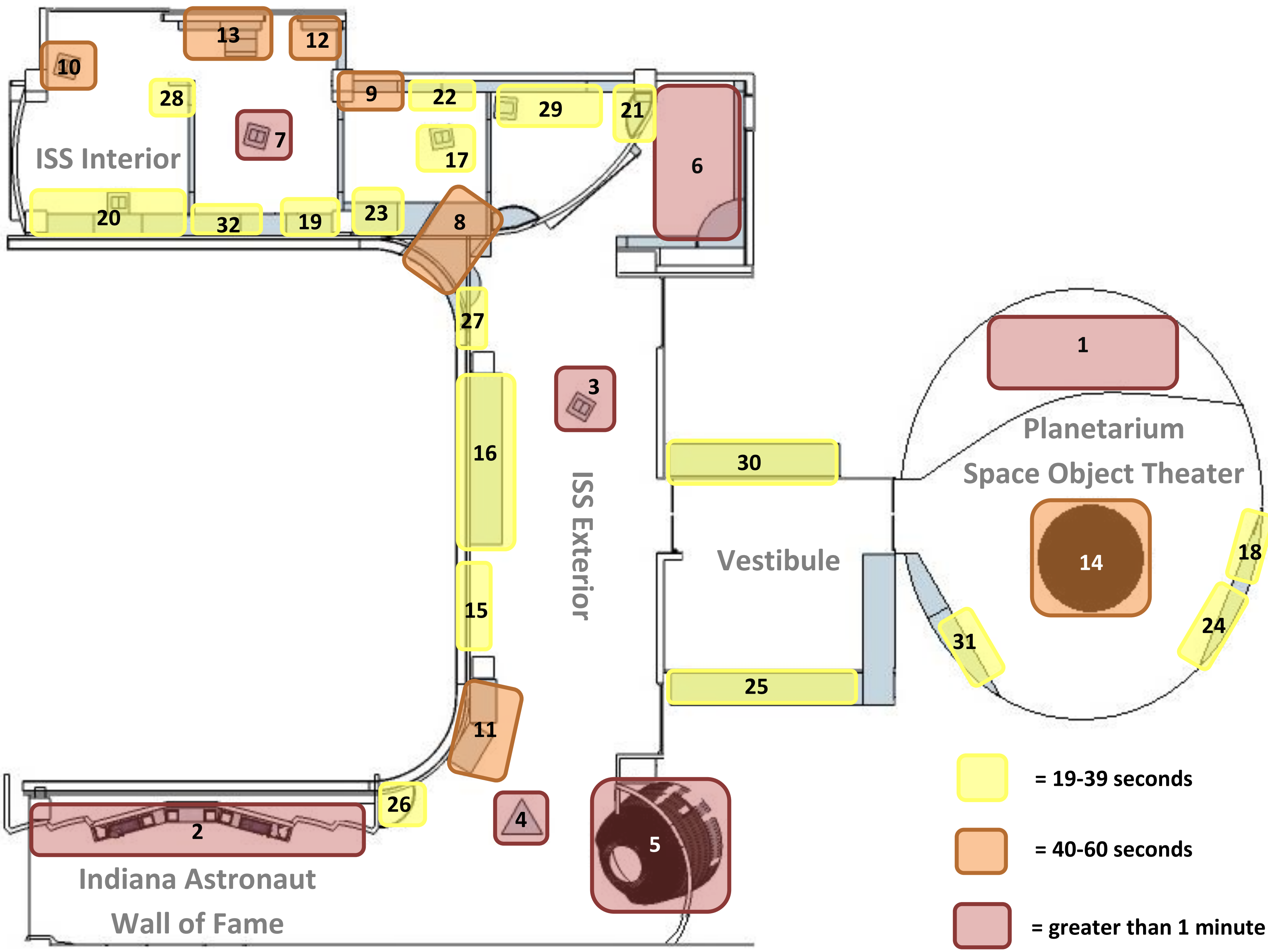

**Table 6.** ***Beyond Spaceship Earth*** **Average Stay Times for elements with an average of 20+ seconds (n=51 families; see Appendix B for the full list of elements).**

| Element (numbers correspond to Figure 2) | | Average Stay Time |
|---|---|---|
| 1 | Space Object Theater Show | 22 min 20 sec |
| 2 | IN Astronaut Wall of Fame* | 1 min 50 sec |
| 3 | Spacewalk iPad* | 1 min 45 sec |
| 4 | Canadarm game | 1 min 27 sec |
| 5 | Soyuz capsule | 1 min 16 sec |
| 6 | EVA pretend play area | 1 min 12 sec |
| 7 | Exercise iPad* | 1 min 11 sec |
| 8 | Chores crawlspace | 52 sec |
| 9 | Veggie activity | 51 |
| 10 | Clean a Spill iPad* | 51 |
| 11 | Glove boxes | 49 |
| 12 | Velcro activity | 49 |
| 13 | What's for Dinner case & audio | 48 |
| 14 | Liberty Bell 7 capsule | 40 |
| 15 | Hubble video | 39 |
| 16 | Truss | 38 |
| 17 | Tend the Plants iPad* | 38 |
| 18 | Glass display case | 38 |
| 19 | Weightlifting activity | 37 |
| 20 | Lower Your Visor activity & labels | 37 |
| 21 | Costume hooks (cupola side) | 35 |
| 22 | Bioreactor activity | 35 |
| 23 | Sleeping quarters alcove | 34 |
| 24 | Rocket display case | 32 |
| 25 | Robots & Spaceships display case | 31 |
| 26 | Costume hooks (glove box side) | 31 |
| 27 | Finding Your Way Around label | 27 |
| 28 | Microgravity video | 26 |
| 29 | Cupola | 25 |
| 30 | Authors display case | 23 |
| 31 | Grissom display case | 22 |
| 32 | Staying Fit in Space video | 19 |

*The Indiana Astronaut Wall of Fame and iPad games were evaluated individually in greater depth for the purposes of reporting to their funder, the Entertainment Software Association; those findings can be reviewed in the ESA Grant Evaluation Memo, authored by Claire Thoma Emmons, January 2017.

## To what extent does the *Beyond Spaceship Earth* exhibit support family learning engagement?

The findings for this evaluation question draw on data collected through tracking and timing observations; Interpretation program observations are reported in a separate section (see page 28). For more details on the methods and samples see Appendix A.

### Overview of the Museum's Family Learning Framework

The Museum uses a framework of family learning established by Dr. Barbara Wolf and Dr. Elee Wood, who in turn drew on and adapted prior iterations and frameworks in use at the museum since 2003. For the purpose of the Museum's evaluation studies, a family is defined as *at least one adult accompanied by one or more children who appear to have a sustained relationship*. This definition serves as the unit of analysis for the observational data collected and analyzed by Museum evaluators regarding family learning. Family learning, building on social constructivism, focuses on changes in knowledge, skills, and attitudes within the family unit. Family learning in museum exhibits is operationalized by the use of the ALFIE (Assessment of Learning Families in Informal Environments) Inventory to categorize observable behaviors into categories. The three primary categories in ALFIE are 1) Participation, 2) Collaboration and Problem-Solving, and 3) Enhancement. Within each category are individual codes used to describe in more detail how a family unit is interacting with each other or with each other and the exhibit element.[2] There are also codes for "non-interactive" behaviors, i.e. behaviors where a family member is on their own at an element; it is not that learning might not be happening in these instances, but that observable learning *between* the family members is not occurring.

### Family Learning at the Gallery-Level

When looking at the proportion of family learning behaviors that occur in BSE, the gallery is comparable to other Museum galleries in that Collaboration & Problem-Solving behaviors occur less often than do Participation and Enhancement behaviors (Figure 3). This general distribution makes sense because Participation includes instances of baseline interaction with an element, such as looking or briefly touching an element, and play in general. Enhancement behaviors are primarily conversations related to the element and also include many more varieties of codes. Collaboration & Problem-Solving, on the other hand, are more in-depth behaviors focused on demonstrating how something works or overtly working together to complete a task or solve a "problem" or "challenge" posed by the element. As such, Collaboration & Problem-Solving behaviors are not applicable to all elements. Display cases and simple interactives, such as the Weightlifting

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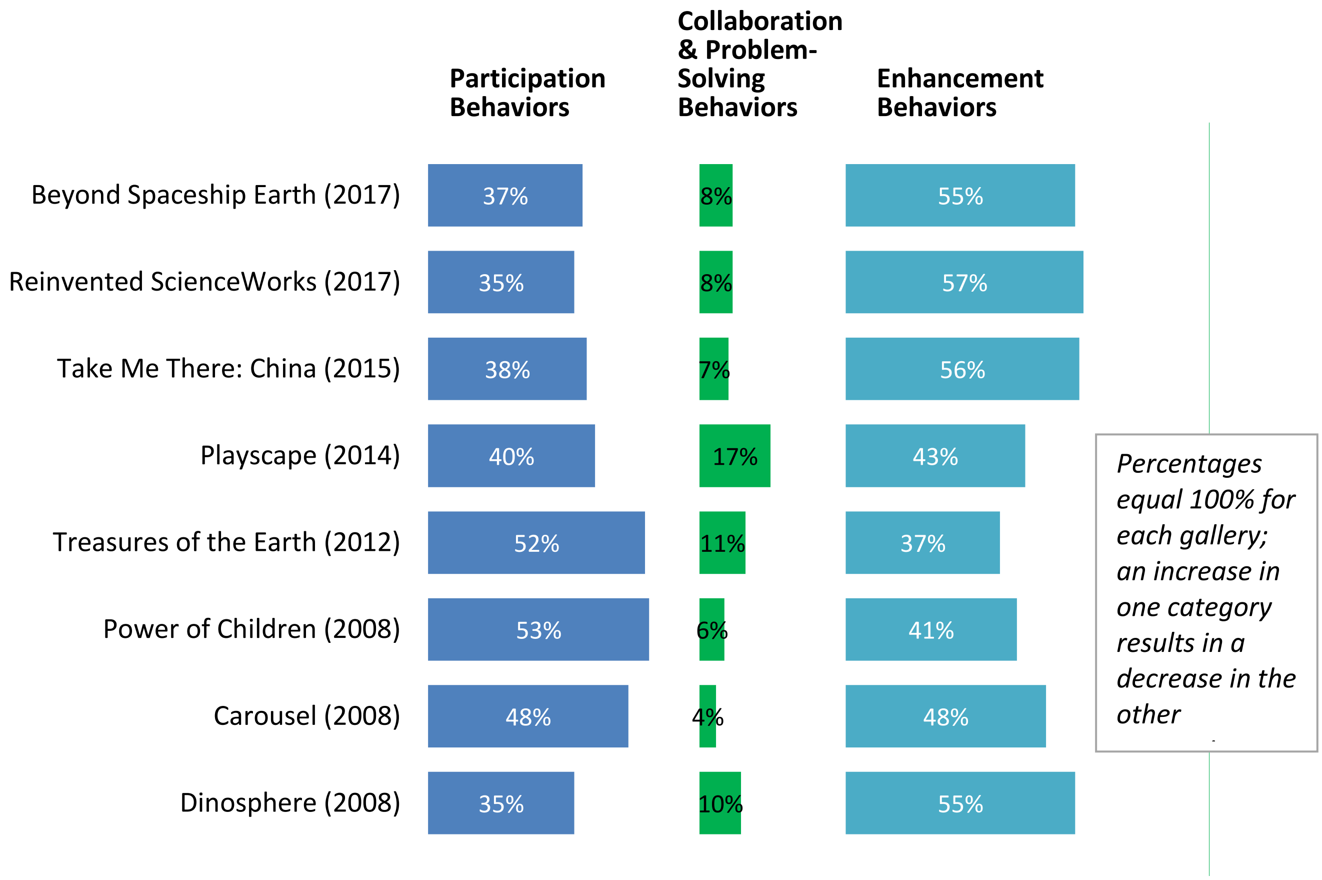
[2] Starting with BSE and *ScienceWorks* and moving forward, the Research and Evaluation Department, in concert with the Exhibit Development Department, has slightly revised the definition of various participation codes to make better use of the full inventory. This included changing "A" to refer to participation with a passive element, such as a label or display case, and "B" to refer to participation with an interactive element. Parallel play is still represented in the codes, but now pretend play is also mentioned specifically (by adapting a code that was previously rarely used).

activity are not expected to foster collaboration although they should foster joint observation and conversation (i.e., Participation and Enhancement).

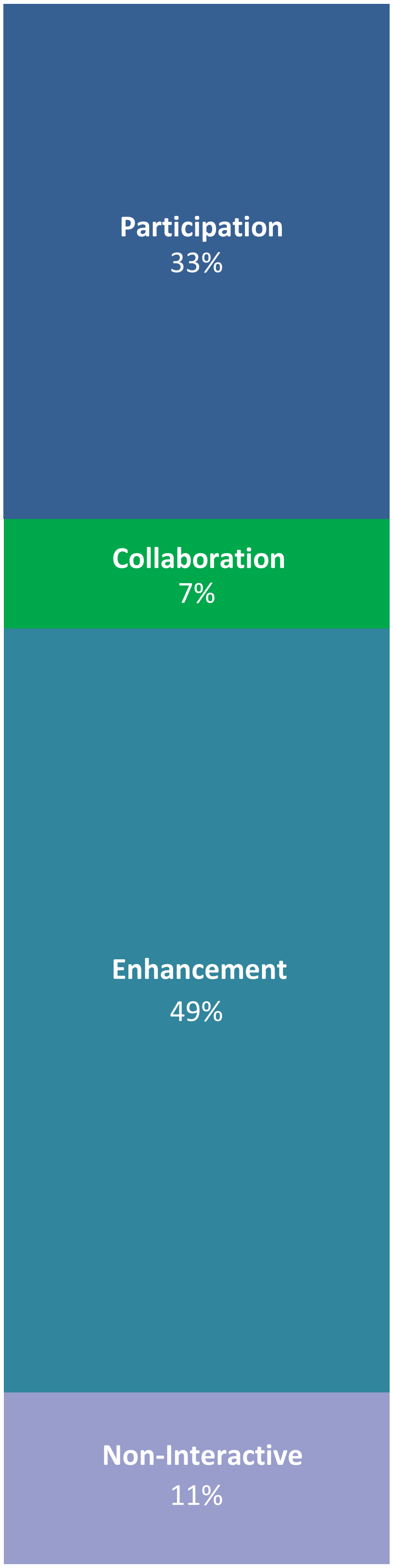
**Figure 3. The ISS exhibit is comparable to other museum galleries in its distribution of family learning behaviors across the three categories of Participation, Collaboration & Problem-Solving, and Enhancement.** Collaboration & Problem-Solving is typically the smallest category because it is not applicable to all elements, such as display cases.




