Summative Evaluation of the *Moon Adventure Game*

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A family working together to complete one of the challenges in the Moon Adventure Game. (Photo by Science Museum of Minnesota for NISE Network)

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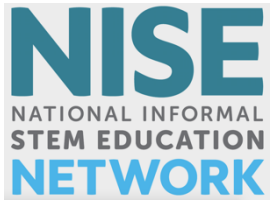

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Executive Summary

The Moon Adventure Game is a challenge-based immersive game, inspired by "escape room" experiences, which asks visitors to take on activities to help them think about what people might need to live and work on the Moon. Creation of the game was a collaborative effort between Arizona Science Center (ASC) and National Informal STEM Education Network (NISE Network) partners from Arizona State University (ASU), the Science Museum of Minnesota (SMM), the Museum of Life and Science, Children's Creativity Museum, Sciencenter, and the Museum of Science, Boston (MOS). The game is designed for three to six players and is intended to be played live with support from a facilitator. The 25-minute gameplay involves five challenges that incorporate scientific concepts connected to lunar exploration, as well as introduction and closing elements. The game was distributed to 350 NISE Network partner organizations across the US in the December 2020. For more information about the game, visit https://www.nisenet.org/moongame.

Summative evaluation of the game focused on both public and professional audiences. The evaluation questions guiding this work included the following:

Public questions:

1) Who and how many members of the public do educational products reach?
2) How do the educational products impact the public's engagement and learning related to space exploration, science, and engineering?

Professional questions:

3) What kinds and how many professionals does the project reach?
4) How do the educational products impact professionals' attitudes related to engaging the public in learning about space exploration, science, and engineering?
5) What kinds of partnerships are formed between museums and community organizations through the project?

Public data were collected primarily through an evaluation survey, with a total of 226 surveys collected across seven museums, with 94 of those from children 12 and under, 13 from teens aged 13 to 17, and 119 from adults. Professional data were collected through an annual partner survey of 80 professionals who facilitated the game and follow-up interviews with 12 of those individuals. Public and professional data were also extracted from a report detailing use of Explore Science: Earth & Space toolkits, which was completed by 327 sites. Following data collection and analysis, the following trends emerged from the data:

1) The Moon Adventure Game reached an estimated 17,470 members of the public and 414 professionals, mostly at small science centers and children's museums.
2) After playing the game, participants felt:
    a. More interested in Moon science and space exploration,
    b. More knowledgeable about Moon science and space exploration,
    c. More confident that they could learn more about Moon science and space exploration in the future, and
    d. A stronger sense of science identity.
3) Participants practiced 21st century skills related to collaboration, problem solving, critical thinking, and innovation through playing the game.
4) Professionals reported high levels of confidence, comfort, and motivation to engage publics in learning about Moon science and space exploration, and about half said that the Moon Adventure Game had a strong influence on these attitudes.

5) Although many professionals stated that their confidence, comfort, and motivation were already high prior to using the Moon Adventure Game, they still said the game's format and outcomes affected these attitudes.

The format of the game, with its high level of staff involvement and close contact, in-person player interactions created significant challenges given the context of the COVID-19 pandemic. The pandemic forced science centers to close, furlough or lay off staff, and pivot to virtual programming, all of which reduced opportunities for professionals to facilitate the game. Still, it appears that those public and professional audiences who were reached by the game were especially engaged because of the format. Overall, even though the Moon Adventure Game was distributed to sites at a particularly challenging time, it achieved many of its goals.

Introduction

1.1 Project Overview

The National Informal STEM Education Network (NISE Network) is a community of informal educators and scientists who are dedicated to supporting learning about science, technology, engineering, and math (STEM) across the United States. Network projects engage publics in learning about current STEM topics, develop and use best practices for learning in out-of-school settings, and build the capacity of informal science education institutions and research organizations to provide meaningful and interactive learning experiences.

In 2019, NASA awarded a grant to Arizona Science Center (ASC) with NISE Network collaborators from Arizona State University (ASU), the Museum of Science, Boston (MOS), Science Museum of Minnesota (SMM), and others, for a project called *Moon and Beyond: An Immersive Game for STEM Learning in Museums and Planetariums*. The main activity of the Moon and Beyond project was to develop a challenged-based immersive game, inspired by escape rooms, which asked players to take on activities to help them think about what people might need to live and work on the Moon. NISE Network professionals collaborated with subject matter experts in education and space science and used unique NASA assets to develop the game. It was distributed, along with robust supporting materials, to hundreds of NISE Network partner organizations across the United States. These partner organizations used the game to engage public audiences in learning about space exploration, science, and engineering, especially families with children and students in grades 4-8.

1.2 Moon Adventure Game

The game is designed for three to six players and is intended to be played live with support from a facilitator. Gameplay takes approximately 25 minutes, and setting and resetting can take 15-30 minutes. The 25-minute gameplay involves five challenges, plus introduction and closing elements.

Images [left to right]: NISE Network development team members test a prototype version of the game in October 2019 (Credit: Emily Maletz); visitors using the final version of the game, working together to match rover data to locations on the map (Credit: Dave Burbank).

In the game, players take on the role of (fictional) researchers living and working on the Moon. As they conduct their research, a moonquake causes damage to their outpost's life support systems. Players must work in teams to solve five challenges, all grounded in real NASA science, to restore the systems necessary to survive. Players must work together to solve the puzzles in each challenge, which include specific Moon science content and are designed to highlight

different scientific skills. See Table 1 for a list of challenges and their associated content and skills (Arizona Science Center, 2020).

Table 1: *Challenges and associated content and skills*

Content and skill messages for each challenge:
Challenge 1: Make a travel plan for your rover • Content: Moon craters • Skills: Interpreting maps and data; teamwork
Challenge 2: Match rover data to locations on the map • Content: Permanently shadowed areas • Skills: Interpreting maps and data
Challenge 3: Extract water from frozen lunar material • Content: Frozen lunar materials in craters • Skills: Sorting material
Challenge 4: Fill your oxygen tanks • Content: Splitting water molecules into hydrogen and oxygen • Skills: Measuring
Challenge 5: Reconnect the power supply • Content: Using conductive materials to close an electrical circuit • Skills: Teamwork

In October 2020, after the game development and prototyping processes were completed, the project team hosted an online workshop to introduce professionals to the game. Physical copies of the game were distributed in a second toolkit (Part B) in December 2020 to all sites who had received the NISE Network's 2020 Explore Science: Earth & Space Toolkit Part A (about 350 sites, Figure 1). In June 2021, the project team hosted another webinar showcasing how different partner sites were using and adapting the Moon Adventure Game at their own sites. Additionally, the NISE Network newsletter included several partner highlights on this topic.

In addition to the physical copies distributed to these sites, digital versions of all materials are hosted on NISE Network's website at https://www.nisenet.org/moongame.

Figure 1: *Map of sites that received the Moon Adventure Game*

1.3 Summative evaluation

The project's primary goal was to engage youth and public audiences in authentic STEM learning related to what people might need to live and work on the Moon, encouraging 21st-century skills such as collaboration, innovation, critical thinking, and problem-solving. Additional goals included: preparing informal educators to offer high-quality public engagement experiences related to space science and exploration; and leveraging a national network and encouraging local collaborations to achieve broad geographic reach across the United States, including groups that are traditionally underserved by STEM institutions and underrepresented in STEM fields. Summative evaluation focused on documenting progress toward these goals via the evaluation questions below.

The evaluation questions guiding the public summative evaluation work include:

1) Who and how many members of the public do educational products reach? and
2) How do the educational products impact the public's engagement and learning related to space exploration, science, and engineering?

The evaluation questions guiding the professional summative evaluation work include:

1) What kinds and how many professionals does the project reach?
2) How do the educational products impact professionals' attitudes related to engaging the public in learning about space exploration, science, and engineering? and
3) What kinds of partnerships are formed between museums and community organizations through the project?

To answer these questions, the following outcomes and data sources were tracked for public and professional audiences:

Table 2: *Project evaluation outcomes and data sources*

PUBLIC AUDIENCES: Learning goals and outcomes for publics	**DATA SOURCES: Project evaluation and reporting**
• Engagement in authentic STEM experiences • Interest related to space exploration, science, and engineering • Learning related to space exploration, science, and engineering • Learning related to 21st-century skills • Development of science identity	• 2021 Toolkit report on partner use of materials • Public evaluation survey – age 12 & under • Public evaluation survey – age 13 & up • Professional interview questions about perceived public learning
PROFESSIONAL AUDIENCES: Learning goals and outcomes for professionals	**DATA SOURCES: Project evaluation and reporting**
• Professional use of educational products • Comfort engaging publics in space exploration, science, and engineering • Confidence engaging publics in space exploration, science, and engineering • Motivation to engage publics in space exploration, science, and engineering	• 2021 Toolkit report on partner use of materials • Annual partner survey • Professional interview questions about professional learning

Methods

2.1 Overview

The summative evaluation utilized data collected from public and professional audiences. Public data were collected primarily through an evaluation survey, and professional data were collected primarily through an annual partner survey and interviews. Public and professional data were also extracted from a report detailing use of the toolkits. Throughout the process, evaluators maintained regular contact with project leaders to refine outcomes and plan the summative evaluation activities. The table below breaks down data collected by its source and audience.

Table 3: *Data collected by source and audience*

Data source	Information needed	Audience
Public evaluation survey	• Engagement in authentic STEM experiences • Interest related to space exploration, science, and engineering • Learning related to space exploration, science, and engineering • Learning related to 21st-century skills • Development of science identity	Public
Annual partner survey	• Frequency of professional use of the game • Comfort engaging publics in Moon science • Confidence engaging publics in Moon science • Motivation to engage publics in Moon science	Professional
Toolkit report	• Number of people who use the game • Characteristics of institutions using the game (i.e., urban/rural, audiences served) • Number of professionals using the game • Types of professionals using the game • Types of community partnerships formed	Public Professional
Professional interviews	• Detail about how institutions and professionals used the game • Perceptions and examples of public learning • Ways the game contributed to changes in comfort, confidence, and motivation to engage publics in Moon science	Public Professional

2.2 Public evaluation survey

The primary method of public data collection was via post-game public evaluation survey, with one version for children aged 12 and under and another for everyone aged 13 and up. The only difference between teen and adult surveys was the consent and demographic information form at the beginning of the teen survey. All sites that received the Moon Adventure Game were invited to volunteer, if they had capacity, to assist with data collection. In total, 12 sites volunteered and participated in a data collection training.