When looking at the family level, the average number of observed, coded behaviors per family in BSE was 46.4 behaviors. On average, each family had 40.6 family learning behaviors and 5.8 non-interactive behaviors coded. The ratio of family learning behaviors to non-interactive behaviors is 7 to 1 for families on average. The average number of family learning behaviors per family in BSE is slightly higher than in TMTC, where families averaged 42.6 interactive family learning behaviors during their visit. This speaks well of BSE considering its much smaller square footage.

There were slightly more instances of children using elements alone in BSE compared to TMTC (23% of stops did not have an adult present, compared to 19% in TMTC). There were very few instances of adults being present but standing back (7% of stops). This indicates that there was a moderate rate of children and adults focusing on different elements, which easily occurs in this exhibit where the footprint is rather narrow and there are lots of elements in close proximity. Family members could be next to each other but focusing on different elements. For example, an adult often read other labels or watched the exercise video while a child manipulated the exercise iPad. Adults did not often go into the crawlspace with children, so they often looked at the Veggie interactive or other elements nearby. Despite this slightly higher rate of being at an element alone, the high ratio of interactive to non-interactive behaviors demonstrates that the 77% of stops when families were together resulted in many observable family learning behaviors. A general overview of family learning behaviors in the BSE gallery is displayed in Figure 4.

**Figure 4. As in other galleries, Participation and Enhancement behaviors occur more often in BSE than do Collaboration behaviors.**




**Participation** behaviors are those that describe ways family members participate with an element, typically when they first approach it. In BSE, half of all participation behaviors (51%) were B, "Family members participate with an interactive element." This was followed by A at 36%, which indicates that families also spent time together looking at passive elements such as the exercise video, the cupola window, and the What's for Dinner display. Although Pretend Play (E) did not make up a large percentage of the overall behaviors (4%), it was observed at the elements designed to foster this behavior: the EVA, crawlspace, costumes, and truss.

**Collaboration & Problem-Solving** behaviors are those where family members work together to solve problems or complete a task. These behaviors were roughly equally divided between adults demonstrating or explaining how to do an activity (I & J) 31%, adults scaffolding or facilitating for the child (K & L) 35%, and family members working together verbally and/or physically to complete an activity (M, N, O) 33%. Members working together simultaneously happened most often at the Canadarm game, various iPads, the bioreactor, and the Velcro station.

**Enhancement behaviors** are typically conversations that enhance the participation or collaboration behaviors occurring at an element. Providing information or directions from a label (P) made up nearly one quarter of all behaviors (22%), which is typical. Calling attention to something (Z), often a display case or video, and pointing at elements (EE) made up another 23% of enhancement behaviors, with many instances of pointing especially. Asking open and closed-ended questions made up another 10% of behaviors.

**Non-interactive** behaviors are children's behaviors that occur when an adult was not present at an element. 73% of these behaviors were the primary child viewing/focusing on an element without an adult (LL). Children engaged in activities successfully while alone (OO, 13%) nearly twice as often as unsuccessfully (PP, 7%).

Other family learning findings compared with previous gallery summative evaluations include:

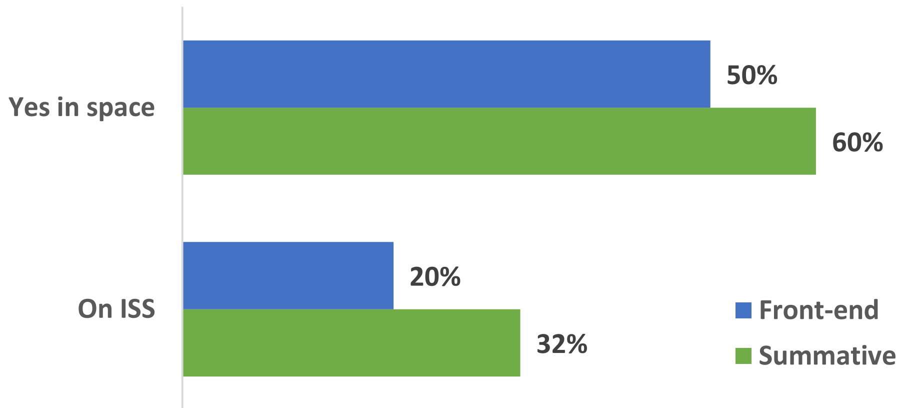
- Within Enhancement, 94% of the behaviors coded were in the "concrete" codes, P through EE. These codes focus on what is going on in the present moment, describing the element, providing instructions, commenting on the child's behavior. The codes for more abstract conversation encompassing past events, family memories, and relating an element to something not immediately visible, codes FF to KK, are typically observed much less frequently. By way of comparison, the concrete codes made up 97% of Enhancement behaviors in *Playscape* and 91% of Enhancement behaviors in TMTC. Based on these three exhibits, it is likely that this trend will always fall in the range of 94%±3% but may fluctuate based on the primary age and/or nature of content in the gallery.
- Within Enhancement, there are two codes for questioning behaviors; CC deals with close-ended questions geared toward identification or right or wrong answers (e.g. "What is that?" "Did you know they are growing plants in space?") and DD with open-ended questions that encourage explanations or have no right answer (e.g. "What do you do here?"). In BSE, 82% of questions were close-ended, or CC, which is considerably less than in TMTC, where 96% of the questions were close-ended, and even less than *Playscape's* level of 93%. In other words, there were more open-ended questions in BSE than the other two galleries.

## Content Learning and Interest Outcomes in the Exhibit

In order to understand the extent to which visiting families were learning more about life aboard the ISS and becoming interested in these subjects, several interview and survey methods were employed with families. These methods included in-depth interviews with families who had children in the target age range after they exited the exhibit (n=50), a one-question poll of visitors of all ages upon exiting the exhibit (n=135), online surveys completed one week post-visit (n=110), and a basic awareness poll conducted before and after the exhibit opened (n=146). Overall, these data demonstrate that visitors to the ISS exhibit leave with new knowledge about astronaut life on the ISS, increased interest in the space program, and a greater appreciation for the research conducted through the space program.

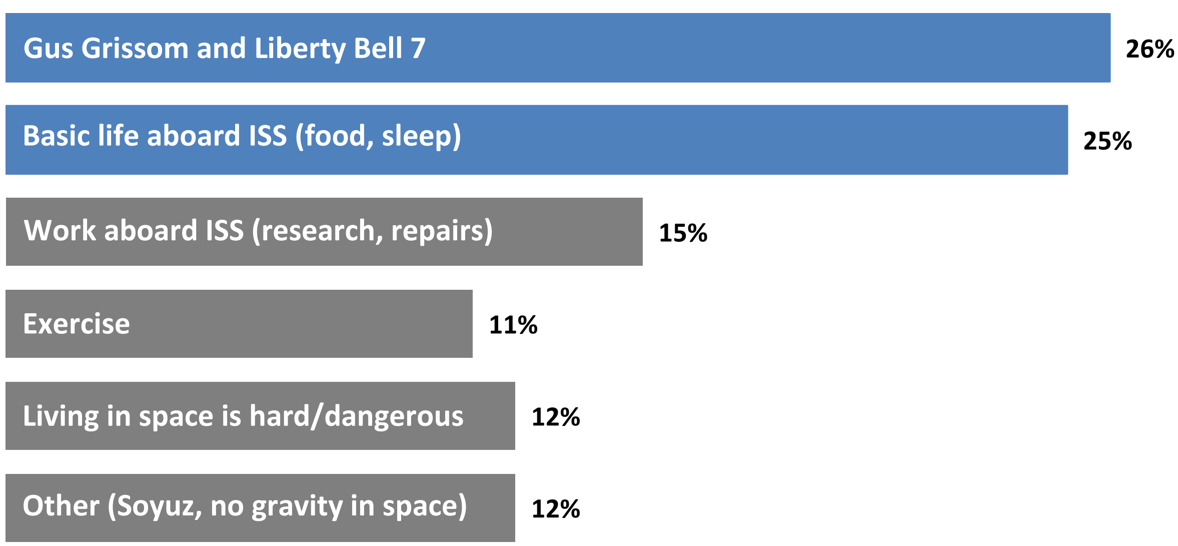
The basic awareness poll revealed a modest increase in the number of children who understood that there are astronauts living in space aboard the ISS right now (see Figure 5). Before the exhibit opened, half of children interviewed (50%) thought that astronauts were currently living in space, but only 20% thought they were living on the ISS; others mentioned generic spaceships or even Mars. Children who were interviewed as they left the exhibit reported thinking that astronauts are currently living in space at a slightly higher rate (60%), and 32% said they thought they were living on the ISS.

**Figure 5. Visitor knowledge that people are currently living in space and that they are on the ISS increased from front-end to summative.**




A one-question poll of visitors as they exited the exhibit revealed the topics of Gus Grissom, the Liberty Bell 7, and aspects of daily life aboard the ISS as being top-of-mind for what they learned in the exhibit (see Figure 6). The families who participated in longer interviews also commonly mentioned how astronauts exercise (13%), special gear (13%), Gus Grissom or the Liberty Bell 7 (10%), and how difficult it is to be an astronaut (10%) as new things they had learned in the exhibit.

**Figure 6.**




When asked specifically if they had learned about any research happening on the ISS, about one-third (30%) reported learning about plant and cell research. When asked whether they had learned about the challenges of living and working in space, most of the groups (82%) could recall challenges, including the need for astronauts to exercise in special ways to stay healthy (26%); inventing special ways to package, prepare, and eat foods without gravity (15%); and other inventions needed to overcome the lack of gravity in everyday life (16%).

Another subset of families were interviewed after interacting with the Indiana Astronaut Wall of Fame database. Among these groups, most children (87%) reported being previously unaware of the diversity of backgrounds astronauts have; increasing awareness of this diversity was one of the major goals of this exhibit area and appears to have been successful. Most groups (88%) also reported that the database sparked their curiosity regarding astronauts and the space program. Some common examples they gave of what they would like to learn more about were: more detail about astronauts' training and more detail about the goals of different missions over time.

Responses from both the exit interviews (n=50) and online surveys from groups who visited the exhibit and watched a space object theater show (n=110) help demonstrate the extent to which *Beyond Spaceship Earth* is supporting and extending visitor interest in the space program and STEM fields. For example, many groups (57%) reported that they were at least slightly interested in the space program before their visit to *Beyond Spaceship Earth*, but **the majority (66%) reported that their groups' interest in the space program had increased following their experience**.

Among both the interviewees and the survey respondents, a majority (84%) reported gaining a greater appreciation for NASA and the space program when asked directly. About half of those interviewed expressed the opinion that it is important to have a space station; common reasons given were to find ways to improve life on earth (33%), to learn more about astronomy [a misconception] (25%), and to learn how to live in space if earth becomes uninhabitable in the future (21%).

The majority (67%) of the groups who completed surveys about one week after their visit reported that they had had additional conversation about the topics presented in *Beyond Spaceship Earth* following their visit. While some mainly talked about things they had learned in the exhibit or recommended the exhibit to other family members, many groups (50% of that subset) had taken additional actions including visiting a local planetarium, looking up more information about Gus Grissom, and checking out library books about astronauts. In both samples, most groups (76-92%) reported that they are likely to seek out experiences related to the space program in the future. These data indicate that the exhibit experiences are successful in both supporting existing interest in the space program and increasing that interest.

## International Space Station Interpretation Program Use and Outcomes

### Family Learning through Interpretation Programs

The Interpretation department launched an array of new programs during the first five months of the *Beyond Spaceship Earth* gallery*.* Intended to complement the immersive design of the International Space Station exhibit, these programs feature actors and facilitators using captivating content, stimulating environments, unique objects, and educational skills to bring this extraordinary exhibit to life. A greater number of informal programs was planned for the exhibit space both to support the immersive environment of the gallery and in response to the practical constraint of not having a large gallery area in which to gather a crowd for a formally structured program.

As part of the summative evaluation for BSE, staff conducted observations of three programs offered in the ISS portion of the exhibit: *ISS Cosmonaut, Robots in Space,* and *Astronaut in Training.* Observations of these programs focused on planned family learning behaviors, program goals and objectives, content connections, and adult engagement (a current interest among Interpretation management). More than 100 families were observed in total over a range of visitation levels, staffing, content topics, and gallery flow. Detailed descriptions of the methods and samples can be found in Appendix A. Highlights related to family learning, program goals and objectives, and customer service from this study included:

- Measured family learning behaviors surpassed metric goals in most programs.
- Strategies for adult engagement were improved on in all programs.
- Staff are successful in using both props and exhibit elements in their formal and informal programs.

A detailed overview of the results by Family Learning objectives and program goals and objectives is provided below for each program.

***ISS Cosmonaut***

*ISS Cosmonaut* is an informal program featuring an actor-interpreter (AI) portraying a Russian Cosmonaut who lives and works on the International Space Station. The goal of this program is to provide both information and stimulate inspiration and curiosity through a more intimate experience. During the program, the AI approaches visitors and engages them in various topics of discussion related to living and working on the ISS with the goal of getting beyond basic facts to discussions of why activities are different in microgravity as well as why those activities are important for the space program. AIs are trained to introduce themselves and interact as if visitors were in space with them and to exercise a combination of visitor-led and staff-prompted conversations.

This program underwent an initial evaluation in Spring 2017 which showed several areas in need of improvement including increasing adult involvement throughout the program, incorporating more than one topic into the conversation, and extending the average length of interactions; staff were retrained, and the program was evaluated again in Fall 2017 and did show improvement in many of these areas. For example, the average interaction length in the fall was 4 minutes, slightly longer than the average from the spring of 3.4 minutes. Even more promising the percentage of interactions that were less than 3 minutes long fell substantially from spring to fall, indicating that staff were more consistently able to cultivate in-depth conversations with groups. Another area of improvement was in the drop of single-topic conversation and the greater frequency of 2-4 topics being covered in an interaction. Staff feel that this is an appropriate target for an interaction with a goal length of 4 minutes.

The topics that were covered most often in conversations (15-25% of interactions) included gravity/orientation (often discussed in tandem with other topics), eating in space, and exercise in space. Topics that were covered more occasionally (5-10% of interactions) included experiments in space, EVA's and upkeep of the ISS, sleeping in space, and other aspects of daily life. AIs often initiated interactions with visitors near the food display case, the exercise elements, and the crawlspace, which probably explains why those topics are some of the most common.