Originally, we planned to select 10-15 sites of varying sizes, locations, and target audiences. However, the effects of the COVID-19 pandemic meant that many museums were still closed when data collection was set to start, and many more were grappling with staffing shortages. Evaluators thus decided to let sites reassess their capacity for data collection during this

challenging time. Of the 12 sites who volunteered, seven ultimately collected data on the Moon Adventure Game. Data were collected from family groups visiting the museum as well as with groups participating in summer camps.

Data collection sites

The seven data collection sites were: Ingram Planetarium (Sunset Beach, NC), McAuliffe-Shepard Discovery Center (Concord, NH), Explorations V Children's Museum (Lakeland, FL), Sciencenter (Ithaca, NY), Cape Cod Museum of Natural History (Brewster, MA), Arizona Science Center (Phoenix, AZ), and Museum of Life and Science (Durham, NC). The sites were mostly in the Northeast and Southeast NISE Network regions, with one in the West. Annual on-site attendance ranged from approximately 15,000 to approximately 500,000.

Some sites collected data with public visitor groups, and some collected data with summer camp classes. Evaluators initially asked sites to collect surveys only with the general public, but later decided to collect data from summer camps as well, since many sites reported using the game with camps. For sites collecting data with general public onsite visitors, data collectors were instructed to invite the group to take the survey on a tablet (e.g., iPad) or, for some sites, on paper, after they completed the game. At least one adult and one child in the groups were invited to complete surveys. For sites collecting data from camps, sites sent consent forms home for parents/legal guardians to sign. Campers filled out paper surveys after finishing the game, and sites scanned and emailed the surveys back to the evaluation team.

The electronic survey began with parental/legal guardian consent and child assent forms. The parental/legal guardian consent form included simple demographic questions for the child. For children and teens, the survey branched to the appropriate age-level questions based on the age entered. Both surveys began with questions about whether groups finished the game. From there, the teen and adult survey asked closed-ended, 4-point scale questions about interest, enjoyment, authentic STEM engagement, and practicing 21st century skills; and open-ended questions about 21st century skills and learning. The last questions were retrospective pre-post questions on a 4-point agreement scale about how the game affected their interest and learning around Moon science and space exploration and their feelings of science identity. Younger children answered also closed-ended questions about enjoyment and learning, but on a 3-point scale with emoji icons to support understanding. Children 12 and under then answered yes/no questions about authentic STEM engagement, interest, and 21st-century skills. The last section again included retrospective pre-post style questions, but for younger children, the questions were modified to be on a yes/no scale and to ask only about whether participants felt more interested/knowledgeable/etc. than before they played the game. See Appendix A for the full instruments.

A total of 226 surveys were collected across sites, with 94 of those from children 12 and under, 13 from teens aged 13 to 17, and 119 from adults. Surveys for adults and teens were combined and analyzed in aggregate. For simplicity, in describing the results below, we will refer to this group (adults and teens) as "adults." We asked sites to collect at least 10 surveys each, but data collection capacity varied across sites, and some sites collected more surveys than others (see 2.7 Limitations section). Data were collected primarily in the summers of 2021 and 2022.

Demographics

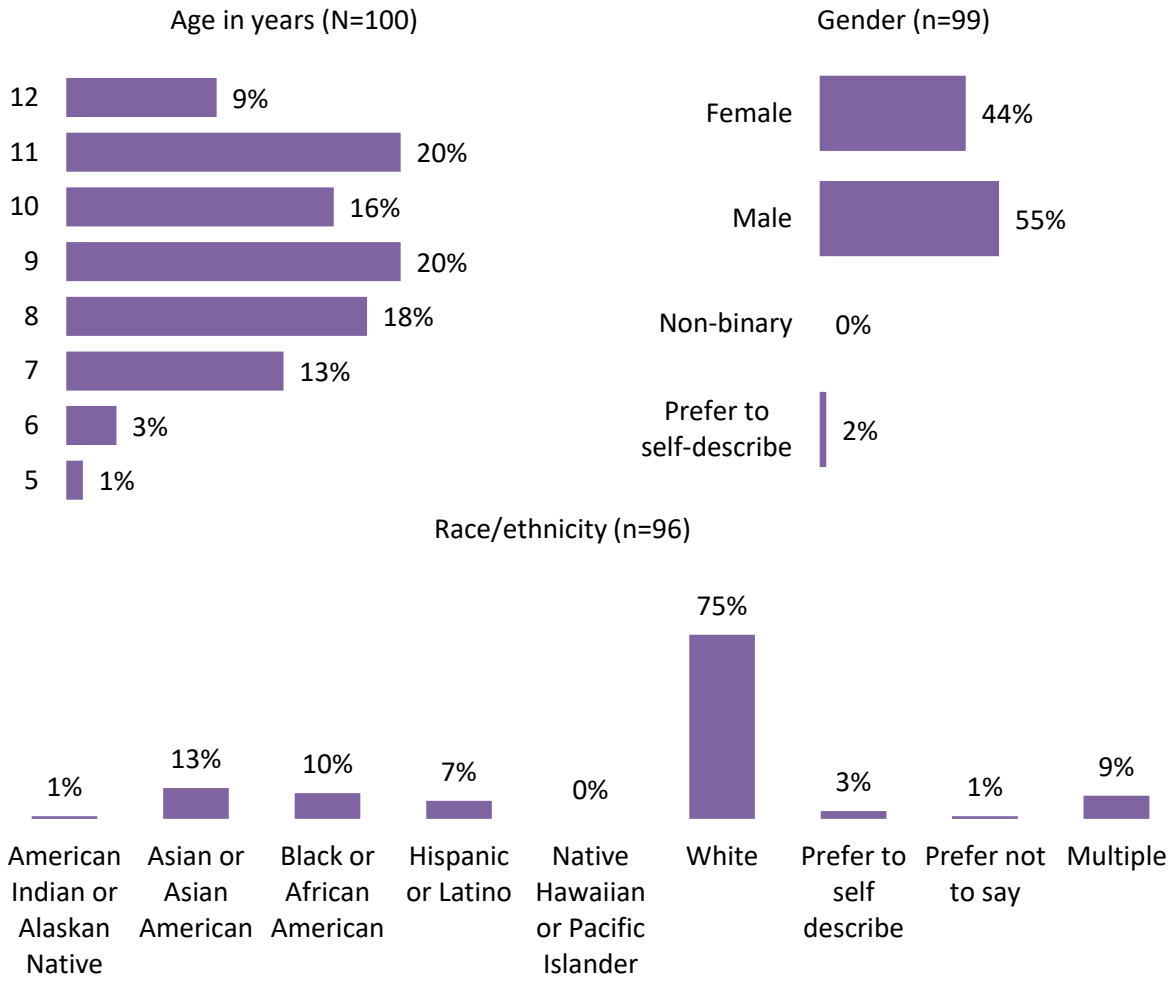
The surveys each included demographic questions asking about age, gender, and race/ethnicity. Adults (aged 18 and up) were also asked to share their group size and age range composition. Figure 2 and Figure 3 show the demographic information for children[1] and adults, respectively.

[1]From data collection sites, six additional participants demographics data was received compared to completed surveys (demographics N=100, completed surveys: N=94).

Children (respondents aged 12 and under) ranged in age from 5- to 12-years old (

Figure ***2***), with 55% identifying as male, 44% as female, and 2% preferred to self-describe. Most identified as white (75%) with 13% identifying as Asian or Asian American, 10% as Black or African American, 7% as Hispanic or Latino, 1% as American Indian or Alaska Native, and 9% as multiple race/ethnicity categories.

Figure 2: *Age, gender, and race/ethnicity breakdowns of respondents aged 12 and under*[2]