Staff have been observed engaging in playful, meaningful conversations with visitors that reinforce space concepts, enthusiasm for the topic, and exhibit content goals. Examples of these exchanges include:

> *Staff: Can you help me? [*As working to Velcro items back in place] *Do you notice anything strange about the way we attach things here?*
> *Visitor: Things are stuck to the walls.*
> *S: Yes! Why might we do so? What would happen I set my tool down?*
> *V: It would float away.*
> *S: Yes! And do you know why?*
> *V: There is no gravity.*
> *S: Yes! In actuality, there is what we call microgravity, which is a very, very small amount of gravity, but yes, there is not nearly enough! So, you can see, we keep our personal items attached to the walls or in drawers (goes on to discuss gravity on earth vs. in space and how those on the ISS further adapt).*
>
> *Staff: What experiment are you working on? Ah! I see you are checking on our potato plants – how do they look? You can see that we monitor the amount of moisture - we want to see what environment works best for them while they are up here in space. Do you have plants in your yard?*
> *Visitor: Yes. Trees.*
> *S: And do you know what trees give us, back into the air?*
> *V: Oxygen.*
> *S: Yes! That is actually one of the many reasons we grow plants on the ISS. They help us keep the air clean. We also grow to experiment – if we ever want to get to Mars, we will need to know how to grow our own food!*
>
> *Staff: What is your favorite food, my friend?*
> *Visitor: Hot dog.*
> *S: And do you like to have a bun with your hot dog?*
> *V: Yes.*
> *S: Well, in space, everything is floating, and so we must be careful with what food we bring*

*here. Bread, such as your hot dog bun, would send crumbs all throughout the space station! Why might that be a problem?*
*V: It could get messy.*
*S: Oh yes, and the crumbs could clog up the technology and cause problems. But never fear, my friend, if you want to become an astronaut, you can still eat your hot dog. We just use a tortilla instead, ha!*

**Table 7. Overall Objectives*: Russian Cosmonaut***

| Objectives | Goal | Actual |
|---|---|---|
| Actor welcomes families to the ISS | 85% | 87% |
| Actor introduces self as a Russian cosmonaut | 85% | 55% |
| Actor has at least one object with them as a conversation starter | 85% | 100% |
| Actor uses this object or exhibit components as part of their interaction with visitors | 85% | 94% |

All of the general objectives were implemented consistently with the exception of actors introducing themselves as Russian cosmonauts (despite the fact that they all use Russian accents in this character); this point will be addressed with staff as it is a key means for opening a discussion of the international teams that all work aboard the ISS.

**Table 8. Family Learning Objectives*: Russian Cosmonaut***

| Objectives | Goal | Actual |
|---|---|---|
| Family member contributes information or asks a question during program. (P) | 85% | 77% |
| Family member shares basic information, explanations, or facts. (W) | 75% | 52% |
| Family member compares something to themselves, other family members or other objects. (FF) | 65% | 74% |

Interestingly, only one of the planned family learning behaviors was meeting/exceeding its goal metric, but it is the behavior that is typically harder to prompt—making comparisons (FF). This illustrates that in the context of the BSE exhibit, it is relatively easy to prompt visitors to make comparisons between life on earth and on the ISS, and cosmonauts are doing so very consistently in their conversations with visitors.

Another area in which staff showed improvement between the two data collection periods was in implementing strategies for adult participation. Initially, about one-quarter of adults were standing back during the interactions, and staff were only observed encouraging adult participation about half of the time. After some retraining on appropriate strategies for inviting and encouraging continued adult interaction, staff implemented the strategies with 75-85% of groups, and adults actively participated in the interactions along with children 85% of the time; adults standing back dropped to 6%. This is a significant improvement in an area that has been a focus of the Interpretation department for the past year.

*ISS Cosmonaut* has much to offer in its flexibility of content topics, success in various attendance volumes, and evidence of conversation variety and visitor-led experiences. Staff will continue to work to increase the implementation of program and family learning objectives that are currently under goal while maintaining the successes in other areas, such as adult engagement and variety of topics covered.

***Up Close and Personal: Astronaut in Training***

*Up Close and Personal: Astronaut in Training* is a formal cart program that offers one of three different content themes: Food in Space, Space Walk, and Space Experiments. During the program, staff formally gather a group of visitors or families to their stationed cart, and using a combination of scripted content and spontaneous question-based methods, present an interactive program to visitors that stimulates problem-solving, inquiry methods, and the comparing and contrasting of experiences with new ideas, technologies, and procedures being utilized on the ISS.

- Food in Space focuses on the relatable and curious topic of eating in space. Located within the ISS, this program invites visitors to handle and interact with examples of "space food." Much of this program focuses on observation of space food, as well as exploring challenges of certain types of typical "Earth" food and drink, and how scientists problem-solve solutions for those living and working on the ISS.

- Space Walk explores EVAs and why they are vital to the survival of those living and working on the ISS. This cart is often located by the external portion of the ISS, where visitors can use a combination of their imaginations and real objects such as models, gloves, and images to explore the exhilaration and difficult work of EVAs.

- Space Experiments open featuring an experiment that explores how to extinguish fire in space. This program relies on fire and water imagery and tools such as a Hoberman sphere to explain how fire behaves differently in various environments and conditions. Relying heavily on the scientific method of questioning and observation, visitors are asked to explore the how and why of the specific conditions within the ISS that makes this a worthy experiment. Other experiments may be highlighted in the future.

For this study, approximately 12 observations were made for each program theme: Food in Space, EVA, and Space Experiments, resulting in 33 total observations. All themes had the same introduction to the ISS and life in space, before moving into the specific content goals of the topic. Each activity was developed with the same structure, thus the results of this evaluation focus on consistency of content delivery and structure.

**Table 9. Overall Objectives*: Up Close and Personal: Astronaut in Training***

| Objectives | Observed Rate |
|---|---|
| Facilitator will welcome families to the ISS | 94% |
| Facilitator will share a brief explanation of microgravity | 94% |
| Facilitator will introduce self as an Astronaut in Training and invite visitors to join them | 91% |
| Facilitator will share a brief explanation of ISS orbit | 88% |
| Facilitator will share a brief explanation of living in space on the ISS | 76% |
| Facilitator will share a brief explanation of ISS Space Lab | 73% |

Objectives for this program were achieved with high levels of consistency and success, which was a great improvement from the remedial period (Table 9). Efforts will continue to be made to improve discrete sub-topics within these objectives, such as developing clearer explanations of what the Space Lab is and why it is important to the work done on the ISS.

**Table 10. Program Structure and Objectives*: Up Close and Personal: Astronaut in Training***

| Objectives | Observed Rate |
|---|---|
| Staff Use Intended Props (object objectives) | 89% |
| Activity Steps…(programmatic objectives) | 85% |
| Families hear about/discuss… (content objectives) | 76% |
| Staff will encourage guests to explore other parts of ISS | 61% |
| Staff mentions future missions/reasons for research (Mars, etc.) | 42% |
| Staff mentions STEM careers beyond "Engineer" and "scientist" | 27% |

Overall, this program also showed great improvements with structural consistency, including usage of props and intentionality with script content points and activity steps (Table 10). The Space Experiments and EVA activities in particular showed substantial improvements in following the intended steps through the activities, resulting in successful program and family learning achievement.

Moving forward, Interpretation is going to continue to examine the Space Experiments program, including considering featuring other ISS experiments, to continue to brainstorm ways of explaining and demonstrating experiments in ways that are clear to the visitor and effective as a simulation, since staff cannot do the actual experiments in the gallery.

**Table 11. Planned Family Learning Behaviors*: Up Close and Personal: Astronaut in Training***

| Family Learning Behaviors | Goal | Actual |
|---|---|---|
| Family members compare something to themselves, other family members, or other objects. (FF) | 80% | 100% |
| Family member contributes information or asks a question during program. (P) | 85% | 94% |

With improvements made after the remedial evaluation, the family learning goals for these programs increased dramatically. In between the remedial and the summative evaluations, Interpretation management worked with staff on strategies for engaging adults and keeping visitors with them through the entirety of the program. Successful use of questioning methods are crucial to these programs, and Interpretation management is pleased with these improvements which are now far exceeding the goal metrics (Table 11).

**Table 12. Adult Engagement Goals*: Up Close and Personal: Astronaut in Training***

| Adult Engagement | Observed Rate |
|---|---|
| Staff invites adult(s) to participate. | 58% |
| Adult actively participates with child. | 52% |
| Adult stands back and is watching and talking. | 48% |

| | |
|---|---|
| Staff is encouraging adult participate throughout interaction. | 48% |
| Adult declines to participate in any way and disengages from program. | 6% |

Something that was found to be consistent across all three of these *Up Close and Personal: Astronaut in Training* programs, as well *Robots in Space* and *ISS Cosmonaut* initially, were results like those above that demonstrate a need to continue to work on connecting with adults throughout the program (Table 12). Based on the analysis of the data, it appears that staff fail to engage with already engaged adults. This is easy to remedy, requiring awareness training and a refresher on how to incorporate participants on all levels into one's program. Given that great improvement was seen in this area with the *ISS Cosmonaut* program, Interpretation expects to find improvements in these metrics in the near future.

***Robots in Space***

*Robots in Space* uses a similar framework as *Up Close and Personal: Astronaut in Training*, but is highlighted separately in this evaluation because of its content and a slightly varied structure. This program introduces visitors to the Canadarm2, as well as other robots on the ISS. On the cart visitors can see imagery, a close up model, and can view the replica featured above them as part of the immersive environment of the exhibit.

Similar to *Up Close and Personal: Astronaut in Training* objectives for *Robots in Spare* were achieved at high rates, meeting the planned metrics by the Interpretation department (Table 13). These results demonstrate a successful remedial period, where coaching focused on consistency of delivery and formality of program presentation and gathering techniques.

**Table 13. Overall Objectives*: Robots in Space***

| Objective | Observed Rate |
|---|---|
| Facilitator will introduce self as an Astronaut in Training and invite visitors to join them | 96% |
| Facilitator will share a brief explanation of ISS orbit | 96% |
| Facilitator will welcome families to the ISS | 88% |
| Facilitator will share a brief explanation of microgravity | 88% |
| Facilitator will share a brief explanation of ISS Space Lab | 88% |
| Facilitator will share a brief explanation of living in space on the ISS | 88% |

There are many content objectives for this program, and as seen in Table 14, those pertaining specifically to Canadarm are being met at very high rates while those that go beyond the concrete topic are not addressed as often. Interpretation management is discussing the amount of content in this program, and whether the removal of a point or two might relax the program and allow staff to feel like they do not have to rush, something that was a part of the feedback process from observers.

**Table 14. Program Structure and NASA Objectives*: Robots in Space***

| **Objective** | **Observed Rate** |
|---|---|
| Families hear about/discuss: description of C2 | 96% |
| Families hear about/discuss: size of C2 | 92% |
| Staff discusses: catching cargo for ISS | 92% |
| Families hear about/discuss: location of C2 | 88% |
| Staff discusses: EVA assist | 81% |
| Families hear about/discuss: history of C2 | 77% |
| Staff mentions future missions where robots will be needed (Mars, etc.) | 65% |
| Staff will encourage guests to explore other parts of the ISS | 62% |
| Staff mentions STEM careers beyond "engineer" and "scientist" | 46% |

In structure and prop usage, Interpretation saw great improvements in the use of objects and consistency in following the scripted steps of the program (Table 15). Interpretation management is pleased that all of the props are being used in most programs.

**Table 15. Use of Program Props*: Robots in Space***

| **Objective** | **Observed Rate** |
|---|---|
| Staff uses intended props: iPAD | 100% |
| Staff uses intended props: 3D model | 92% |
| Staff uses intended props: controls | 88% |
| Staff uses intended props: overhead model | 88% |

Both family learning goals for this program are being met very consistently for almost all families who participate (Table 16). This indicates that the strategies for prompting behaviors in this program are very successful and that most families are able to participate in a conversational exchange with the staff facilitator.

**Table 16. Planned Family Learning Behaviors*: Robots in Space***

| **Family Learning Behaviors** | **Goal** | **Actual** |
|---|---|---|
| Family members compare something to themselves, other family members, or other objects. (FF) | 85% | 96% |
| Family member contributes information or asks a question during program. (P) | 75% | 95% |

While the family learning goals for the program are being met at high levels, the adult engagement strategies were unevenly implemented (Table 17). As with *Up Close and Personal: Astronaut in Training,* staff will have follow up coaching and brainstorm opportunities to increase the rate at which staff are encouraging adults to participate throughout interactions. As mentioned earlier, most adults in question are already verbally participating, so some focused retraining and peer review should lead to improvement in this area.

**Table 17. Adult Engagement Goals*: Robots in Space***

| Adult Engagement | Observed Rate |
|---|---|
| Staff invites adult(s) to participate | 69% |
| Staff is encouraging adult participate throughout interaction. | 54% |
| Adult stands back and is watching and talking. | 50% |
| Adult actively participates with child. | 31% |
| Adult declines to participate in any way and disengages from program. | 19% |

Overall, all of the gallery programs are succeeding in meeting goals for family learning as well as content learning. The wide variety of programs developed allow visitors to explore many different aspects of life and work on the ISS in greater detail during their time in the gallery, and all of the program formats provide visitors with ample opportunity to ask their own questions. The Interpretation department has learned a great deal from developing and refining these programs, and these learning will be applied to the development of future programs, both in BSE, other galleries, and the *Sports Legends Experience*.

## Schaefer Planetarium and Space Object Theater Use and Outcomes

This section focuses on the following evaluation questions:

1. What are the visitation patterns in the Space Object Theater?
2. To what extent do the project components increase participant interest in STEM topics?
3. To what extent do families and students have a better understanding of the variety of STEM fields and careers that contribute to NASA's space program?

The findings for this section draw on data collected by gallery counters and program counts, post-visit surveys with families, a feedback wall activity with families, and post-visit surveys with teachers. For more details on the samples, see Appendix A.

### Capture Rate

The total number of visitors who entered the Space Object Theater during its first year of operation was over 200,000 based on infrared door counters. Initial observations indicated that some of these visitors did not watch a show; rather they viewed the Liberty Bell 7 and other display cases during the periods between shows. To account for this difference between the door counters and the number of visitors who view shows, staff physically counted and recorded individual audiences at every show. This number was compared to the "entering" number recorded by the door counter to allow for the estimation of capture rates moving forward. Using this ratio, it is estimated that a total of 176,700 visitors, representing 14% of museum visitors, watched shows in the Space Object Theater during its first year of operation.

In the Space Object Theater, three types of shows are offered: *Flight of the Liberty Bell 7* is an automated sound and light show that makes substantial use of sound and light effects in addition to using historical video footage to tell the story of Gus Grissom's space flight, landing, and recovery. This show plays 9 to 10 times per day, so the vast majority of visitors who watch a show see this one. Interpretation also offers two staff-led examinations of the Liberty Bell 7, *Gus Grissom and the Liberty Bell 7,* a narrative told by an actor portraying astronaut Gordon Cooper, and the *Up Close and Personal: Liberty Bell 7,* where visitors hear the story of the Liberty Bell 7 and its exciting trip to space*.* These staff-led programs are presented a total of three times per day. In future years, additional first person characters will be added for portrayal by actor-interpreters, including a female character. The attendance at each of these show types is reported in Table 18, with the majority of visitors viewing the sounds and light show due to its more frequent showings.

**Table 18. Attendance at specific Space Object Theater shows during the first year of operation**

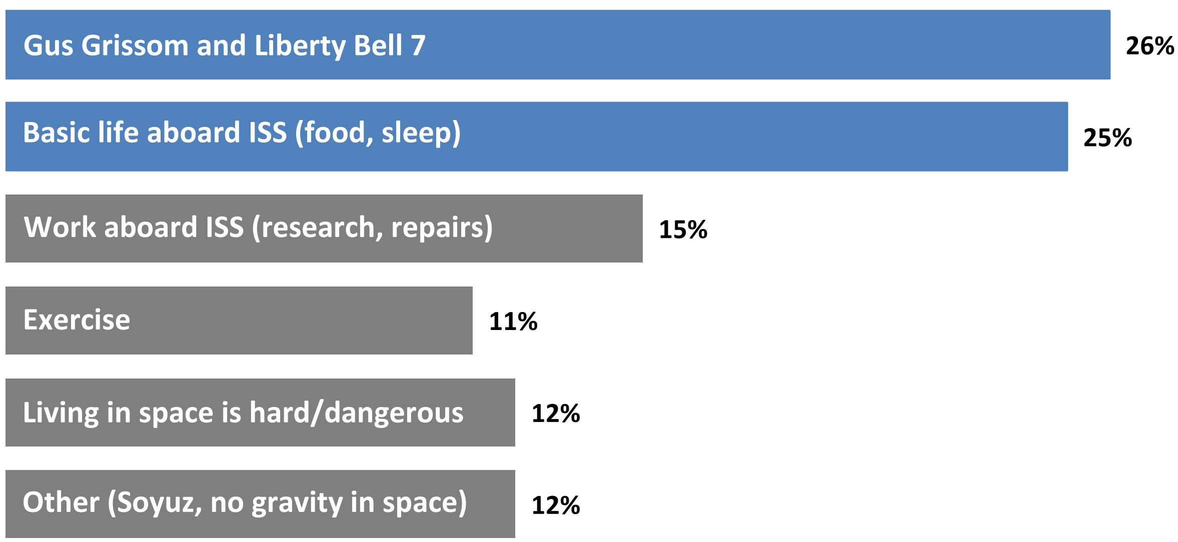
| Shows | Attendance |
|---|---|
| *Flight of the Liberty Bell 7 (Sound & Light)* | 125,200 |
| *Gus Grissom and the Liberty Bell 7 (Actor Interpreter)* | 29,400 |
| *Up Close and Personal: Liberty Bell 7* | 22,100 |
| TOTAL | 176,700 |

Attendance records indicate that typical annual visitation to the SpaceQuest Planetarium was 150,000, so it appears that the greater frequency of shows and ease of open, non-ticketed seating has led to a nearly 25,000 person increase in the number of visitors watching shows annually.

## Visitor Learning Outcomes and Interest

A brief interview asking visitors to name one thing they had learned in the exhibit (which was posed to everyone, including visitors who watched space object theater shows and those who only visited the exhibit), demonstrated that learning about Gus Grissom and the Liberty Bell 7 was very memorable for those who did watch shows (Figure 7). A front-end study for BSE found that the vast majority of visitors were not familiar with Grissom or the story of the Liberty Bell 7 and thus the learning opportunity surrounding the topic was very large.

**Figure 7. A one-question poll of visitors as they exited the exhibit revealed the topics of Gus Grissom, the Liberty Bell 7, and basic aspects of daily life aboard the ISS as being top-of-mind for what they learned in the exhibit. (n=135)**




In a follow-up survey, some family groups (25%) reported both adults and children had more questions and greater interest following the Space Object Theater show. Several groups mentioned that seeing the real capsule and experiencing the journey through the Space Object Theater programming made the history more real and interesting. Almost all of the survey respondents (96%) are "somewhat likely" or "very likely" to watch a show about Liberty Bell 7 again during a future visit.

> **Examples of increased interest:**
> *"The performance made me want to do some follow-up research on the Liberty Bell 7 and Gus Grissom."*
>
> *"The kids were all excited to learn more and had lots of questions!"*

It was anticipated that the Planetarium would be a regular stop for school groups, given that the SpaceQuest Planetarium was popular with field trips. To gauge teacher opinions about the benefits of the Liberty Bell 7 program for their students, a follow-up survey with teachers after their field trip was conducted. Most teachers (75%) strongly agreed that the sound and light show informed students about the launch and events surrounding the Liberty Bell 7. The majority (65%) also strongly agreed that the show supported student interest in the space program and gave students a greater appreciation for the early space program and the courage of astronauts. The majority of teachers (65%) had either done an activity related to the space program before their visit or were planning to do something related after the visit. This survey also found that the current programs in the Space Object Theater were appreciated by teachers. Most teachers (85%) indicated that they are very likely to bring their students to see the show again next year. Some teachers (35%) indicated that they would bring their students to multiple shows in the same school year if additional shows on other topics were offered, but 65% of teachers reported that the Liberty Bell 7 shows currently offered met their needs.

## STEMLab Program Outcomes

This section focuses on the following evaluation questions:

1. To what extent do family groups engage in the intended family learning behaviors in lab programs?
2. To what extent do the project components increase participant interest in STEM topics?
3. To what extent do visitors and students have a better understanding of daily life and work aboard the ISS, including research activities, as a result of project components?
4. To what extent do families and students have a better understanding of the variety of STEM fields and careers that contribute to NASA's space program?
5. To what extent do project components foster positive attitudes towards engineering?
6. To what extent do families and students practice STEM process skills while participating in project components?

The findings for this section draw on data collected through observations of school and family programs delivered in the STEMLab (the Museum's lab classroom, which is located within the *ScienceWorks* gallery but presents programming related to all galleries), interviews with families, and follow-up surveys sent to families and teachers. For more details on the methods and samples, see Appendix A.

### Family Programs

Two different formats of family programs focusing on the engineering process were selected for evaluation to determine the extent to which family learning behaviors and the practice of STEM skills were prompted. Various facilitation strategies were also recorded in order to understand how staff can best foster the desired skills, behaviors, and a positive attitude toward engineering. In addition to observations, families were interviewed directly following one of the programs, and a subset of families who participated in the other program format were sent a follow-up online survey. The programs included:

- *Out of this World Engineering* is a workshop-style program led by an actor-interpreter (AI) using a multimedia PowerPoint and various props to introduce families to some of the challenges of living in the microgravity environment of the ISS. The AI then leads families through the engineering process of identifying problems and brainstorming possible solutions that would allow basic inventions including a cup, a dumbell, and an electric razor to work in space. The families then build prototypes for the space version of these items using a crate of provided materials.
- *Robots in Space, Eat Your Veggies, Circus Physics*, and *Avoid Detection* are all "open-ended" programs led by science educators. The facilitator presents background information on the topic and then provides materials and an engineering-style challenge for families to solve. For example, programming a simple robot to navigate across a map or building a prototype of a microgravity plant growth system are two of the challenges.

### *Out of this World Engineering*

Two families were typically observed during each program, so during the 30 programs observed, data were collected on a total of 59 families. Slightly more than half (60%) of all children observed were males, while adults were split 50/50 between genders. Half of all children observed (52%) were estimated to be in the 6 to 9 year old age range. Of the remaining children, 20% were in the 10-12 range, indicating that this program is drawing interest from older youth; 20% of children attending the program were in the 3-5 range, although they were typically part of a group that included older children.

### Observed Findings

AIs successfully met their presence and initiation goals 93-100% of the time. These standard Interpretation department metrics include wearing the appropriate costume, making a clear and effective gather, actively initiating interactions, being welcoming and inviting to all guests, using an appropriate voice level, and using both body language and verbal cues to encourage adult participation. Staff made a connection to the *Beyond Spaceship Earth* exhibit at some point during the program 75% of the time, and they encouraged families to take their engineering checklist home and try the process again in 83% of observations. There were only 3 observations in which neither of those connections/encouragements took place, so in most instances, staff are delivering one or both of these prompts.

Four of the five content goals and objectives for *Out of this World Engineering* were met at 100%, indicating that staff delivered the program with a high degree of fidelity, even as they brought their individual personalities to bear on the character. The four content goals and objectives that were met in 100% of the observations included: introducing the steps of the engineering design process, defining vocabulary words ("engineer" and "prototype"), prompting families to work together to modify an object, and showing examples of reengineered NASA objects. The fifth content goal was to prompt families to try the engineering design process again at home, which as noted above was met in 83% of observations.

Almost all of the intended family learning behaviors were met over 90% of the time (Table 19).

**Table 19. Family Learning Behaviors for *Out of this World Engineering***

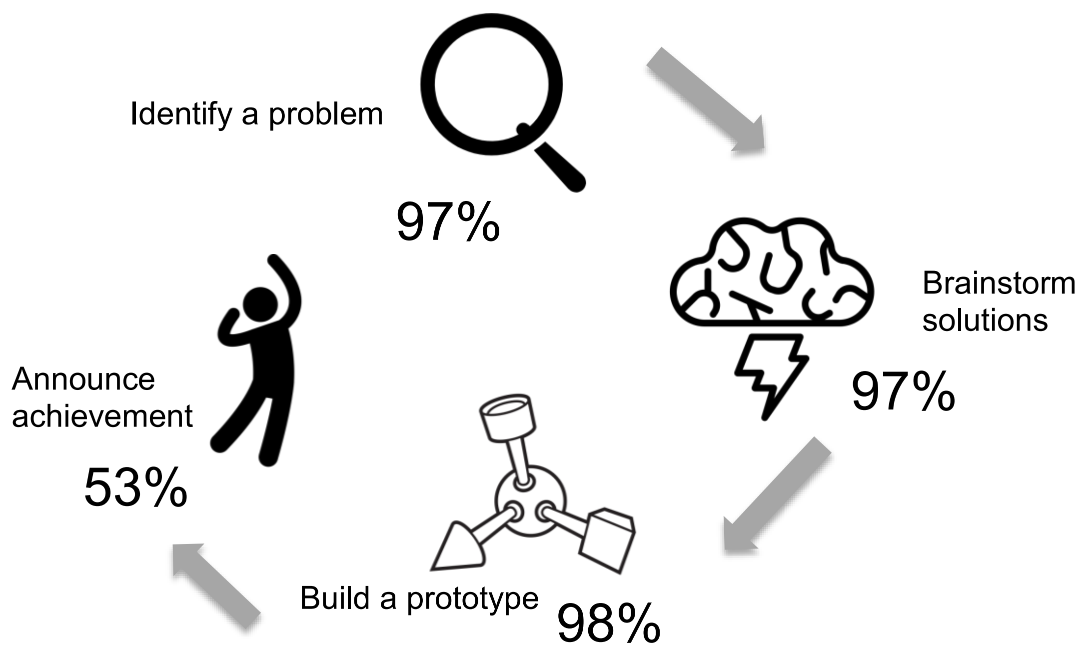
| Family Learning Behaviors | Anticipated | Observed |
|---|---|---|
| Family members follow instructions together (B). | 90% | 97% |
| Adult facilitates problem solving (L). | 85% | 97% |
| Family members verbally and/or physically work on activity simultaneously to complete it (M). | 85% | 93% |
| Family member contributes information during program (P). | 60% | 93% |
| Family member compares something to themselves, other family members, or other objects (FF). | 60% | 49% |

The only family learning behavior that did not meet its goal was "family members comparing something to themselves." This typically happened in the program when prompted by the AI; as part of the script, the AI asked for examples of differences between life on earth and on the ISS.

Usually, once one visitor contributed that there was no gravity on the ISS, the AI moved on. So if the visitor who made that comparison was not a member of an observed family, the behavior was not counted as occurring for the observed family. The opposite was true of the "contributes information" behavior; there are multiple opportunities for family members to answer questions and contribute ideas during the program, and the high rate at which it was observed among families reflects this. The rate at which the comparison behavior occurs would likely be increased if staff prompted multiple groups to provide comparisons between life on earth and the ISS or if staff prompted a different comparison later in the program.

Because a key component of this program is promoting the practice of various STEM skills, observers also recorded anticipated STEM behaviors and indicators of a positive experience with STEM (see Figure 8). Almost all families demonstrated the STEM skills of identifying a problem with an object (97%), brainstorming possible solutions to that problem (97%), and building a prototype of the re-engineered object (98%). Additionally, half of all families were observed announcing achievement (53%) and expressing excitement or enjoyment of the engineering process.

**Figure 8. The STEMLab Program *Out of This World Engineering* encouraged high levels of STEM process skills (n=30).**

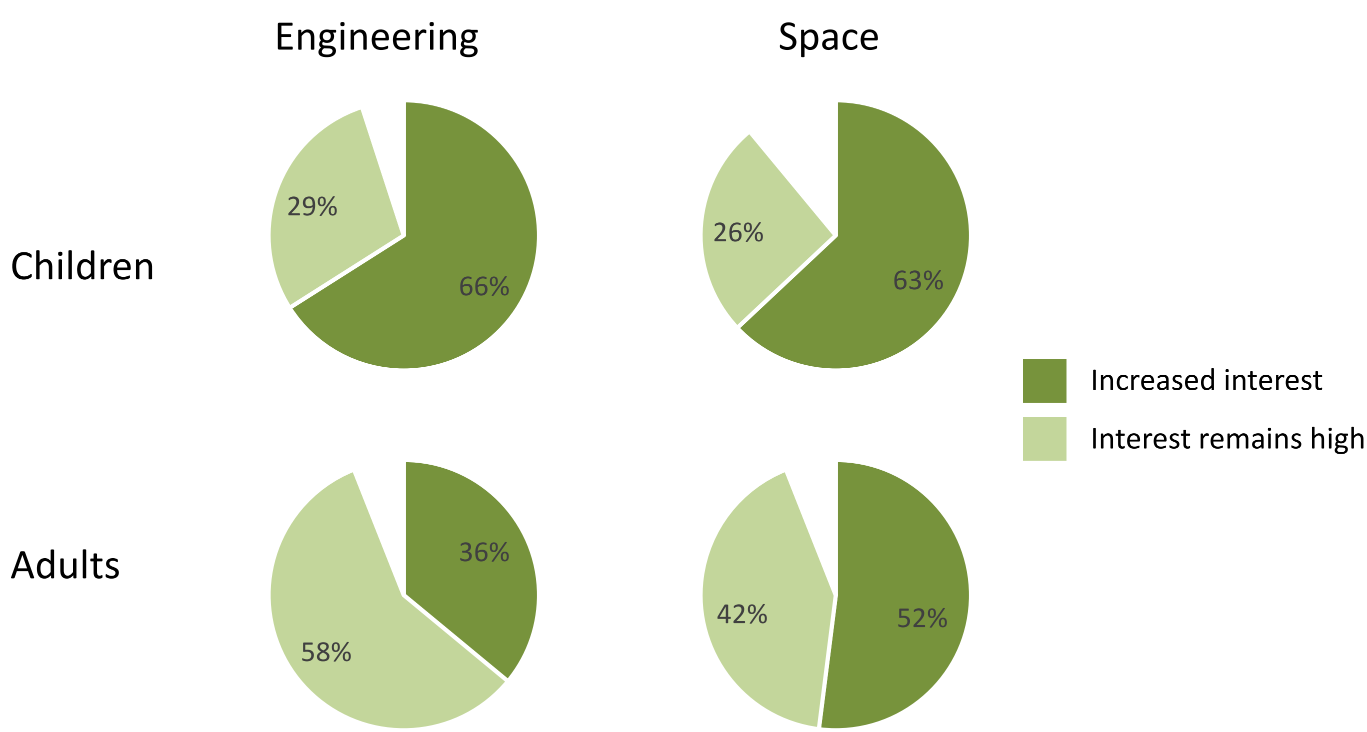



**Family Exit Interview Findings**

At the end of each *Out of this World Engineering* program, one of the two families observed was asked to participate in a short interview. 30 programs were observed with 27 followed by an exit interview. Almost all of the families interviewed included at least one child in the 6-12 age group, the target age for the program.