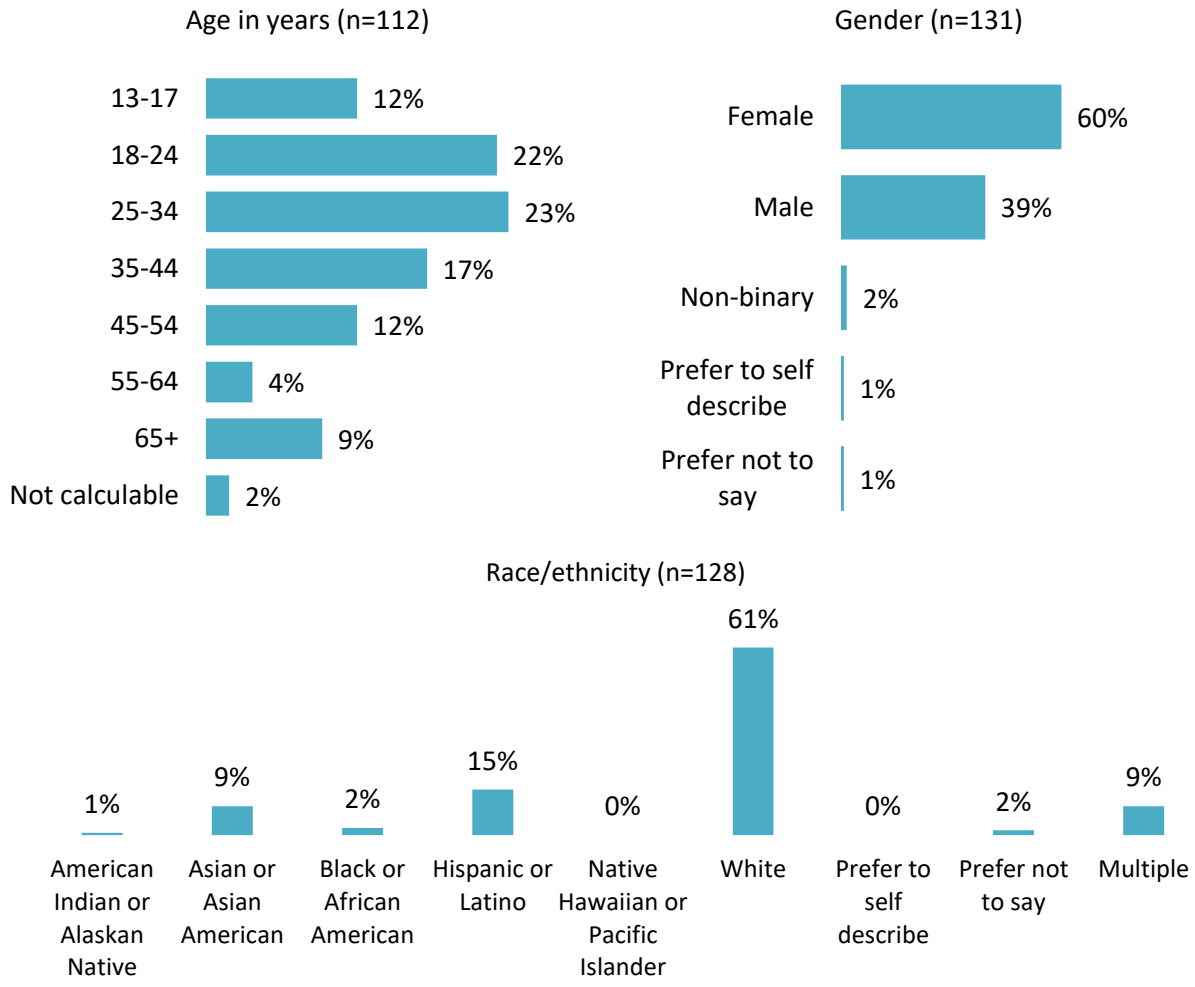


Adults (respondents aged 13 and up) ranged from 13 years old to 77 years old (n=112, Figure 3). 12% were teens (aged 13- to 17-years old) and 88% were individuals 18 years-old and up (n=112). The median age was 31 years, and nearly a quarter of the sample was in each of the following categories: 18-24 years old (22%, n=112) and 25-34 years-old (23%, n=112). 60% identified as female, 39% as female, 2% as non-binary, and 1% preferred to self-describe (n=131). For race and ethnicity, over half identified as white (61%, n=128), 15% as Hispanic or Latino, 9% as Asian or Asian American, 2% as Black or African American, 1% as American Indian or Alaska Native, 9% as multiple race/ethnicity categories, and 2% preferred not to say. Respondents aged 18 and up were also asked how many members of their group were of the following age ranges: children, age 0-7; children, age 8-12; teens, age 13-17; and adults, age 18+. 49% of groups

[2] Participants could select multiple categories for gender identity and are represented in each category selected.

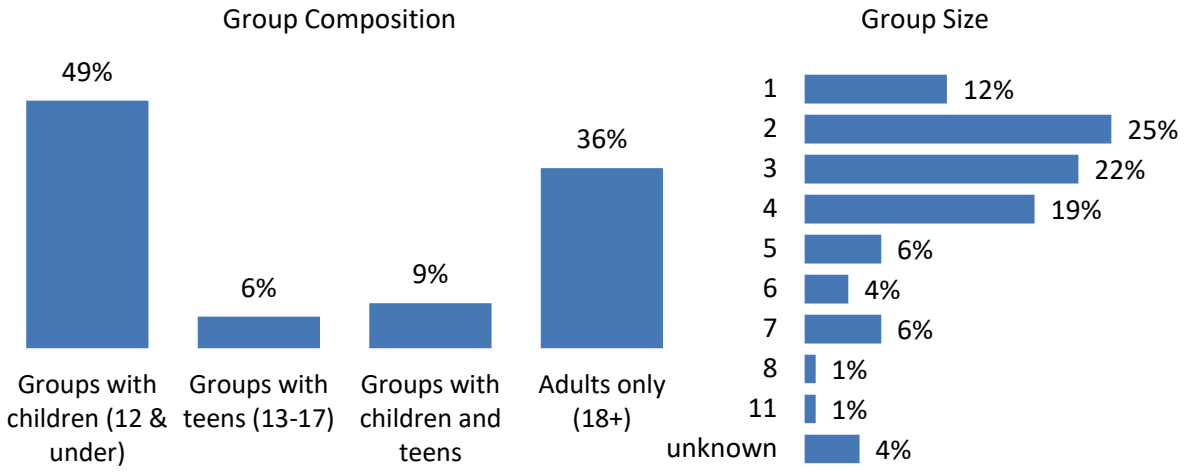
included children aged 12 and under; 6% included teens; 9% both children and teens, and 36% were adult only groups (n=112, Figure 4). Group sizes ranged in size from 1 individual to 11 individuals, with a median group size of 3 (average 3.13, n=112, Figure 4).

Figure 3: *Age, gender, and race/ethnicity breakdowns of respondents aged 13 and up*[3]



[3] Participants could select multiple categories for gender identity and are represented in each category selected.

Figure 4: *Group composition and size breakdowns based on responses from adults aged 18 and up (n=112)*



2.3 Annual partner survey

Similar to public audiences, the main data source for professional impacts was a survey, this time an annual partner survey. The NISE Network typically sends an annual partner survey each fall to contacts at partner sites who are participating in current projects. The survey often asks professionals questions about educational resource use, content knowledge, collaborations, impacts of materials, sense of community within the network, and more (Beyer, Anderson, & Kunz Kollmann, 2021). In late 2021, we collaborated with NISE Network leaders to add questions specific to the Moon Adventure Game to the annual partner survey. The survey was distributed in late October 2021 and received 211 total responses.

In the Moon Adventure Game portion of the survey, professionals at institutions who received the game were asked first if their institutions used the game at all, and if so, how often they personally facilitated it. The survey also asked professionals to share email addresses of others at their institutions who facilitated the game so the survey could be sent to them as well. Those whose institutions had not received the kit or who had never facilitated the game were filtered out of the survey. Anyone who had facilitated the game was eligible to fill out the rest of the survey questions.

Eligible professionals were then asked closed-ended questions on a 10-point agreement scale about their level of confidence, comfort, and motivation to engage publics in learning about Moon science and space exploration. Next, professionals were asked to rate, on another 10-point scale, how much their use of the Moon Adventure Game affected their comfort, confidence, and motivation. To conclude, professionals were asked an open-ended question about what aspects of the game most contributed to their comfort, confidence, or motivation, and finally if there was anything else they wanted to add about the game's impact on them, their visitors, or their institution. The Moon Adventure Game portion of the annual partner survey is included in Appendix A.

2.4 Toolkit report

After sending out a toolkit of resources, NISE Network leaders ask all institutional partners who receive a toolkit to fill out a report with information about their institution and how they used the toolkit materials that year. Respondents report details about when and how they used the

toolkits, as well as how many members of the public were served through their programming, whether they collaborated with other organizations, and what types of audiences they felt were reached by their programming with the toolkits. NISE Network leaders attempted to get completed reports from every single institution that received toolkit, which in 2020 and 2021 was 357 institutions. Toolkit B contained the Moon Adventure Game, and 355 sites received this toolkit.

In 2020, the project team added questions to the report about whether institutions were using the Moon Adventure Game, which then were used to invite sites to help with data collection. In 2021, the toolkit report included questions for institutions about their frequency of use of the Moon Adventure Game as well as for an estimate of how many members of the public used the game. In 2020 and 2021, the kit report also asked about collaborations and partnerships, though not specifically around the Moon Adventure Game.

2.5 Professional interviews

To better understand professionals' experiences with the Moon Adventure Game and how it affected their attitudes and practices, interviews were conducted with a subset of professionals who completed the annual partner survey. Aiming for 10-15 interviews, twenty professionals were invited to participate in an interview. Evaluators invited all those who reported "frequently" facilitating the game (ten professionals), plus a randomly selected five each who reported using the game "occasionally" or "rarely." In the end, twelve professionals completed interviews.

Evaluators asked questions about how the interviewees' institutions used the game (how often, in what context, modifications made, etc.), in what contexts the interviewees personally facilitated the game, perceptions of public learning and 21st-century skill use, and more detail about interviewees' comfort, confidence, and motivation to engage publics in learning about Moon science and space exploration. Evaluators looked back at each interviewee's survey answers for these attitude questions and prompted interviewees to explain their ratings as best they could. As a thank you for their time, each interviewee received a $50 gift card. The full interview questions are included in Appendix A.

2.6 Analysis

This evaluation involved analysis of both qualitative and quantitative data. Qualitative data analysis was done primarily through inductive coding. Inductive coding involved reviewing the data and identifying the most frequent themes (Patton, 2002). Open or inductive coding was used thereafter. For all coding, one team member completed the initial coding process and reviewed the codebook at several points along the way. This team member then discussed questions or uncertainties with the rest of the team until a consensus was reached.

Quantitative analysis consisted of descriptive and inferential statistics. Descriptive statistics included counts, percentages, medians, and averages. Where appropriate, inferential tests such as chi-square ($\chi 2$) or Mann-Whitney U tests were used to assess differences within the data. Statistically significant differences—defined by an alpha level of .05—are marked with an asterisk (*). The details of these inferential tests are included in footnotes throughout the text.

2.7 Limitations

The evaluation had several limitations. The biggest challenge was, of course, the onset of the COVID-19 pandemic and the effects it had on science museums around the country. Though some museums were only closed for a few months in the first half of 2020, many others were closed to the public for a year or more. This likely reduced the number of sites that used the Moon Adventure Game, and thereby the number of sites able to collect data. Even if they were

open, the game was a facilitated, hands-on, in-depth learning experience, making it difficult or impossible for sites to use the game while trying to limit transmission of the virus. The limits on game use impacted the sites available for public data collection, the number of professionals who used the game, and the public reach of the game.

Individual sites also sometimes faced challenges with data collection. Some sites were willing collect data but ultimately were unable to collect 10 surveys due to COVID-related impacts (including some being forced to temporarily re-close). However, some sites (notably Arizona Science Center) managed to use the game with many visitors, resulting in an unbalanced distribution of surveys across sites.

Figure 5: *Number of public evaluation surveys collected by site.*

Site	Adults (13+)	Children (12 & under)	All Ages
Arizona Science Center	94	30	124
Cape Cod Museum of Natural History	16	12	28
Exploration V Children's Museum	2	0	2
Ingram Planetarium	14	6	20
McAuliffe-Shepard DC	2	4	6
Museum of Life and Science	4	24	28
Sciencenter	0	18	18
Totals (N)	**132**	**94**	**226**

As part of the analysis, the response patterns between Arizona Science Center and the rest of the data were investigated to ensure that no biases were introduced. We used chi-square ($\chi 2$) tests to compare survey results for each question and found no significant differences between Arizona Science Center's data and the rest of the data. Full analysis is included in Appendix B.