*Out of This World Engineering* is designed to support and increase interest in engineering and the space program. Both children and adults were asked to report whether they were more, less, or equally interested in engineering and the space program after the program as compared to before. **The majority of children (66%) reported more interest in engineering following the program**, and most of the remaining third indicated that their interest stayed the same but was already high (Figure 9). Responses among adults mirrored this trend; many adults maintained an already high interest (58%), and about one-third (36%) reported an increased interested following the program. No one reported a decrease in interest, and only a very few still had little interest in engineering (5% children, 6% adults). Regarding interest in the space program, many adults (52%) and the majority of children (63%) reported increased interest following the program. An additional 42% of adults and 26% of children said that they maintained their already high interest. Again there were no reports of decreased interest, although a few more maintained low interest in the space program (11% children, 6% adults). Overall, interviews confirmed that the *Out of this World Engineering* program was successful in supporting and/or increasing interest in both engineering and the space program for more than 90% of program participants.

**Figure 9. Interest in both engineering and the space program increased among children and adults.**




In order to understand what program participants, particularly children, learned about engineering, interviewees were asked to complete the following sentences: "On the topic of engineering, I used to think…and now I know…" Half of children (52%) reported that they didn't know much at all about engineering before this program; those who knew a bit (22%) described it very generally as "building stuff" or thinking that it was very technical. Two children mentioned that they thought it was "hard," and only 1 child described it as "cool." Because of participation in the program, **half of children (52%) gained a more nuanced understanding of engineering,** including the engineering process for developing solutions and that improving upon existing technology—as well as inventing new things—counts as engineering. Whereas only one included a child who described thinking about engineering in positive terms before the program, 10 groups (37%) included children who reported that they now thought of engineering positively, using words such as “cool,” “awesome,” and “fun.” One child even responded that s/he now wants to be an engineer *“I actually want to be an engineer”*! One-quarter of children also described surprise at the number of items that had to be re-engineered for astronauts to use them in space.

After having participated in the engineering process during the program, **half of all families (48%) indicated that they are *more likely* to pursue additional engineering experiences in the future**. Most of the others (41%) reported that they are also highly likely to seek out other engineering experiences, but that they were just as likely to do so as before participating in the program. None of the families were less likely to participate in a future activity. Of those who intend to do similar activities, 53% described a new engineering challenge, such as building ramps or a robot.

In summary, actor-interpreters successfully implemented this program’s strategies, and for the most part, the program exceeded its objectives for content and family learning. In addition, the program successfully prompted visitors to practice STEM skills and provided a positive experience that increased interest in engineering for many families.

**Open-ended Program Formats**

Open-ended programs in the STEMLab were developed and delivered by Museum science educators. Staff developed two programs featuring research aboard the ISS: an introduction to robotics and an exploration of growing plants in space. Previous programming in the STEMLab followed a highly scripted format in which facilitators provided specific step-by-step instructions that led families to a predetermined outcome, such as extracting DNA from wheat germ or making cheese in a test tube. In contrast, these programs follow the format of the educator introducing background information using slide show visuals and then providing families with materials and an engineering challenge with no predetermined outcome. Simultaneously, staff also developed two other programs with content unrelated to the BSE project by following the same format. In order to understand whether this program *format* was successful in meeting its goals, and to help staff improve upon engineering workshop-style programs in the future, three programs were observed using the same criteria regardless of the content of the program (*Eat Your Veggies*, *Circus Physics*, and *Avoid Detection*). The observations focused on family learning behaviors, engineering skills, and staff facilitation strategies; 54 families were observed during 32 separate programs. For more details on the method and sample, see Appendix A.

The program goal was met most of the time (79%), while the objective was reached in 98% of observations. The program goal was achieved when families worked together to solve an engineering challenge, while the objective depended on the program content (design and build a plant growth system from found items, construct a working catapult using provided materials, and construct a costume to avoid detection on an infrared camera). The difference in the success rate between the objective and the goals was due to the fact that it was possible for an individual in a group to complete the objective, but unless the family worked together, the program goal was not reached. For example, sometimes the adult did not assist their child(ren) because they became engrossed in building their own prototype. Increasing the rate at which family members work on a single prototype or product is a potential area for improvement which staff have discussed. Interestingly, one program consistently had families working together to build a single prototype, and that program met the goal much more consistently than the programs in which family members often built prototypes individually. Therefore, designing programs that encourage families to work together on a single prototype or model will meet this type of goal more often.

The open-ended format resulted in very consistent verbal participation by family members and high success in prompting adults and children to work together, as seen in the table below. Adults facilitating problem solving for children was observed to a lesser extent, but the behavior was still seen among the majority of families. This is a behavior whose metric could be improved in the future, again using the strategy of encouraging family members to work together on one product instead of working on individual products.

**Table 20. Planned Family Learning Behaviors: Open-ended Programs**

| Behaviors | Observed Rate |
|---|---|
| Family member contributes information during program (P). | 89% |
| Family members verbally and/or physically work on activity simultaneously to complete it (M). | 83% |
| Adult facilitates problem-solving (L). | 62% |

Staff were curious about the working style of family groups in more detail, so groups were categorized based on the predominate style, detailed in Table 21. It is promising to see that half of all families either worked together as equal partners (16%) or in a child-led manner (35%). It is notable that in the program which prompted families to work on a single product, **all** families worked together. By comparison, it was observed in another program that 41% of families contained at least one child working without an adult; this program allowed family members to take home their creation, so usually each child wanted to make their own. During a debrief of the evaluation results with staff, it was discussed that future program development will consider the impact take-home designs have on program goals; by creating a single final product that remains at the museum, families will be more likely to engage in teamwork rather than working on their own version.

**Table 21. Adult-Child Working Styles**

| Styles | Observed Rate |
|---|---|
| Child(ren) leading/directing the adult(s) | 35% |
| Adult(s) leading/directing the child(ren) | 24% |
| Child(ren) and adult(s) working together as equal partners | 16% |
| Family members all working alone | 10% |
| Child(ren) working alone while adult(s) work with another child(ren) | 10% |
| Child(ren) working alone without an adult present | 6% |

Because a key component of the open-ended program format is fostering the practice of various STEM skills, one anticipated STEM behavior and two indicators of a positive experience with STEM were looked for in each program. Most family members achieved one of the anticipated STEM behaviors by displaying persistence while testing and refining their prototypes (85%). Although high overall, this behavior was lower in one of the three programs; staff noted that that program was more conceptual and did not allow for actual testing and refining of the prototype, which is key to a full experience of the engineering process. Additionally, half of all families were observed announcing achievement (53%) and expressing excitement or enjoyment of the engineering process (49%). These results indicate that families were positively engaged in the engineering process.

During future program design, findings from this study will provide insight for developing programs that encourage staff-visitor interactions, promote family teamwork, and emphasize experimentation and problem-solving through STEM processes. The key recommendation for staff to consider is designing for communal projects rather than those that visitors will want to work on individually.

### *Family Robotics* Survey

The evaluation of one of the open-ended programs was selected to include family feedback via an online survey. At the end of each *Family Robotics* program, survey slips were handed out, encouraging adults to send their feedback via Survey Monkey. 36 adults completed the survey during the window of opportunity. After the program, 56% of participants described that they took away the importance of detail and trial and error in the practice of coding. Of those individuals, 57% noted the necessity of specifically coding a robot (*"We learned that we control robots and that they only do exactly what we say"*). This was followed by comments on robotics and their functioning and purpose (12%), 10% were surprised by the difficulty of the program, and 10% simply stated the program was fun and entertaining. Interestingly, 7% of adults noted that the program was overall an introduction of the concept of "trial and error" for their children. Lastly, 5% did not comment on a specific takeaway, and instead commented that it encouraged their children to continue coding and exploring robotics on their own.

Adults perceived and reported that their own interest in robotics and coding increased more than that of their child(ren) after the program (A=47%, C=38%). A number of adults stated that their children already held a high interest in robotics (44%). Concerning their interest in space exploration, findings demonstrated that adult and child responses were very similar: 32% of adults and 38% of children reported an increased interest in space. This was almost tied with those keeping a same level of high interest, (38%=A, 32%=C).

When asked whether their family continued discussion or activities about robotics and/or the space program after their visit, 56% said they were more likely to seek out other forms of

**Examples of continued interest in robotics:**

*"The instructor recommended my son the coding app "Hopscotch" and he is really enjoying it. He learned what is cording and is interested it. I really appreciate it."*

*"The boys talked about joining the robotics club at their school."*

*"My kids want a robot now and they want to follow curiosity on Twitter."*

coding and robotic activities, while 44% stated their family was already highly likely to do so. The survey was sent a week after families participated in the program, and already 45% of families reported completing some form of activity. Many of the activities were personal projects conducted primarily by the children in the group (56%). Although adults stated that for the most part their children were pursing the activity independently, 56% of the personal projects resulted in the adult looking for or purchasing a coding app or programmable robot at their child's urging. The remaining 44% continued previous activities that not only included using pre-owned robot and coding activities, but also children creating their own activities from personal supplies. The remaining 42% of responses were divided between discussions about the topic matter and sharing knowledge and experience with others.

## School Programs

### Student Observations

A total of 625 students were observed in spring 2017 during the *Coding with Robonaut* field trip program. These students were part of 24 school groups. Grade levels ranged from 3rd to 7th grade, with more than half in the 4th and 5th grade (58%). Each class was asked how many students had past experience with the coding process. 37% of students had some previous experience with coding, so this program provided a first experience with coding and software engineering for the majority of students (63%).

Overall, almost all groups (96%) were able to successfully write, test, and rewrite code to direct a robot to complete a task. Most groups (88%) worked together, while 83% of all students had the chance to manipulate the coding platform on the iPad. Observers noticed at least 17% of groups celebrating success when they completed the challenge. Overall, observations show a high level of success in engaging students and giving them first-hand experience with the coding process for robots.

### Teacher Survey

Of the 24 school groups that attended the *Coding with Robonaut* program in the StemLab, 14 teachers completed the online follow-up survey. Before the program, only 36% of teachers had taught a related activity in the classroom; of those who did, almost all covered coding and robotics. Following the program experience, most teachers (79%) intended to complete related activities in the classroom; 40% of these would continue coding projects, 30% planned to focus on NASA activities not related to the robotics program, such as rocket building projects, while various other projects (such as design and space study) made up the remaining 30%.

Teachers were also asked to reflect on how the program supported their education standards, the extent of STEM skill use, and whether participation increased student interest in STEM based careers. It was found that the program efficiently supported STEM standards for most of the teachers (91%), and 82% of teachers agreed that the program's format and content

**Examples of strengths:**

*"The students were able to use robots that are not affordable to the school. The robots were kid friendly for introducing programming. "*

*"This program was designed perfectly for the 30 students because they were all able to do hands on activities, collaborate, and information was given to them in small increments."*

complement their own curriculum. Teachers believed that students who attended were encouraged to practice STEM skills (91%), and 100% thought that their students were offered a unique experience otherwise not available. Concerning the content explored in the program, 100% of teachers stated that the program supported a positive attitude toward engineering. Most teachers believed this was an effective way to introduce their students to careers that contribute to the space program (82%), while the majority believed it increased student interest in the space program itself (73%). The combination of student observations and teacher feedback about the *Coding with Robonaut* program indicate that is is successful in providing students with a unique and positive engineering coding experience while also supporting teachers' curriculum.

# Unit of Study Outcomes

This section addresses the following evaluation questions:

1. To what extent do the project components increase participant interest in STEM topics?
2. To what extent do students have a better understanding of daily life and work aboard the ISS, including research activities, as a result of project components?
3. To what extent do students have a better understanding of the variety of STEM fields and careers that contribute to NASA's space program?
4. To what extent do project components foster positive attitudes towards engineering?
5. To what extent do students practice STEM process skills while participating in project components?

The findings for this section draw on data collected through surveys from 3rd-8th grade teachers who reviewed the curriculum, surveys from 4th-6th grade teachers who taught the curriculum to their students, and surveys and project documentation from 4th-6th grade students who participated in the curriculum in their classrooms. For more details on the methods and samples, see Appendix A.

The *Beyond Spaceship Earth* unit of study is a single booklet designed for grades 3-8 that provides an introduction to the International Space Station itself, including how it orbits the earth and generates electricity with solar panels, life and research aboard. Possible classroom experiences teachers can choose to implement with their students include:

- Experimenting with solar powered motors to learn about how the ISS generates electricity from solar panels
- Exploring rehydrating dried foods to emulate how food is packaged and prepared in space
- Growing crystals in solution to simulate ISS research
- Using the engineering design process to brainstorm a solution to a challenge of living and/or working on the ISS and build a prototype

The unit includes student handouts, background information for teachers, color photos, lists of resources, and detailed instructions including discussion prompts for each activity.

## Teacher Reviews

36 teachers, representing grades 3rd through 8th were given a copy of the unit of study. 11 taught the unit in their class, while the remaining 25 reviewed it. Grade levels taught were equally distributed. Those who taught the unit completed the same survey as those who reviewed it with additional in-depth questions about the impacts on students and their own findings.

### Fit with Academic Standards

Teachers compared the unit's content and lessons to state standards for their grade level; 45% felt it fit state standards "quite a bit" while 30% stated it fit "to a great extent". When asked to specify individual standards, teachers reported that the unit relates to most closely to the following:

- Highest ranked: Design and Engineering and Physics were cited the most in both groups.

    - Design and Engineer Process: Total= 30%; Taught = 28%; Reviewed= 30%.
    - Physics: Total= 30%, Taught=24%, Reviewed=32%.
- Others: Teachers who taught the unit focused their remaining percentages primarily in two categories: prototyping and other.
    - Prototyping, Total= 11%; Taught= 16%; Reviewed= 9%.
    - Investigation, Total= 10%; Taught= 4%; Reviewed =12%.
    - Plants, Total= 6%; Taught= 4%; Reviewed= 7%.
    - Analyze and interpret data, Total= 4%; Taught= 4%; Reviewed= 4%.
    - Space exploration and astronomy, Total= 2%; Taught= 0%; Reviewed = 3%.
    - Other, Total= 7%; Taught = 20%; Reviewed = 3%.
        - Two teachers who taught the unit stated that the lessons did not match any science standards. They taught 4th-5th grade; one explained that the unit was most beneficial as a language arts course, while the other thought it connected with some math processing standards. It should be noted that other teachers who taught the course to the same grade levels cited the course as meeting science skill standards.

Furthermore, half of all teachers (53%) said the unit fit with their typical classroom instruction or curriculum "quite a bit" or "to a great extent". The curriculum it fit best with included the solar system and space (21%), science and physics lessons (21%), and engineering and design (15%). The greatest number of teachers (43%) reported that they would be likely to use at least parts of the unit in the future, probably combining it with lessons drawn from other curriculum rather than teaching it as a stand-alone unit.

**Content Appropriate for Grade**

Because the unit was written for a wide range of grade levels, teachers were asked if the content was appropriate for their grade level as is or whether they felt the need to simplify or increase complexity for their students. The majority (61%) of teachers rated the content as being appropriate for their class. While all teachers found much of the content to be appropriate, the need to simplify or increase complexity differed predictably between the highest and lowest grade levels. Findings were as following:

- 3rd and 4th grade (n=14): 57% found the content appropriate, followed by 36% who would need to simplify the lessons.
- 5th and 6th grade (n=13): 69% found the content appropriate, with 15% indicating simplification, and another 15% wanting to increase complexity.
- 7th and 8th grade (n=10): 60% found the content appropriate, followed by 30% who would increase complexity. The remaining 10% would simplify the lessons.

This indicates that the unit's content may be most appropriate for 5th and 6th grade students but that it can also work with modest adaptations for the full range of grade levels 3rd-8th.

**Unit's Value in Teaching Science Skills to Students**

Across all grade levels, teachers agreed that the unit taught STEM skills "quite a bit" (35%) or "to a great extent" (51%). When asked to give examples of specific skills the unit supports, teachers

either described 1) specific topics (30%), or 2) scientific method components (70%) (n=76 skills described).
The specific STEM topics mentioned by teachers included:

- Engineering and design
- Model building and tool use
- Mathematics
- Measuring

Components of the scientific method/STEM process skills mentioned included:

- Analyzing and interpreting data
- Constructing explanations and designing a solution
- Posing questions and defining a problem
- Designing experiments
- Critical thinking
- Hypothesizing
- Investigations
- Collecting data

**Ease of Use**
The teachers who taught the unit in their classrooms were asked to reflect on how easy or difficult it was to implement and teach the unit. The average rank fell in between "somewhat difficult" and "mostly easy" to use with 55% indicating that it was "mostly easy" to use. Some of the aspects of the unit that teachers reported as challenging to implement included finding/affording all of the materials (50%) and a longer-than-usual preparation time.

**Unit's Ability to Increase Student Interest in Space and Develop a Positive Attitude toward STEM**
Those who taught the unit to their students were also asked to reflect on whether participation with the unit 1) increased student interest in the space program and 2) fostered positive student attitudes toward science, engineering, and NASA. Many teachers (45%) felt that the unit increased student interest in the space program "quite a bit," while an additional 45% felt student interest was increased "to a great extent." Most teachers also agreed that the unit promoted a positive attitude toward science (81%), NASA (81%), and engineering (63%).

Examples that teachers gave for increased interest and positive attitudes include:

- **Interest in NASA careers:** *"Several students are now expressing interests in working for NASA, being astronaut, engineer, etc."*
- **Continued research:** *"One student expressed how she bought a book on space. Another student talked to me about how they watched a TV program on the Space Program."*
- **Began a club:** *"I had some chose to stay after to learn more and it started an astronomy club."*
- **Excitement about model building and testing:** *"My students really enjoyed their projects and took a lot of pride in their creations."*

**Overall Strengths**

All teachers described the unit's overall strengths as part of the survey. The most commonly mentioned strengths were engaging content and activities (37%), and design (25%). A few teachers also mentioned relevant content (16%), alignment with standards (14%), and provided resources (8%). Teachers found the unit to be interesting and informative for all involved. Teachers were in agreement that the BSE unit contained content and imagery that "really piqued the students interest" while also "bringing attention and interest to the ISS; some…kids didn't know it existed."

**Examples of Unit strengths:**

*"This unit includes engaging investigations."*

*"This unit is based on cutting-edge science for NASA. Students are more engaged, their imaginations allowed to be a part of the learning…knowing that NASA…knowledge is ever changing, we are all learning new things."*

**Areas for Improvement**

Although the hands-on experiences and activities were praised by teachers, some ran into financial and time constraints (30%). As one teacher said, "many of the experiments need a lot of equipment that I do not have," and also, "many of the experiments take longer than the time that I have." Other teachers felt the unit suffered from lack of information. One felt that it "assume[d the] teacher is familiar with the ISS", while others desired more premade materials for the students: "I would have also liked to have seen just a student booklet with specific steps they have to complete."

Many suggestions related to developing an online element to the unit including templates for activities and worksheets, online resources, copies of content and direct links to websites and videos (48%).[3] A few teachers suggested creating multiple units that were tailored for different grade levels (13%), with an additional 16% asking for "directions on equity for all students—challenges for gifted and talented students and modifications in scaffolds." Most teachers who taught the unit (82%) did augment the unit in some way, primarily by including online resources (videos, articles, and NASA sites—67%), and having preparatory lessons and activities for their students (28%). The examples they gave will be considered for inclusion in future versions of the unit, which will remain freely available on the Museum's website for years to come.

**Unit Quality Compared to Others and Likelihood of Future Use**

When comparing the BSE unit to other freely available curriculum they had experienced, most teachers (88%) stated it was "higher quality" than other science units. In correlation with the overwhelmingly positive rating of the unit, teachers found it "a much better, cohesive unit than…seen anywhere else." When asked their likelihood of using the curriculum in the future, 54% of teachers were very likely to use half or more of the unit, followed by 40% who would use a couple of experiences in their class. Those who only reviewed the unit were more likely to predict that they would use a couple of the experiences (54%), whereas almost all teachers (90%)

**88%**

**of teachers think the BSE unit of study is higher quality than other freely available curriculum.**

[3] Some of these resources do exist on the Museum website, but teachers may not have been aware because they were mailed a hardcopy of the curriculum.

who actually taught the unit were very likely to use half or more of the unit in the future. This suggests that once a teacher integrates the unit into their curriculum they are likely to continue to use it in later years.

Overall, teacher reviews of the unit of study for *Beyond Spaceship Earth* demonstrated that the curriculum connects to state standards and regular classroom curriculum is successful in teaching science content and STEM process skills, increases student interest in the space program, and is perceived by teachers to be of high quality and relatively easy to use.

## Student Learning Outcomes

In order to better understand the outcomes of participating in the unit's activities, students whose teachers used the unit of study in their classrooms completed surveys that asked a combination of content and attitudinal questions. Student products from a culminating engineering design group project were also reviewed. A total of 324 students in 4th-6th grade taught by 10 different teachers completed surveys.

**Challenges and Value of Living in Space**

Most students (84%) who completed the curriculum knew that there are astronauts currently living on the ISS; this is considerably higher than youth interviewed at the museum. Student perceptions of the value of sending astronauts to live in space included the following main reasons:

- Exploring space (29%)
- Scientific experiments and understanding microgravity (25%)
- Understanding how humans live and survive in space (17%)

One of the main content outcomes for both visitors to the exhibit and for student who experience the unit of study is to understand some of the challenges of living in space and how those challenges have been overcome. Students were asked to provide two examples of challenges to living in space. Almost all students (97%) could provide two examples of challenges. The most common responses fell into the categories of physical health/hygiene, gravity, and food/supplies (described below). Challenges mentioned less often included risk (14%), personal mental state and entertainment (7%), and oxygen and environment (5%).

1. Physical health/hygiene (26%): Students referenced challenges for staying clean, "It's hard to brush your teeth," using the restroom, "Using the bathroom without it floating in the air," and remaining healthy, "Staying healthy and strong." Half (52%) of all comments in this category reference difficulty in exercising and staying fit. For example, some responses are basic, "working out," while others directly referenced issues such as muscle deterioration, "Your muscles can weaken."
2. Gravity (24%): This included general comments about the difficulty of moving and floating in space, but also direct references to microgravity/no gravity.
3. Food/supplies (21%): Mentions of food were usually linked to issues of eating; supplies often referred to limited food and astronauts' dependence on deliveries.

After listing two challenges, students were asked to explain how one of them had been overcome. Almost all students (89%) provided a reasonable response. Half of responses (55%) fell into one of the two following categories:

1) Physical health/hygiene (32%): 77% of solutions from this category were about exercise.
2) Food/supplies (23%): 88% of answers in this category were solutions to food quality, consumption, and storage.

Interestingly, 10% of all answers were not solutions, but instead comments that "there is no solution," or examples of how astronauts have adapted to conditions. For example, "Microgravity has not been overcome but [they] do experiments to see how things work and get used to them," and "They float around instead of walking." The responses students gave to these two questions indicate that the majority (62%) have a basic, if not advanced, understanding of how at least one challenge to working in space has been overcome.

**Student Projects: Challenges and Solutions**

78 projects and/or project summaries were returned by 10 teachers. Each project was reviewed using three criteria: 1) What challenge did the project address?, 2) Did students conceptualize a viable solution to that challenge?, and 3) Was the prototype new/useful?

1) What challenge did students address? Projects generally fell into 5 categories (n=77):
    - ISS structure and EVA's (45%): Students from multiple classes created prototypes to assist astronauts inside and outside the ISS. Several inventions for the interior of the ISS (e.g., a "gravity box," or a glass dome expansion for cosmetic reasons) were not necessary for survival or research work; while an air-leak detector was noted as innovative. Clothing was incorporated into this category after a group proposed magnetic boots for maneuverability in and outside the ISS, and another created a vacuum-style dryer for clothing. Students focused largely on maneuvering and working outside the ISS; developing safety measures for the astronauts on EVA's (i.e. a separate pod for traveling outside the ISS, a tether magnet, and Kevlar shield cage). Spacesuit function was explored by several groups, including improved maneuverability: "Gloves molded around astronauts hand. Has built in light, radio, and GPS," and health and safety, "Water supply in space suit...can drink out of while doing a spacewalk."
    - Health and Sanitation (17%): Sanitation interest was focused primarily on students considering new ways to shower. A novel prototype was a "shower that uses vents to suck water down and over the person's body. It then has vents above to take in the excess water and soap when person is done. A dryer removes excess water." One class focused on health-based projects, with more than half of the class addressing the storage of deceased astronauts. While most health prototypes were innovative or new, only half are possible to create or necessary. Projects of note were a portable x-ray machine, a Velcro-covered mat for practicing yoga, and a process for freezing a deceased astronaut.
    - Food and Drinks (14%): Food and drink prototypes tended to be unnecessary or reproduced current technology. Two projects were novel; one group designed a gasless rocket for transporting food, the other proposed attaching a terrarium module dedicated to growing fresh foods. They demonstrated understanding of current issues faced by astronauts and solutions that are in line with current scientific research (clean energy and self- sustainable farming).
    - Safety (12%): While certainly creative, none of these projects were considered new or innovative; the majority (62%) were unnecessary (e.g., "gun to destroy asteroid

that will cause human extinction") or scientifically impossible to create (e.g., "A mask that relies on electromagnetic waves to create oxygen for astronauts").

- Other (12%): Several groups created different beds; an issue that has already been adequately solved. Some groups addressed boredom, for example with a magnetic game board. One group showed comprehension from a class experiment (not found in the unit) by creating a "bait and box to catch…a loose [fruit] fly."

2) Did they come up with a viable solution to the challenge? Overall, 74% of all projects had a reasonable/non-imaginary solution to the stated problem. The remaining solutions either defied laws of physics (i.e., making oxygen from electromagnetic waves, adding a room to the ISS that would have gravity) or did not demonstrate full understanding of the source of the challenge (i.e., taking livestock to the ISS so that astronauts will have more fresh food ignores the issues related to rocket fuel consumption, not to mention the numerous challenges that would arise with attempting butchery in microgravity).
3) Is the prototype new/useful? One-third of group projects (36%) were either unnecessary—like a makeup vanity—or the prototypes would not be physically possible to build—a wheel to move the ISS in case of asteroid. Close to one-third (29%) of projects tackled challenges that have already been adequately solved and do not require new solutions. The other third (35%) did tackle an unsolved or new challenge or significantly improved upon an old design and therefore demonstrated an advanced understanding of the demands for life and work on the ISS and a creative solution to an existing problem.

Similar to the survey responses, the projects indicate that most students completed the unit of study with at least a basic awareness of challenges of living and working in space. When prompted to develop their own solutions to a challenge, some student solutions were in the realm of science fiction, but the majority of students used the engineering design process to develop a reasonable solution, and several projects were very innovative and showed a nuanced understanding of the nature of life and work on the ISS.

**Science Research on the ISS and NASA Careers**

Another main goal of the BSE project is for participants to gain awareness of scientific research that is conducted on the International Space Station; the unit of study contains information about multiple different experiments and why they are conducted on the ISS. Just over half of students (56%) reported learning about experiments on the ISS. Life science topics (plants and animals) made up 50% of all studies students reported. Interestingly, 31% of student responses came from experiments not found in the unit (such as animals/insects), indicating that this was an area where teachers augmented the content.

Almost all students (96%) reported learning about careers in the space program besides astronaut. Careers listed fell into 4 overarching categories:

1. Engineer and Designer (36%): This included designers of spacecrafts and those who repair them.
2. Scientist (34%): Scientists, mathematicians, and nutritionists were categorized together.
3. Mission Control (11%): Not only did students reference mission control, they also specified those who worked with computers and did communication jobs.
4. Other (14%): Other careers included doctors, recovery crew, trainers, etc.

Additionally, students reported learning from the activities in the unit about daily life on the ISS (i.e, exercise, sleep, experiments) (52%), food creation and consumption (18%), mobility in microgravity (11%), and general information about astronauts (15%).

**What are students still curious about?**

Almost all students (93%) demonstrated ongoing curiosity about NASA and the space program (Figure 10). Points of interest/ questions fell into the following categories:

1) The International Space Station and Living in Space (49%): Students not only wanted to know more about what it's like to live in space, but also more about the station itself. This also includes questions about food in space, and also how astronauts spend their free time.
2) Health and Hygiene (16%): Students were primarily interested in how astronauts shower and use a toilet in microgravity.
3) Remaining areas of interest range across 5 topics: Five additional topics were all mentioned by 8% or less of student taking the survey. These topics were: EVA's and Risk, Gravity and microgravity, Space and other planets, and Experiments.