Findings and discussion

3.1 Public audiences

As outlined in Section 1.3, the evaluation questions for public audiences included the following:

1) Who and how many members of the public do educational products reach? and
2) How do the educational products impact the public's engagement and learning related to space exploration, science, and engineering?

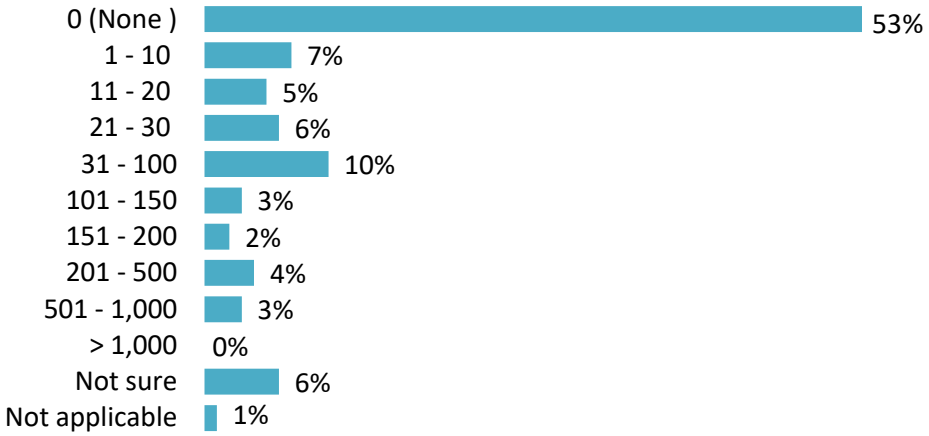
The 2021 toolkit report was used to understand the public audiences reached by the Moon Adventure Game. In this report, all sites who received the kit were asked to share how many members of the public engaged with the game and what audiences their institution serves. These data are reported in aggregate (see Section 3.1.1).

Impact of the game on publics' learning and engagement was investigated in relation to five aspects: knowledge; engagement and interest; science identity; confidence; and use of 21st-century skills. Changes in each of these aspects are described below first for children (aged 12 and under), then for adults (aged 13 and up). These results draw upon the public evaluation survey as well as, where applicable, the professional interviews in which professionals shared their observations around what members of the public learned and their practicing of 21st century skills in the game. In the public evaluation survey, adults were asked retrospective pre-post questions in which they rated their agreement to a statement about each of these aspects for both what they would have said before and what they would say now after having played the game. Statistical tests were run comparing these two ratings, and statistically significant results ($p<0.05$) are indicated with an asterisk (*) in the respective figures. While the test for each aspect was statistically significant, most individuals experienced no change in their ratings, so we have included the distribution of change scores (which indicate the extent individual participants' ratings changed) in the respective figures and in the description of results to help depict the changes that did occur and their extent.

3.1.1 The Moon Adventure Game reached an estimated 17,470 members of the public across the US in 2021.

In the 2021 toolkit report, sites were asked how many members of the public they reached with the Moon Adventure Game. They selected from a list of ranges: 0, 1-10, 11-20, 21-30, 31-100, 101-150, 151-200, 201-500, or 501-1000 people. Of the 357 sites that received a kit, 324 sites responded. 131 sites said they used the game with public audiences (40%, n=324, Figure 6). Of sites who used the game, respondents most commonly said they reached 31-100 members of the public (10%, n=324). To estimate how many members of the public were reached, the number of sites in each of these categories was multiplied by the midpoint for the category (e.g., 5.5 for 1-10). Thus, the Moon Adventure Game is estimated to have reached 17,470 members of the public through these sites. This translates to an average of 49 members of the public reached for each site who used the game.

Figure 6: *Institutions' estimates of public reach of the Moon Adventure Game (n=324 institutions)*



In addition, sites that used the Moon Adventure Game were asked to report on what types of audiences traditionally underserved by STEM institutions and underrepresented in STEM fields they reached in 2021, including racial and ethnic minorities, girls, rural audiences, and more. As shown in Figure 7, almost all sites reported reaching girls, racial and ethnic minorities or communities of color, and low-income audiences. The least-reached groups included American Indian/Alaska Native audiences and audiences speaking a non-English language other than Spanish.

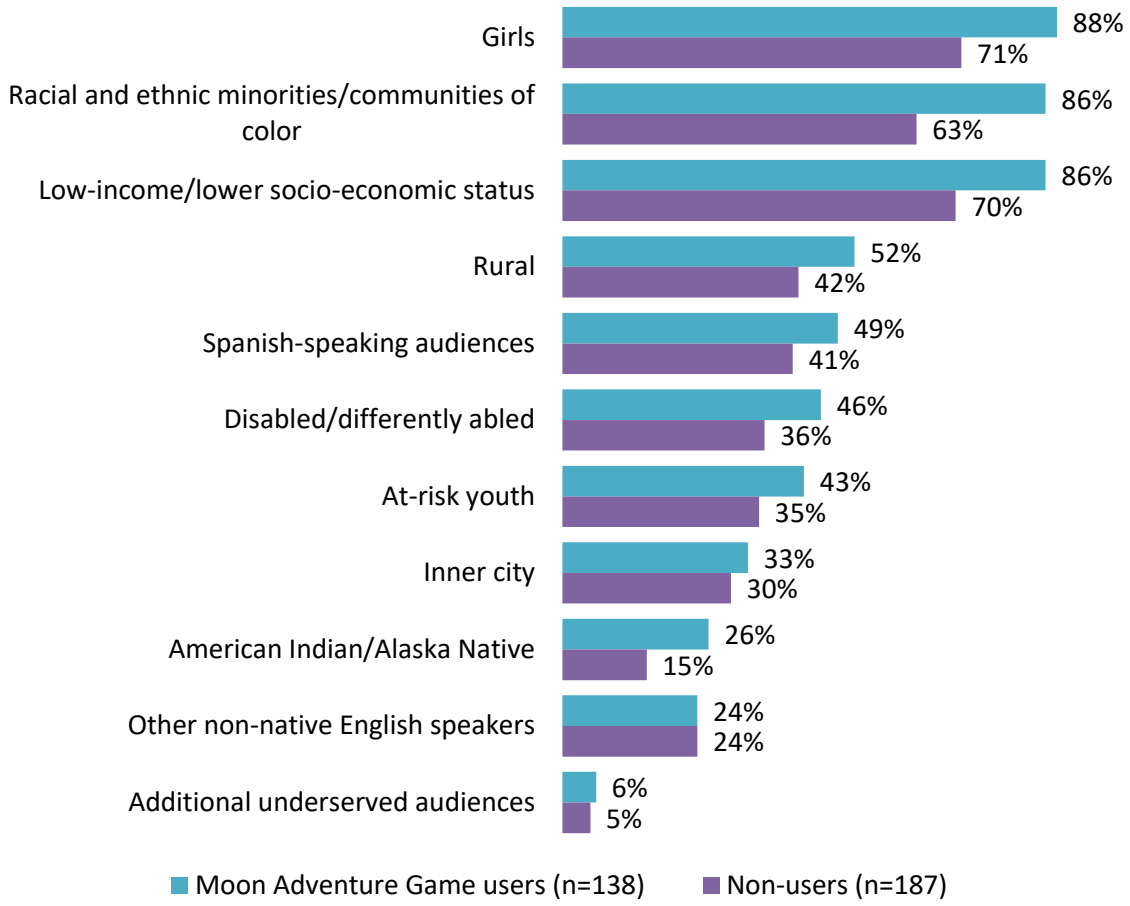
In addition, when comparing institutions that did use the Moon Adventure Game to those that did not, institutions that used the Moon Adventure Game were more likely to report serving almost all the listed categories of audiences traditionally underserved by STEM organizations and underrepresented in STEM fields. Some of these are affected by the institution's location (e.g., rural) and local demographics (e.g., Spanish- or other non-native English-speaking audiences), but there could be other characteristics of Moon Adventure Game-using institutions that influenced the audiences they serve, such as special programs or outreach efforts.

Summary:

The data indicates that a moderate number of visitors were reached by the Moon Adventure Game in 2021, fewer than are typically reached through a NISE Network toolkit containing hands-on activities. There are a number of explanations for this. First, the evaluation, and therefore the reach counting took place during the COVID-19 pandemic. This meant that many sites were not able to implement the game at all. Others had limited visitation which also meant a lower reach number. Another reason for the moderate reach is the design of the activity itself. The game can only support one small group using it at a time because the activities are in sequence and need to be re-set after each group, and it takes about 25 minutes to play through the game for each group. Therefore, the game will necessarily have a lower throughput than other kinds of activities that are a shorter duration or can allow for more users at a time.

Although the game had moderate reach, it achieved the project goal for at least 85% of organizations using the game to engage audiences who are traditionally underserved by STEM institutions and underrepresented in STEM fields, as nearly all sites that used that game reported reaching girls, racial and ethnic minorities or communities of color, and low-income audiences. In addition, the game may have reached more of these audiences due to the institutions that ended up using it.

Figure 7: *Audiences traditionally underserved by STEM organizations and underrepresented in STEM fields reached by institutions using the Moon Adventure Game compared with institutions not using the game (n=325)*



3.1.2 Participants <u>learned</u> more about the Moon and space exploration through the game.

<u>Children (12 & under):</u>

On the public evaluation survey, children were asked how much they had learned about the Moon and if, after playing the game, they felt they knew more about the Moon or space exploration. Nearly half of children said they learned a lot about the Moon (46%, n=91, Figure 8), and most children felt that they knew more about the Moon or space exploration after playing the game (75%, n=88, Figure 9).