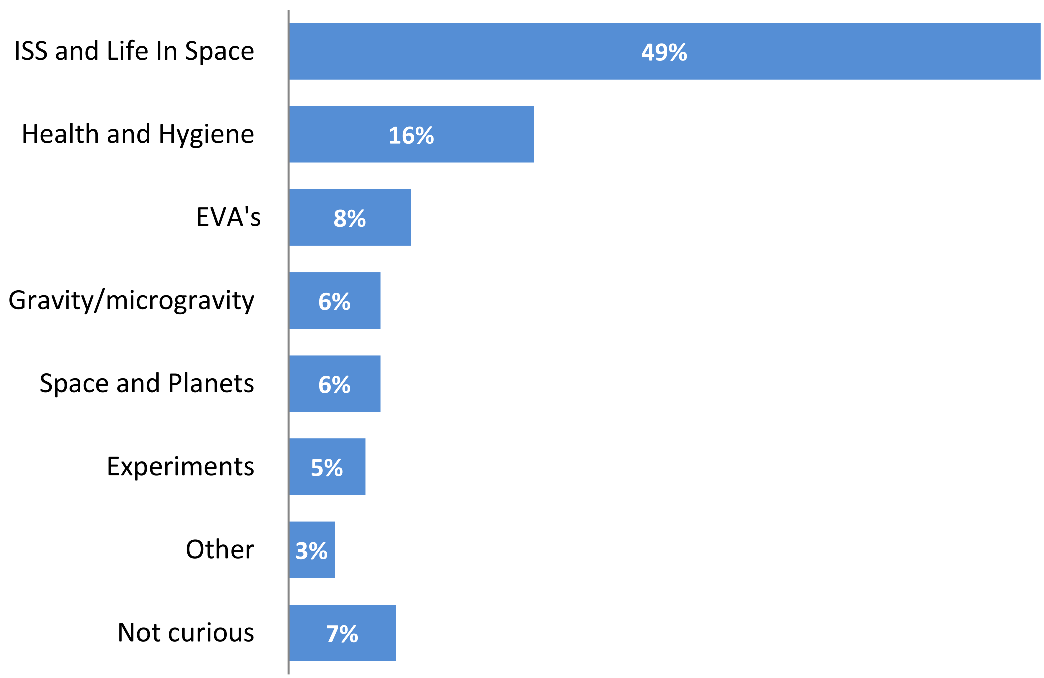
**Examples of curiosity:**

*"I wonder how they built the ISS out in Space."*

*"…what a full day on the ISS would feel like."*

*"How do astronauts change physically in space after a time period?"*

**Figure 10. Most students (93%) remain curious about life on the ISS and would still like to learn more**




When asked about their level of interest in space and NASA, many students indicated that they maintained the same high level of interest as before participating in the unit of study, but over half (56%) of those surveyed are now **more** interested in space and NASA (see Figure 10). Furthermore, 44% of students reported that their current career interest [when they grow up] is

STEM-related. When asked if they enjoyed doing the engineering project, students indicated they did like the project; the majority of students (65%) also reported that they would be quite interested in doing another similar project. These responses regarding interest and ongoing curiosity about the topics demonstrate that the unit of study is both supporting existing interest and increasing interest in the space program and engineering design process among youth.

# Overall Project Goals

This section compares project goals across all project components (which are covered in detail in each of the previous report sections). The data is drawn from the evaluation activities described in previous sections and in Appendix A and includes data from the same subset of questions that was posed to participants across several different project activities.

Although no single project component meets all of the goals on its own, when the components of the BSE project are taken together as a whole, nearly all project goals are met. The one goal that is met to a lesser extent than the others is related to science research on the ISS; while the topic is highlighted in a couple exhibit elements and addressed in a passing way in some programs, it is the sole focus of just one gallery program. As a result, fewer visitors are exposed to the goal of science research on the ISS as compared to the other project goals which are covered more extensively. The science research goal is being met to a greater extent among students who participate in the unit of study in their classrooms. In Table 22, green indicates a goal is being met to a high extent, yellow means the goal is being met to some extent but not as highly, and white indicates a goal is being met to little or no extent.

**Table 22. All project goals were met through at least two BSE activities, and a few are met across all activities.**

| Project Goals | ISS Exhibit | Space Object Theater* | STEMLab Programs | Unit of Study |
|---|---|---|---|---|
| Increase interest in space exploration | | | | |
| Increase interest in engineering | | | | |
| Understand daily life on the ISS | | | | |
| Understand challenges of living and working in space | | | | |
| Aware of science research on the ISS | | | | |
| Aware of range of careers that contribute to space exploration | | | | |
| Have a positive experience with engineering | | | | |

*The Schaefer Planetarium and Space Object Theater was not funded in any part by the NASA award NNX14AD06A, but all other project components did receive all or partial funding from that award.

The table above also demonstrates that for the BSE project, goals related to engineering were better achieved in program formats, while daily life on the ISS is best conveyed through the highly immersive exhibit. Visitors learned about challenges of living and working in space through all project components.

# Conclusions and Recommendations

Taken as a whole, *Beyond Spaceship Earth* meets the goals set by the Experience Development and Family Learning Division and described in the grant proposals. Observation data in the ISS exhibit demonstrate visitors' use of elements throughout the gallery coupled with a very long gallery stay time given its relatively small size. The analysis of family learning data show the gallery supports a range of family learning behaviors, including adult-child participation, collaboration, and conversations focused on using elements and label reading.

Likewise, evaluation of programs in both the exhibit and the STEMLab demonstrate a consistent ability to achieve planned metrics using a wide variety of facilitation techniques, from first-person characters to open-ended engineering challenges. The classroom curriculum made freely available to teachers has been found to meet both its content learning goals and to support and increase student interest in the space program while being perceived as high quality by teachers who have used it.

Data from interviews and surveys with families reveal that the gallery and programming support content acquisition focused on awareness of living and working in space and STEM careers, provide positive experiences with engineering, and support and increase interest in the space program and STEM in general, which extends beyond the museum visit.

## Recommendations

The summative evaluation findings do not suggest that any significant changes to the operation of individual elements or the gallery layout are necessary. One recommendation based on the findings from the in-depth evaluation of the iPad games is that the Coding Robonaut game, which currently is only available for download as part of the BSE app, be added to the gallery if space allows (or another game needs to be replaced) because of its success in fostering critical thinking skills and introducing children to aspects of basic computer coding.

If a traveling version of the exhibit were ever produced, staff are encouraged to consider the following recommendations:

- Where possible, include theming that emulates the immersive nature of the permanent exhibit to give visitors a sense of standing in the space station.
- Include more than one example of research and experiments conducted on the ISS with simulated activities for visitors.
- Offer a combination of both high- and low-tech interactives to convey information and experiences related to living and working in space; highly successful interactives in the permanent exhibit include weightlifting (low-tech), Canadarm game (high-tech), veggie activity (low-tech), and pretend play areas.
- Add the Coding Robonaut game or an element that leads visitors through the engineering design process to increase the potential of the exhibit to introduce visitors to engineering (this outcome is addressed mainly through programming in the current BSE project).

- Include an exhibit section with hands-on activities that goes into more detail about jobs held by people whose work directly supports the space program from the ground.

Detailed recommendations for individual gallery and STEMLab programs and the unit of study are included in the body of the report. Overarching areas for improvement are few but include:

- Consider developing more gallery programs that focus on project goals that are not being strongly met by the exhibit alone, including science research aboard the ISS and exploration of the variety of careers and disciplines that contribute to the space program from the ground.
- Continue to improve on the rate of adult engagement strategies in all gallery programs.
- Implement the truly open-ended version of an engineering challenge program when it makes sense for the family group to work together on building a single prototype. This will increase the success of those programs in terms of family learning behaviors. In situations where it makes most sense for each visitor to work more individually, use a more close-ended structure and employ existing strategies for prompting family learning behaviors.
- Develop a resource landing page for each unit of study on the museum website with active links to videos and other online resources for teachers. Provide editable versions of student worksheets for download when possible to make it easier for teachers to adapt materials.

# APPENDIX A: Description of Methods

## Tracking and Timing

A total of 51 tracking and timing observations were conducted as part of the summative evaluation. Data were collected between August and October 2016 on both weekend days and weekdays by members of the R&E department. Data collectors displayed a sign near the gallery entrance and selected the next family that was entering the gallery. Families were approached by the data collector and asked for their consent to participate in the tracking study (i.e., the family was cued). With the consent of an adult in the group, the data collector started audio recording details of the family's visit.

One child within the group was selected to be the primary child. In families with multiple children, if one child appeared to be older than 4 years old, this child was selected. In families where 1) the children appeared to be the same age, 2) all children were over 4 years, or 3) all children were 4 years or younger, the primary child was selected at random. All data that was collected was tied to the behavior of the primary child. Data collected included group demographics, crowd level in the gallery, the overall time spent in the gallery, the time the primary child spent at each element at which they stopped, a narrative description of family interactions at element stops, and the path taken through the gallery. If the primary child separated from other group members, the data collector continued to track the primary child.

Tracking and timing data were entered into FLARE, a custom-built dashboard for tracking and timing data entry and analysis. The audio recording of the in-depth observations were transcribed, saved in FLARE, and coded in FLARE. The ALFIE Inventory of family learning behaviors was used to code family learning interactions between the primary child and adult family members. Once entered into FLARE, all data were compiled into Excel reports and analyzed using descriptive and inferential statistics where necessary.

For the 51 families observed, the average number of people per family was 3.9. The typical group contained one or two adults and two children (average number of adults per family=1.6; average number of children per family=2.3). The age distribution of the primary children was as follows: 0% were between 0 and 2 years, 10% were 3 to 5 years old, 37% were between 6 and 8 years, 45% were 9 to 12 years, and 8% were between 13 and 18 years. Observations were split almost evenly between boys and girls as the primary child (53% male and 47% female). The tracking and timing observations were distributed across busy and light visitation days, with 17% of the observations occurring when the gallery was crowded, 61% when it was moderately busy, and 25% when the crowd level was low.

## Feedback Wall

A participatory evaluation technique, a feedback wall, was used to gather visitor data on new learning resulting from a visit to the gallery. Data were collected on two days in October 2016 during fall break by R&E staff and interns. Families exiting the gallery were asked to tell data collectors "one new thing you learned" from visiting the gallery. Data collectors wrote the answer, usually one word or a short phrase, on a sticky note shaped like a star and then invited the visitor who contributed to stick the star on a portable whiteboard. The whiteboard was situated facing the gallery exit so passing visitors could see the contributions. Once data collection was complete, the responses were removed from the whiteboard, entered into Excel, and analyzed for common themes. A total of 135 responses (i.e., stars) were collected from visitors.

## Gallery Exit Interviews

As part of the summative evaluation of the BSE ISS exhibit, evaluators interviewed families exiting the gallery to learn more about 1) families' perceptions of the gallery concepts, 2) families' experience visiting the gallery, and 3) the degree to which the gallery met its goals. The interviews used a standard set of questions and were conducted in October and November of 2016. Adults with at least one child in the gallery's target age range (i.e., 4 years or older) were continuously sampled as they exited the gallery. Questions were directed to adults and children, and all members of the group were encouraged to participate in the interview. All data were entered into Excel for coding and analysis.

A total of 50 families were interviewed. In these 50 groups, the average number of children per family was 2. Slightly more of the adult interviewees were female (63%) and 50% were in their 40s. Half of those interviewed were members (53%) and only 28% of interviewees had visited the ISS exhibit before. Considering all the children in the sample, 53% were in the 6-12 age range; 38% of families did include at least one child under the age of 5.

A second short interview was conducted with families exiting the galley to learn more about 1) prior visitation to the gallery, 2) staff interaction and location, and 3) the extent to which various topics were addressed in the gallery. The interviews used a standard set of questions and were conducted in March and May 2017 during mornings and afternoons. Adults with at least one child in the gallery's target age range were continuously sampled as they exited the gallery. Questions were directed to adults only. All data were then entered into Excel for coding and analysis. A total of 50 families were interviewed, with an average of 2 children per family. Many of children (53%) were between the ages 6 and 12.

## Child Awareness Post Opening Interviews

Evaluators interviewed children in both family and school groups within the gallery's target age range as they exited the galley. 100 children were asked NASA-focused questions, while another 100 were asked about the ISS. Questions were in the same format, asking if they 1) Had heard of NASA/Are there humans living in space and 2) What NASA does/Where are they living. The first question was close-ended, while the second was open-ended. The second question was only asked if a child responded "yes" to the first. Interviews were conducted throughout the Spring of 2017 during mornings and afternoons. To minimize children repeating what another said (typically a younger child repeating the older) the youngest child was interviewed first. When necessary, and based on the evaluator's judgement, school group responses were recorded as a sum instead of individually. All data were entered into Excel for coding and initial analysis. Findings were compared to data from a set of similar interviews collected before the gallery was opened to determine the extent to which gallery visitation increased awareness of these topics.

## Longitudinal Family Surveys

During October 2016, visitors who watched shows in the Schaefer Planetarium and Space Object Theater, and therefore also visited the ISS exhibit, were invited to leave their email address and contacted with an online survey about one week after their visit. All individuals who completed the survey were sent a $5 Amazon gift card as a small incentive. The purpose of the surveys was to determine the extent to which the experience increased knowledge of and interest in the space program and what, if anything, families had done related to the gallery since their visit. Data from Survey Monkey were exported into an Excel database for analysis. 110 adults completed the survey.

## Program Observations

Interactions between family visitors and museum staff were observed in two settings: gallery programs and STEMLab programs. The observation method and sample for each program type are described below.

**Gallery programs:** Three gallery programs offered in *Beyond Spaceship Earth* were selected for observation in order to measure the success of each program in achieving its goals and planned family learning metrics:

- *ISS Cosmonaut:* Led by Actor Interpreters, this informal program features a Russian Cosmonaut who lives and works on the International Space Station. Visitors interact with the Cosmonaut, engaging in various topics of discussion such as: living in space, daily upkeep of the space station, work done on the ISS, and different people involved in the work or development of the ISS. Data was collected in Spring and Fall 2017 by Rachael Mathews, Interpretation Program Developer/Evaluator, Claire Thoma Emmons, Evaluation Research Coordinator, Mary Mauer, Research Assistant for Research and Evaluation, Josh Estes, Interpretation Manager, and Interpretation Staff/Managers.
- *Up Close and Personal: Astronaut in Training:* Led by Gallery Facilitators, this formal program introduces families to one of three different content themes: Food in Space, Space Walks, and Space Experiments. Staff presented an interactive program to visitors that stimulates problem-solving, inquiry methods, and the comparing and contrasting of experiences with new ideas, technologies, and procedures being utilized on the ISS. Data was collected between March and April 2017 by Rachael Mathews, Interpretation Program Developer/Evaluator, Mary Mauer, Research Assistant for Research and Evaluation, Josh Estes, Interpretation Manager, and Interpretation Staff/Managers.
- *Robots in Space:* Led by Gallery Facilitators, this formal program introduces visitors to the Canadarm2, as well as other robots on the ISS. Program methods and goals coincide with those for the Up Close and Personal Program. Data was collected between March and April 2017 by Rachael Mathews, Interpretation Program Developer/Evaluator, Mary Mauer, Research Assistant for Research and Evaluation, Josh Estes, Interpretation Manager, and Interpretation Staff/Managers.