Figure 8: *Children's ratings for "How much did you learn about the Moon?" (n=91)*

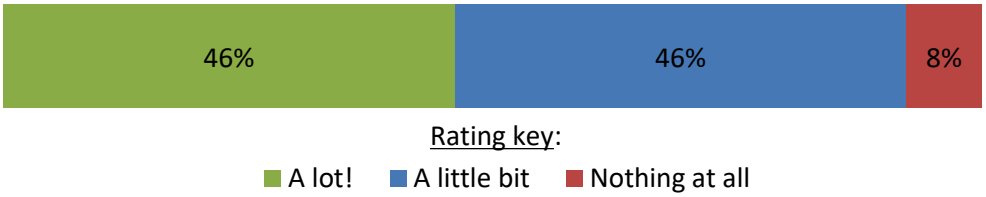
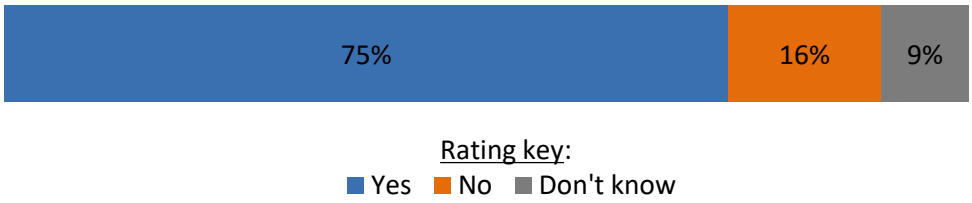


Figure 9: *Children's agreement with the statement "After playing the game today, I know more about the Moon or space exploration than I did before." (n=88)*

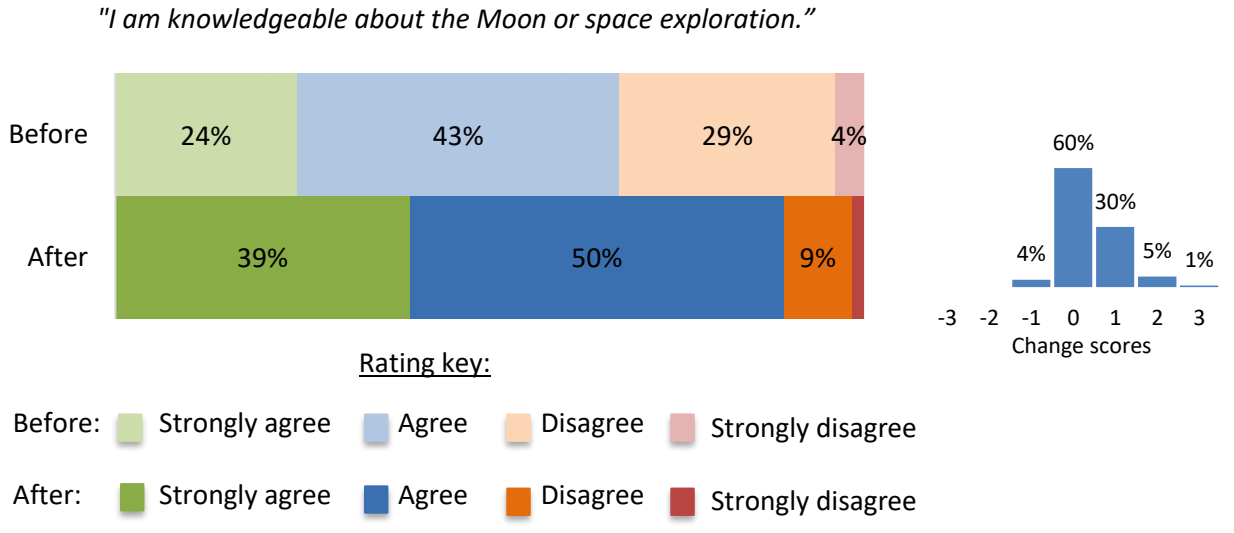


Adults (13+):

Similarly, adults were asked a retrospective pre-post question on the public evaluation survey to understand how much they had learned about the Moon or space exploration. In this question, adults were asked to rate their agreement to the following statement "I am knowledgeable about the Moon or space exploration" on a 4-point scale from "strongly disagree" to "strongly agree" for both how they would have rated it before ("Before" rating) and what they would say now that they have played the game ("After" rating). Adults reported that their knowledge about the Moon or space exploration increased after playing the game. Before playing the game, 67% rated that they would have agreed or strongly agreed, and 89% agreed or strongly agreed after (N=132, Figure 10). These increases were statistically significant, with a moderate effect size (N=132, p=0.000, z=-5.764, r=-0.355).

Overall, 40% of individuals reported that they felt their knowledge changed from before playing the game to after (N=132). Changes in individuals' ratings from before to after (change score) ranged from going down one point to increasing by two points. Of those who experienced change, most reported their individual rating increasing by one point (75%, n=53), meaning their rating moved up one point on the scale. For example, 55% moved from "disagree" to "agree," and 45% moved from "agree" to "strongly agree" (n=40).

Figure 10: *Adults' ratings of their knowledge of the Moon or space exploration (n=132)*



When asked to provide an example of what they learned, by far, the topic adults most frequently described was learning about electrolysis (38%, n=105)—splitting water molecules into hydrogen and oxygen—which was the content focus of Challenge 4, with participants saying "We

learned that you can make an oxygen supply from water" and "[that] water ice is a potential source of oxygen for breathing and hydrogen for fuel." The next most described topics were using conductive materials to close an electrical circuit (12%, n=105), which was the content focus of Challenge 5, followed by temperatures on the Moon (12%, n=105) and Moon craters which was the content focus of Challenge 1 (10%, n=105). Table **4**, below, summarizes the most frequently described topics and provides example quotes for each. In addition, within the responses to this survey question, a suggestion for improving the game was also identified, in which one adult wrote: "Wish the answers we explained better. For example, the kids saw bubbles but didn't realize they were oxygen." For a full list of topics adults described learning about, see Appendix C.

Table 4: *Top content areas described in adults' responses about their learning (n=105)*

Content learned	Frequency	Response Examples
Splitting water molecules into hydrogen and oxygen	40 (38%)	*"I learned about Electrolysis."* *"How astronauts make oxygen in space"* *"We learned that we can [create] our own oxygen through electrolysis"*
Using conductive materials to close an electrical circuit	13 (12%)	*"The difference between insulators + conductors"* *"…that you can restore electricity with humans"* *"Humans are ['conductors']"*
Temperatures on the Moon	13 (12%)	*"The hottest and coldest place in Faustini"* *"Temperature"* *"…And there are extremely cold places on the moon."*
Moon craters	10 (10%)	*"About crater temp."* *"I learned about [its] craters"* *"Craters are huge."*

Professionals' observations of visitor's learning:

To understand in more detail what visitors learned about Moon science and space exploration in playing the game, professionals were asked if they observed game participants learning about these content areas while playing the game and, if so, to share an example of the topics they learned about.

Like the examples shared by adult visitors, the most frequently described topic professionals observed visitors learning about was electrolysis (5 of 12). For example, one professional observed that "[it] seemed like the most interesting part for a lot of folks with [sic] was splitting

up the water molecule into its component parts." One professional also shared how visitors learned not only conceptually how electrolysis worked but also how its use was or could be applied to real-life situations, saying:

> *One of the things that people learn is not only can you use the oxygen for breathing and that we're you know currently doing that on the International Space Station, but you know, on the moon, you can also use the hydrogen to make rocket fuel.*

Professionals also talked about a range of topics highlighted in visitor examples, such as one professional noted visitor learning about electrical circuits, saying "I think they especially like the end activity where they have to connect things together. There's definitely some learning that happens there just through trial and error," and another professional describing learning about frozen lunar materials, "A lot of people didn't know that there was water ice on the moon. You will find it frozen in a crater that's permanently in the shade. That's, for a lot of people, brand new information."

However, professionals also noted learning about topics less frequently highlighted by adult visitors in the public evaluation survey. Multiple professionals also highlighted learning about application of the science presented to NASA missions or other space exploration efforts, like one professional noting "[most] of them had not really heard that there was an ARTEMIS project, that we were going back to the Moon, that was not something that they were even really aware of," and another professional saying:

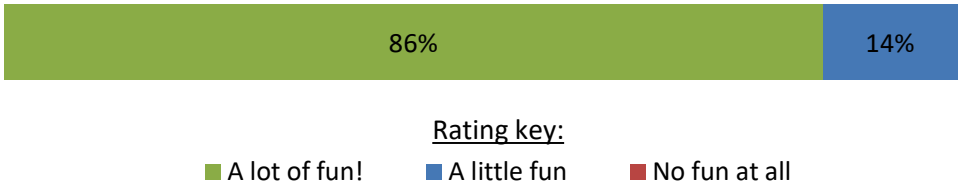
> *And then I asked them to think about why you would want to do [electrolysis] on the moon, and eventually they come around to, oh, it's really expensive to lift all that take it to the moon, and then take it to Mars because that's one thing that the video at the beginning does is say the ARTEMIS mission isn't just about the moon. It's about using the moon, to learn how to make it a steppingstone to Mars, and so that gives it a bigger context. When you start them thinking about that bigger context you can start thinking about the moon as a gas station, as it were, to refill your rockets to go to Mars, and so that's always a big eye opener.*

Summary:
The data indicates that both children and adults learned more about the Moon and space exploration through the game. One particular topic they learned about was electrolysis, which was used in Challenge 4 to split water molecules into hydrogen and oxygen to "refill their oxygen tanks" in the game. For this reason, it is not surprising that visitors frequently mentioned learning about it since this process was directly demonstrated. In addition, the role-playing scenario of the game may have helped put into context how it may be used in real-life space exploration and increased awareness of how it may be applied in NASA missions or other space exploration efforts.

3.1.3 Participants found the game fun and engaging and were more interested in the Moon and space exploration after playing.

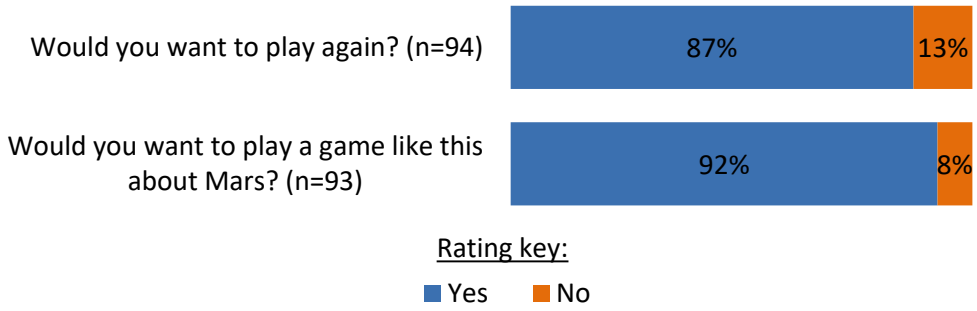
Children (12 & under):
In the public evaluation survey, children were asked to rate how fun they found the game on a 3-point scale. All children who participated said the game was at least a little fun, and 86% of them found the game to be "A lot of fun!" (n=92, Figure 11).

Figure 11: *Children's ratings for "How fun was the game?" (n=92)*



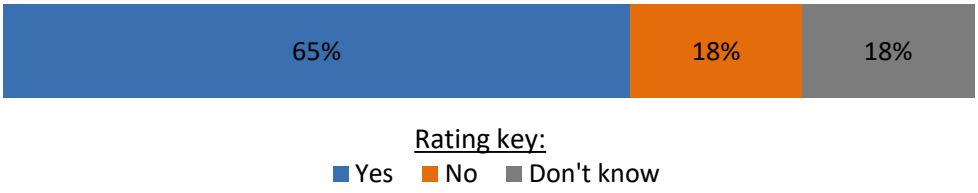
Additionally, when asked if they would want to play the same game again or be interested in playing a similar game about Mars. Most children said they would be interested in playing the same game again (87%, n=94, Figure 12) and in playing a similar game (92%, n=93), indicating that they found the game engaging.

Figure 12: *Children's interest in playing the game again or playing a similar game (n varies by question)*



Beyond interest in playing the game or a similar one, the game piqued many children's interest in the Moon and space exploration. When asked on the survey if they agreed with the statement "After playing the game today, I am MORE interested in the Moon or space exploration than I was before," 65% of children said they were more interested in these topics after playing the game (n=79, Figure 13).

Figure 13: *Children's agreement with the statement: "After playing the game today, I am <u>more</u> interested in the Moon or space exploration than I was before." (n=79)*



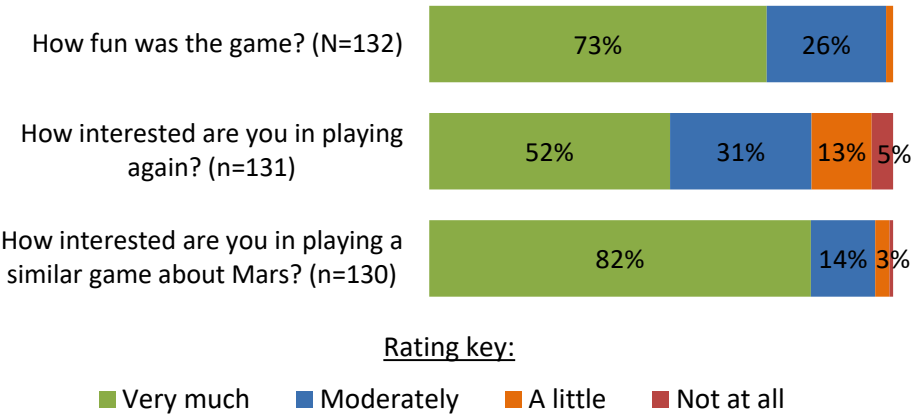
<u>Adults (13+):</u>

Similar trends were seen in looking at the data for adults. Adults were asked to rate on a 4-point scale from "Not at all" to "Very much" how fun they found the game as well as how interested they would be in playing the game again or in playing a similar game about Mars. All adults found the game fun, with 73% selecting the highest rating of "very much" (N=132,

Figure **14**). 83% of adults expressed at least moderate interest in expressed interest in playing the game again, with about half saying they were "very interested" in playing it again (52%,

n=131). In addition, 82% of adults said they would be very interested in playing a similar game (n=130).

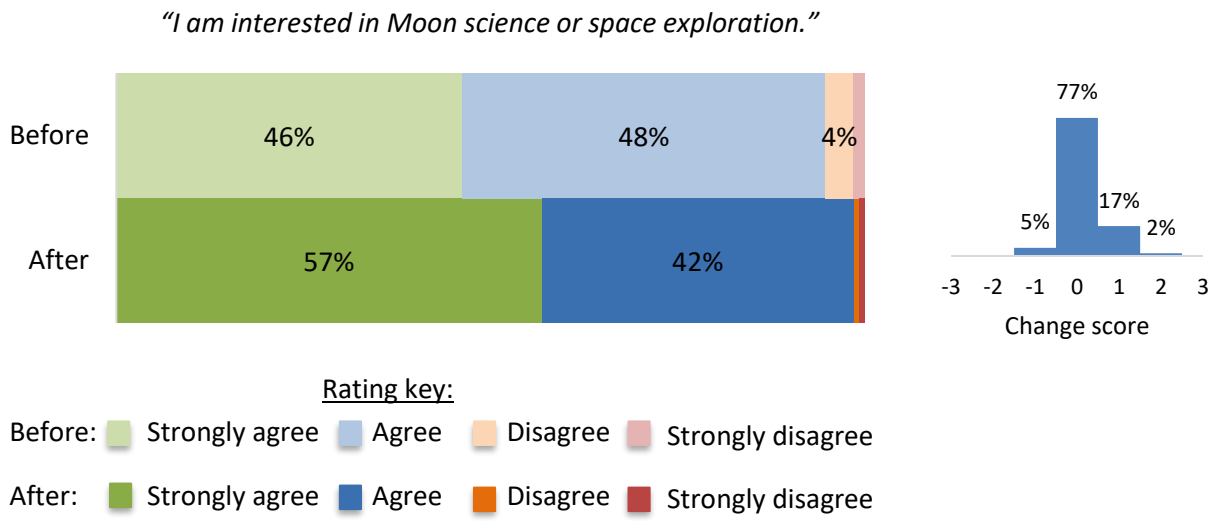
Figure 14: *Adults' ratings of how engaging they found the game (n varies by question)*



As for investigating the extent to which adults learned about the Moon and space exploration (see Section 3.1.2), adults were asked to rate their agreement on a 4-point scale in a retrospective pre-post question on the public evaluation survey to the following statement: "I am interested in Moon science or space exploration." Adults interest in these topics had increased after playing the game (Figure 15). Before playing the game, most were interested in Moon science and space exploration with 94% responding either "agree" or "strongly agree." And they became even more interested in these topics after using the game as seen by the increase from 46% of adults selecting "strongly agree" for their level of agreement before playing the game, to 57% strongly agreeing after playing the game. The changes in interest were statistically significant (N=132, p=0.001, z=-3.32, r=-0.205) with a small effect size indicating that only slight increases occurred.

Looking at the extent of change experienced for participants, individuals reported changes in ratings ranging from decreasing by one point to increasing by two points (N=132, Figure 15). Most adults reported no change in their rating (77%, N=132). For adults, whose ratings changed, they most commonly reported moving up the scale by one point (73%, n=30), such as going from "agree" to "strongly agree."

Figure 15: *Adults' ratings of their interest in Moon science or space exploration (N=132)*



Summary:
Taken together, these responses indicate that members of the public who used the game found the game format engaging. Not only did they want to use the Moon Adventure Game or a similar one again, they also indicated that the game increased their interest in the content areas of Moon science and space exploration. These findings indicate that the Moon Adventure Game format is promising and that it should be considered for future projects as a way to engage visitors and increase their interest in different content areas.

3.1.4 Participants' science identities increased after playing the game.

Children (12 & under):
Children were asked on the public evaluation survey whether they had done anything like what a scientist does. Nearly all children thought that they had done something like what a scientist does while playing the game (95%, n=87,
Figure 16), indicating that they identified what they were doing in the game as science.

In addition, they were asked if they agreed with the statement: "After playing the game today, I feel MORE like a 'science person' than I did before." Over half of children reported feeling more like a "science person" after playing the game (61%, n=79, Figure 17).

Figure 16: *Children's ratings for "Did you do anything in the game that was like what a scientist does?" (n=87)*

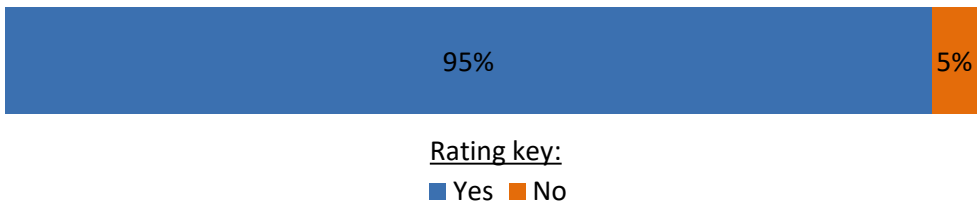
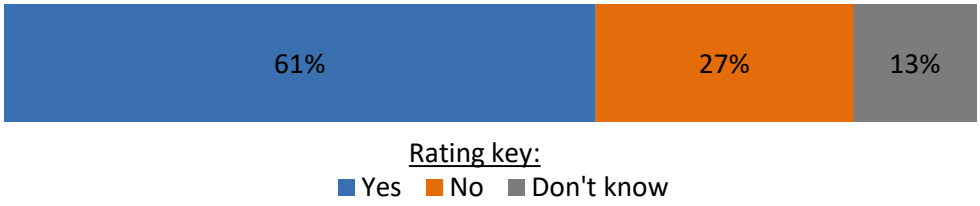