A total of 101 families were observed taking part in these programs: 73 during *Cosmonaut,* 26 during *Robots in Space*, and 33 during *Astronaut in Training*. For each program, observers focused on one family with a child in the gallery's target age range. Using an observation form designed to follow the program's one sheet, the data collector indicated whether planned family learning behaviors, program goals, and program objectives were achieved along with examples. In cases where the family left the program before it was finished, the data collection also ended. The groups included a total of 269 children and 182 adults. The majority of children (73%) were estimated to be between the ages of 3 and 9. Most of the adults in the families observed were female (126 women compared to 58 men), and the same amount of girls (135) as boys (134) were observed taking part in the programs.

**STEMLab Programs:** Five programs offered in *ScienceWorks* STEMLab were selected for observation. Three were NASA-based, while the remaining two (*Circus Physics* and *Avoid Detection)* were created at the same time and with the same format as the NASA program *Eat Your Veggies.* Four of the five programs are available to families; the fifth is offered to school groups only. The purpose of this evaluation was to measure the programs' success in achieving their STEM goals and planned family learning metrics:

- *Out of This World Engineering:* Led by Actor Interpreters, this program features a NASA engineer named "Eddy". Visitors are introduced to the steps of the engineering method and work together to improve a common household item for use on the ISS. Data was collected between February and July 2017 by Claire Thoma Emmons, Evaluation Research Coordinator, and Mary Mauer, Research Assistant for Research and Evaluation.
- *Circus Physics, Eat Your Veggies,* and *Avoid Detection*: Led by STEMLab Science Educators, these formal programs lead families through an engineering challenge for one of three different topics: catapults, plant growth in space, and infrared-proof materials. Staff presented an open-ended program to visitors that stimulates problem-solving, teamwork, and utilization of STEM skills with the creation of an engineered prototype. Data was collected during October 2017 by Claire Thoma Emmons, Evaluation Research Coordinator, Becky Wolfe, Manager for Science Education and Resources, Mary Mauer, Research Assistant for Research and Evaluation, and one STEMLab intern.
- *Robots in Space School Program:* Led by STEMLab Science Educators, this formal program introduces school groups to robots in space by exploring robotic coding and the process of software engineering. Staff presented a guided program to visitors that stimulates problem-solving, teamwork, and utilization of STEM skills by coding simple robots to complete a challenge. Data was collected between January and May 2017 by Claire Thoma Emmons, Evaluation Research Coordinator, and Mary Mauer, Research Assistant for Research and Evaluation.

A total of 85 families and 24 school groups were observed taking part in these programs: 30 families in *Out of This World Engineering*, 24 families in *Circus Physics,* 14 families in *Eat Your Veggies,* 17 families in *Avoid Detection*, and 24 school groups in *Robots in Space*. For each family-based program, observers focused on two families with a child in the program's target age range. *Robots in Space* observations focused on the entire school group. Using an observation form designed to follow the program's one sheet, the data collector indicated whether planned family learning behaviors, program goals, observable STEM skills, and program objectives were achieved along with examples. In cases where the family left the program before it was finished, the data collection also ended. *Out of This World Engineering* observations were followed by an interview of one observed family. The majority (74%) of families interviewed reported that this was the first time they attended a program in either the original or the renovated STEMLab, and half of families (52%) were visiting the museum for the first time. Despite the high number of first-time visitors, two thirds (67%) of families had already visited the *Beyond Spaceship Earth* exhibit before this program. Observation data were entered into Excel and analyzed using descriptive statistics.

The 85 families observed for this portion of the study included a total of 216 children and 158 adults. The average family size was 3 individuals. Families observed were typically composed of 1 adult and 2 children. The majority of children (72%) were estimated to be within the target age range for the programming (ages 8 and older). Many of the adults in the families observed were women (92 women compared to 66 men; although the split was even in *Out of This World Engineering*), and an even number of boys and girls were observed (112 and 104 respectively). Programs typically held 4 family groups. For the 27 families interviewed after the *Out of This World Engineering* program, most were parents with their children (78%). Most children were between ages 6 and12. Additionally, families who attended a program introducing coding and robotics were invited to leave their emails at the end of the program and were sent an online survey about one week after their visit. A small incentive ($5 Amazon gift card) was sent to every family who completed the survey, which focused on the extent to which families perceived the content goals of the program and queried whether there had been any extension of the program experience after the museum visit. 35 families completed this survey.

The 24 schools observed included 625 children and were nearly divided equally between genders (298 being female and 362 male). Grade levels ranged from 3$^{rd}$ to 8$^{th}$ grade with many in the 4$^{th}$ and 5$^{th}$ grade (58%). The teachers of these classes were emailed a follow-up survey about two weeks after their field trip and offered a small incentive ($5 Amazon gift card) for providing feedback about the quality of the program and extent to which intended student outcomes were met. 14 teachers completed the survey about the *Robots in Space* program. Additionally, teachers who brought their students to see shows about Liberty Bell 7 in the space object theater were also sent a follow-up survey 1-2 weeks after their field trip to determine the extent to which the renovated planetarium, which now offers a much smaller set of show options to school groups, was meeting their needs and expectations. 20 teachers completed the survey about space object theater shows.

### Unit Methods

Fifty-five teachers initially volunteered to participate in a study focused on the quality of a new unit of study about astronaut life and research aboard the International Space Station that was created in conjunction with the gallery *Beyond Spaceship Earth*. Forty teachers were invited to review the content of the unit and share their thoughts and opinions through a survey. The remaining fifteen were asked to teach 6 lessons in their classroom and return a completed survey, student surveys, and student documentation from the unit's final activity. An incentive ($25 Amazon gift card for teachers who reviewed the unit, and $100 Amazon gift card for those who taught it) was offered. All teachers were given a deadline of June 1, 2017.

### Surveys

Those who taught the unit completed the same survey as those who reviewed with an addition of in-depth questions about the courses impact on students and their own findings. Ultimately, 36 teachers, teaching grades 3rd through 8th agreed to participate and were given a copy of the unit. In the end, 11 teachers taught the unit in their class, and 25 reviewed it.

Student surveys included 324 students from 10 teachers, ranging from the 4th to 6th grade. Gender of students was nearly equal with 169 males and 154 females. Surveys included open and close-ended questions and ranking scales. After being entered into Excel, evaluators analyzed responses using descriptive statistics to determine student comprehension of the unit content and their interest in STEM and NASA careers.

### Student Projects

The final lesson of the unit required students to create a prototype that can assist astronauts living on the ISS. The purpose of project analysis was to determine student comprehension of the everyday challenges faced by astronauts and their ability to use STEM problem solving skills. 10 teachers returned documentation in the form of emails, photographs, video presentations, written summaries, and student reports. Evaluators entered the data into excel with final analysis of each project on three criteria: 1) What challenge did the prototype address? 2) Was it a viable solution to a challenge? 3) Is the prototype useful? One project was eliminated from the analysis; the group never formed a concept and did not complete any of the project steps.

# APPENDIX B: Full Element List by Area

This is a comprehensive list of areas and elements in BSE. Exhibit area titles are bold and left justified.  Elements are marked with solid bullets; in the timing and tracking, elements were timed and had ALFIE social interactions assigned to them. Additionally, an asterisk (*) is used to mark the "thematic action-task areas" or "ta-tas" in the gallery. A ta-ta is an element that combines multiple dissimilar features into one unified element on the basis of its theme. In BSE, the only "ta-ta" was the Sleeping Quarters alcove, which combined a display case, environmental touchables, and a mock sleeping bag that visitors can get inside.

**ISS Interior**

- Interior environment & theming
- Welcome Aboard label
- How do Astronauts get to ISS label
- Lower Your Visor activity & labels
- Sunglasses display case
- Clean a Spill iPad
- Microgravity label & video
- Staying Fit in Space label & video
- Weightlifting label & activity
- Exercise iPad
- What's for Dinner labels, display case, & audio
- Velcro label & activity
- Mission Patches display case
- Sleeping quarters alcove & display case*
- What to Wear label & drawers
- Chores label & crawlspace
- Tend the Plants iPad
- Veggie label & activity
- Bioreactor label & activity
- Cupola label, video, & spinner
- Costume hooks (cupola)

**Spacewalk Exterior**

- Exterior environment & theming
- EVA pretend play area
- Finding Your Way Around label
- Spacewalk iPad
- Truss
- Hubble video & label

- Glove boxes & labels
- Costume hooks (gloves)
- Canadarm game
- Soyuz capsule & label

**Indiana Astronaut Wall of Fame**

- Aviation & Engineering Labels
- Wall with display cases, touchscreens, and pictures
- Biology & Astrophysics Labels

**Planetarium Vestibule**

- Authors display case
- Star Trek display case
- Robots & Spaceships display case
- Queue line

**Dome**

- Liberty Bell 7 & labels
- Mercury Suit display case
- Grissom display case
- Rocket display case
- Glass display case
- Seats

# APPENDIX C: Element Stop & Stay Time Details

**Table C1.** ***Beyond Spaceship Earth*** **Element Capture Rates, indicating the % of families who stopped at each exhibit element (n=51 families)**

| Element | Percent of Families stopping at element (n=51) | Number of families stopping at the element (n=51) | Number of stops at the element (including multiple stops by same family) |
|---|---|---|---|
| EVA pretend play area | 78% | 40 | 44 |
| Canadarm game | 75% | 38 | 71 |
| Truss | 75% | 38 | 44 |
| Weightlifting label & activity | 75% | 38 | 42 |
| Glove boxes & labels | 73% | 37 | 54 |
| Lower Your Visor activity & labels | 71% | 36 | 42 |
| Chores label & crawlspace | 67% | 34 | 40 |
| What's for Dinner case & audio | 63% | 32 | 35 |
| Soyuz capsule | 61% | 31 | 37 |
| Costume hooks (cupola side) | 59% | 30 | 36 |
| Sleeping quarters alcove | 59% | 30 | 35 |
| Cupola | 55% | 28 | 34 |
| Space object Theater Show | 49% | 25 | 25 |
| IN Astronaut Wall of Fame | 47% | 24 | 24 |
| What to Wear drawers | 47% | 24 | 25 |
| Spacewalk iPad | 43% | 22 | 23 |
| Exercise iPad | 43% | 22 | 26 |
| Robots & Spaceships case | 41% | 21 | 27 |
| Staying Fit in Space video | 41% | 21 | 25 |
| Veggie label & activity | 39% | 20 | 27 |
| Bioreactor label & activity | 39% | 20 | 24 |
| Vacuum Up Fluids iPad | 37% | 19 | 21 |
| Liberty Bell 7 capsule | 35% | 18 | 31 |
| Authors display case | 29% | 15 | 21 |
| Velcro activity | 27% | 14 | 16 |
| Tend the Plants iPad | 25% | 13 | 14 |
| Microgravity video | 25% | 13 | 14 |
| Star Trek display case | 25% | 13 | 15 |
| Rocket display case | 22% | 11 | 12 |
| Grissom display case | 20% | 10 | 12 |
| Hubble video | 18% | 9 | 10 |
| Mercury Suit display case | 18% | 9 | 11 |
| Glass display case | 14% | 7 | 9 |
| Mission Patches display case | 12% | 6 | 6 |
| Finding Your Way Around label | 8% | 4 | 4 |

| | | | |
|---|---|---|---|
| Sunglasses display case | 6% | 3 | 3 |
| Costume hooks (glove box side) | 4% | 2 | 3 |
| Welcome Aboard label | 2% | 1 | 1 |
| Biology & Astrophysics labels | 2% | 1 | 1 |
| Aviation & Engineering labels | 2% | 1 | 1 |
| How do Astronauts get to ISS label | 2% | 1 | 1 |

**Table C2. *Beyond Spaceship Earth* Average Stay Times for All Elements (n=51 families)**

| Element | Average Stay Time* |
|---|---|
| Space Object Theater Show | 22 min 20 sec |
| Welcome Aboard label | 2 min 4 sec** |
| IN Astronaut Wall of Fame | 1 min 50 sec |
| Spacewalk iPad | 1 min 45 sec |
| Biology & Astrophysics labels | 1 min 43 sec** |
| Canadarm game | 1 min 27 sec |
| Soyuz capsule | 1 min 16 sec |
| EVA pretend play area | 1 min 12 sec |
| Exercise iPad | 1 min 11 sec |
| Chores crawlspace | 52 |
| Veggie activity | 51 |
| Clean a Spill iPad | 51 |
| Glove boxes | 49 |
| Velcro activity | 49 |
| What's for Dinner case & audio | 48 |
| Liberty Bell 7 capsule | 40 |
| Hubble video | 39 |
| Truss | 38 |
| Tend the Plants iPad | 38 |
| Glass display case | 38 |
| Weightlifting activity | 37 |
| Lower Your Visor activity & labels | 37 |
| Costume hooks (cupola side) | 35 |
| Bioreactor activity | 35 |
| Sleeping quarters alcove | 34 |
| Rocket display case | 32 |
| Robots & Spaceships display case | 31 |
| Costume hooks (glove box side) | 31 |
| Finding Your Way Around label | 27 |
| Microgravity video | 26 |
| Cupola | 25 |
| Authors display case | 23 |
| Grissom display case | 22 |

| | |
|---|---|
| Staying Fit in Space video | 19 |
| Mission Patches display case | 18 |
| Aviation & Engineering labels | 16 |
| What to Wear drawers | 14 |
| Mercury Suit display case | 14 |
| How do Astronauts get to ISS label | 14 |
| Star Trek display case | 13 |
| Sunglasses display case | 10 |

*The average stay time is calculated using the time spent at the element during each stop. In BSE, some families returned to an element multiple times during their visit, so the average stay time is the average length of time they spent during any one of those stops; it may not accurately represent the total time a family is likely to spend at an element during their full visit in the gallery.
**Average is based on only 1 group.

## Total Time per Family for Selected Elements

**Table C3. Several elements had longer total times per family when multiple stops were combined to reflect total time spent during the exhibit visit.**

| Element (n=total families) | Average Time per Stop | Average Total Time per Family |
|---|---|---|
| Canadarm Game (n=38) | 1 minute 27 seconds | 2 minutes 42 seconds |
| Glove Box & Labels (n=37) | 49 seconds | 1 minute 11 seconds |
| Liberty Bell 7 capsule (n=18) | 40 seconds | 52 seconds |