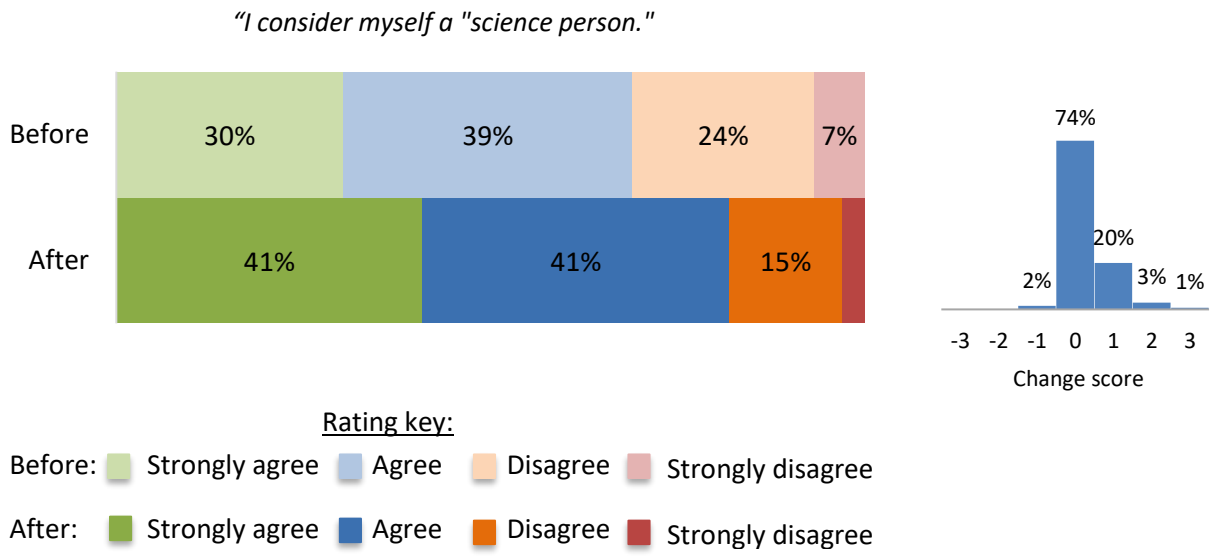
Figure 17: *Children's agreement with the statement: "After playing the game today, I feel more like a 'science person' than I did before." (n=79)*



Adults (13+):

Adults were asked on the survey to rate their agreement on a four-point scale (strongly disagree to strongly agree) to the statement: "I consider myself a 'science person,'" using a retrospective pre-post question format like was used in measuring impacts on the extent of adults' knowledge about (see Section 3.1.2) and interest in Moon science and space exploration (see Section 3.1.3). Similar to the trends seen in children's responses about their science identities, adults' science identities showed increases after playing the game with 30% saying they would have strongly agreed before playing the game and 41% agreeing after playing the game (N=132, Figure 18). These changes were statistically significant with a moderate effect size indicating an incremental increase in ratings were experienced by some adults (N=132, p=0.000, z=-4.957, r=-0.305). Individuals reported changes in their ratings that ranged from moving down the scale one point to moving up three points. Most adults had no change to their rating (75%, N=132, Figure 18), but, for those who did, they most commonly reported moving up one point on the rating scale (84%, n=32), such as moving from "agree" to "strongly agree" or "disagree" to "agree."

Figure 18: *Adults' ratings of their science identities (N=132)*



Summary:

These findings indicate that the game had impacts on players' science identities. In particular, the game helped some visitors feel more like a science person. As indicated by data from the child surveys, this is likely because visitors felt like they were participating in activities similar to what a scientist does. For example, the role-playing format of the game may have supported visitors in seeing themselves as scientists as they worked to solve the game's puzzles. In

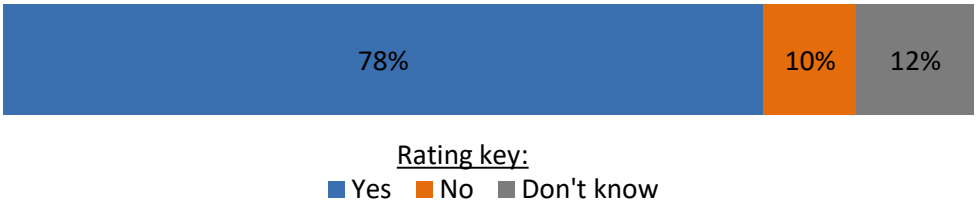
addition, playing the game takes about 25 minutes which is a moderate amount of time to engage in an activity and playing the game requires active engagement by the learner. Together, these aspects may support shifts in science identity greater than may be observed in modes that are shorter and less active.

3.1.5 Playing the game increased participants' confidence in their ability to learn about the Moon or space exploration.

Children (12 & under):

Using the same format described in the above sections, children were asked if they agreed with the following statement: "After playing the game today, I am MORE confident I can learn more about the Moon or space exploration in the future. 78% of children said after playing the game they felt "more confident" in their ability to learn about the Moon or space exploration in the future (n=83, Figure 19).

Figure 19: *Children's agreement with the statement: "After playing the game today, I am more confident I can learn about the Moon or space exploration in the future." (n=83)*

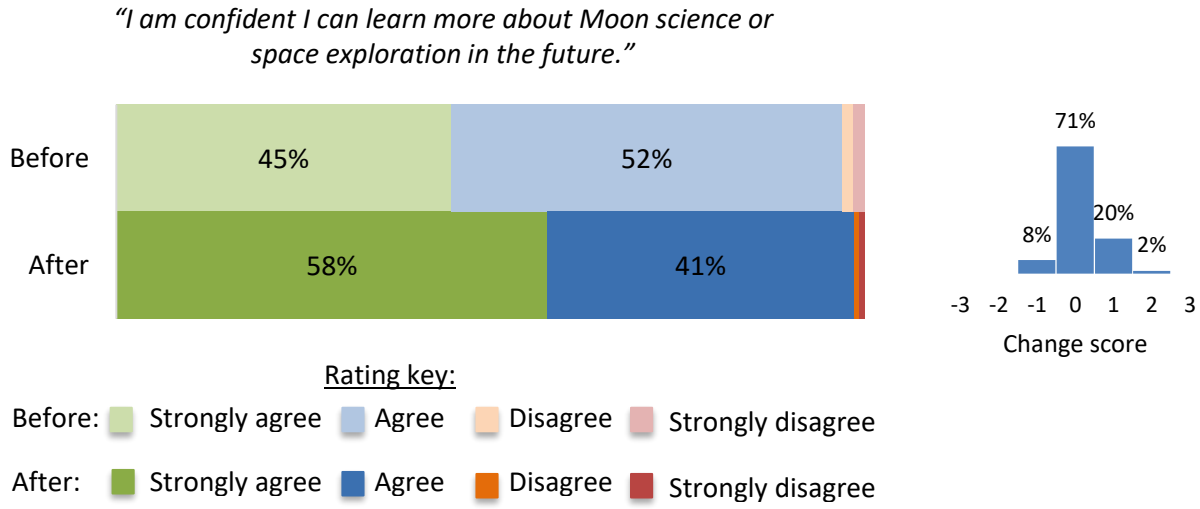


Adults (13+):

The game's effect on adults' confidence in their ability to learn more about these topics was measured through a retrospective pre-post question on the public evaluation survey. Adults were asked to rate their agreement on a 4-point scale for each timepoint to the following statement: "I am confident I can learn more about Moon science or space exploration in the future." Adults started with a high level of confidence in their ability to learn more about these topics with 45% of adults selecting "strongly agree" and nearly all agreeing or strongly agreeing with the statement, "I am confident I can learn more about Moon science or space exploration in the future" (N=132, Figure 20). And they became even more confident with 58% of adults selecting "strongly agree" (N=132). The increase in ratings was statistically significant but had a small effect size. This means that adults experienced only slight increases in their confidence (N=132, p=0.003, z=-3.016, r=-0.186).

Indeed, if we look at the change in scores from the pre-to-post-rating, we see that the change scores ranged from -1 to 2 with 71% of adults reporting no change (Figure 20). Of those whose ratings changed, the majority increased by one point on the rating scale (68%, n=38). Nearly all of these respondents moved from selecting "agree" to "strongly agree" (96%, n=26).

Figure 20: *Adults' ratings of their confidence in being able to learn more about Moon science or space exploration (N=132)*



Summary:

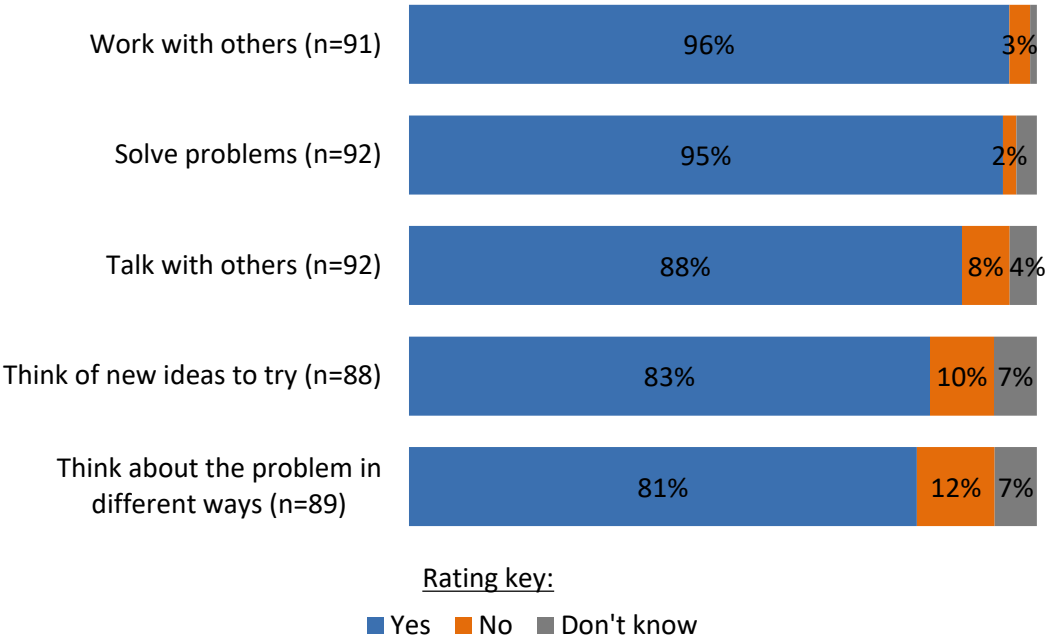
The data indicate that the game had a moderate impact on visitors' confidence in their abilities, particularly around learning about Moon science and space exploration. This impact may be due to success in learning more about these topics in playing the game. Most participants reported that they knew more about Moon science and space exploration after playing the game (Figure 9 and Figure 10). The experience of having learned about these topics may create a positive feedback loop, and increasing their confidence they could learn more about them in the future.

3.1.6 Participants practiced 21st-century skills related to collaboration, problem solving, critical thinking, and innovation through playing the game.

Children (12 & under):

The game aimed to develop players' 21st-century skills related to innovation, collaboration, critical thinking, and problem solving. To understand which of these skills children felt they had used, children were asked if they had done the following things while playing the game (21st-century skill noted in parentheses): "work with others" (collaboration), "solve problems" (problem-solving), "talk with others" (communication), "think of new ideas to try" (innovation), and "think about the problem in different ways" (critical thinking). Almost all children reported using each of the following 21st century skills in playing the game: work with others (96%, n=91, Figure 21) solve problems (95%, n=92), talk with others (88%, n=92), think of new ideas to try (83%, n=88), think about the problem in different ways (81%, n=89).

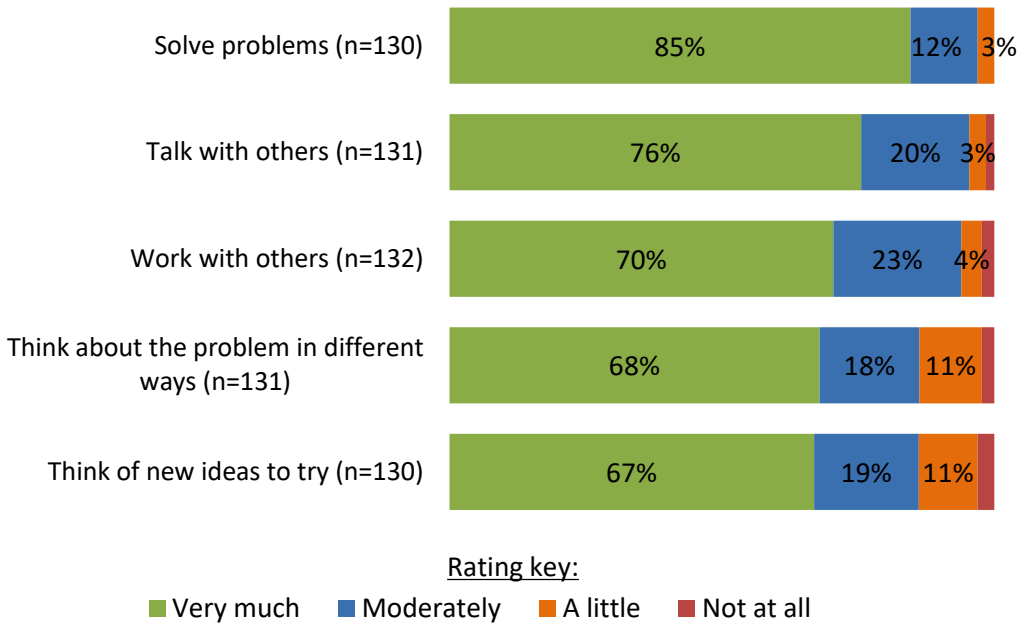
Figure 21: *Children's ratings of if they used these 21st century skills in the game (n varies)*



Adults (13+):

Likewise, adults were asked to rate how much they did these actions (e.g., work with others, talk with others, think of new ideas to try, think about the problem in different ways, solve problems) to help their team solve the game's challenges. Adults felt they had done all these things, with the following percent of adults saying they had "very much" done the respective actions: 85% for "solve problems" (n=130, Figure 22), 76% for "talk with others" (n=131), 70% for "work with others" (N=132), 68% for "think about the problem in different ways" (n=131), and 67% for "think thought of new ideas to try" (n=130).

Figure 22: *Adults' ratings of how much they used these 21st century skills in the game (n varies)*



To understand in how visitors used these skills, adults were asked to share an example of using these skills through an open-ended question on the post-game survey. Examples were coded to understand both what skills were used and in what activities they were used. Of the 98 total responses, 69 individuals described at least one skill (21st-century or otherwise), and 61 individuals described at least one activity.[4] Please see Table 5 for the list of skills identified and Table 6 for the list of activities identified as well as for example quotes for each category.

"Work with others" (collaboration) was the most frequently talked about skill (32%, n=98, Table 5), participants saying things like, "It made you work with others" and "The blocks had everyone participating. Child matched the craters, Grandpa saw the arrows, and Mom saw the words." Then, the next most frequently described skills were "talk with others" (19%, n=98, communication), and "solve problems" (15%, n=98, problem solving). These results mirror what was seen in the closed-ended responses in Figure 22 where most adults (70%-85%) reported having used each of these skills "very much."

To understand in what ways these skills were used, responses which described both a skill and an activity were analyzed. Of the total 98 responses, there were 38 responses in which both a skill and an activity were identified (39%, n=98). Due to the small number of these responses, the following results are limited but suggest some ways in which visitors utilized the 21st-century skills of interest in the game. In these responses, "reconnect the power supply" from Challenge 5 (34%, Table 7) and "match rover data to locations on the map" from Challenge 2 (26%, Table 8) were the most frequently described activities (irrespective to which skill was described). In terms of skills, "work with others" was identified in responses describing activities for four of the five challenges in the game, illustrating that this skill was used in a variety of activities across the game (Table 9). In addition, "solve problems" represented only 18% of the 38 responses with both a skill and an activity (Table 10), but the responses about problem

[4] In addition, 6 responses were coded as "Other." They described neither skills nor activities.

solving mostly illustrated its use in reconnecting the power supply in Challenge 5 (71%, n=7, Table 10). For a full table of the intersection of skill and activity codes, see Appendix D.

While the above analysis focuses on trends seen in the intersection of coding for skills and activities related to the individual challenges of the game, one response was of note in that it highlighted how 21st-century skills were used in other ways within the game, too. One participant shared how their group practiced communication ("talk with others") to communicate with the museum staff member facilitating (e.g., mission control): "Playing w/ my daughter we communicated about all the tools and following instructions and calling mission control."

Table 5: *Skills identified in adults' examples of 21st-century skill usage in the game (n=98)*

Skills	Frequency (%)	Response Examples
Work with others	31 (32%)	*"We had to work together to figure out the clues and it [was] hands-on fun for the kids!"* *"Teamwork"* *"We all took pieces of the moon crater map and worked together"*
Talk with others	19 (19%)	*"We had to share ideas to solve the problems"** *"Talking about which way the blocks should go on the map in order to get the correct message."* *"Talked with kids to map out rover"*
Solve problems	15 (15%)	*"Problem solving"* *"Figured out restoring the power"*
Think of new ideas to try	10 (10%)	*"We had to work together to try and close the circuit. Everyone thought of ideas to try."** *"With the blocks -- matching arrow-to-arrow (new ideas to try)"*
Think about the problem in different ways	5 (5%)	*"Lots of critical thinking used."* *"Worked together to try different methods to solve problems"*
Other skills	8 (8%)	*"Come up w/ a plan"* *"Fine motor skills while catch the blue cubes."*
No skill mentioned	23 (23%)	*"FLIPPING TEMPLATE To MATCH SURFACE"* *"Held the conductor pieces together"*

*Responses where more than one skill was mentioned

Table 6: *Activities identified in adults' examples of 21st-century skill usage in the game (n=98)*

Activities:	Frequency (%)	Response Examples
Reconnect the power supply	25 (26%)	*"The electric circuit problem"* *"Though of different ways to arrange conductive pieces"*
Match rover data to locations on map	15 (15%)	*"Placing overlays on map"* *"Worked together to place [blocks.] Figured out we needed to line up arrows to read message"*
Extract water from frozen lunar material	6 (6%)	*"Used a cooperative assembly line for the ice mining station"* *"When my teammate put an 'ice cube' in wrong and I [helped]"*
Fill your oxygen tanks	5 (5%)	*"Electrolysis"* *"We couldn't get bubbles in the oxygen separation experiment. We tried adding more salt and checked connections. We [finally] found that we needed to change batteries."*
Make a travel plan for your rover	3 (3%)	*"Talked with kids to map out rover"* *"One child provided part of grid coordinates + other child provided 2nd part"*
Other activities within game	1 (1%)	*"Playing w/ my daughter we communicated about all the tools and following instructions and calling mission control"*
Activity could not be identified	7 (7%)	*"Kids worked together nicely to figure out all the clues"* *"Discussed each challenge"*
No activity mentioned	31 (32%)	*"Kids worked together to strategize"* *"Sharing resources to solve the problem quickly"*

Table 7: *Adults responses with both a skill and an activity identified that were coded as the activity "Reconnect the power supply" in Challenge 5 (n=38)*

Challenge 5: Reconnect the power supply (34%, n=38)
• Participant 38: "*Though of different ways to arrange conductive pieces*" • Participant 54: *"Dad [snagged] a wire from the previous step. Some felt it was cheating [others] saw the need for the success of the mission"* • Participant 68: *"We had a hard time getting the power supply working [again], so we tried different configurations to get it to work. We talked amongst one another to solve the problem. It was a bit of trial and error."* • Participant 106: *"Worked together to hold together circuit for #5"* • Participant 113: *"Suggested a different implement to use to conduct electricity"* • Participant 118: *"Talking about what conductors do vs insulated items"* • Participant 119: *"We talked out loud about how to solve the problems in a quick and efficient manner such as when we conducted electricity and decided to use the ruler"* • Participant 121: *"We had to work together to try and close the circuit. Everyone thought of ideas to try."* • Participant 122: *"My son was able to figure out how to go longer by using a metal ruler instead of a smaller spinon (sp?) [sic]"* • Participant 173: *"Figured out restoring the power"* • Participant 175: *"we worked together to find multiple different conductive tools. everyone observed a different piece of the puzzle"* • Participant 181: *"We talked together to figure out new ideas on the last challenge."* • Participant 212: "*Working as a team was important for challenge 5."*

Table 8: *Adults' responses with both a skill and activity identified that were coded as the activity "Match rover data to locations on the map" in Challenge 2 (n=38)*

Challenge 2: Match rover data to locations on the map (26%, n=38)
• Participant 37: "*Worked and talked to complete the 2nd [challenge]. Tried different ideas and worked together"* • Participant 43: "*Tried a new code for lock"* • Participant 70: "*We all took pieces of the moon crater map and worked together"* • Participant 91: *"Talking about which way the blocks should go on the map in order to get the correct message."* • Participant 105: *"With the blocks -- matching arrow-to-arrow (new ideas to try)"* • Participant 136: *"To solve the rover location data, we had to problem solve what the overlays and cubes meant"* • Participant 142: *"Worked as a team to solve problem two. Each person gave an idea on how to solve the puzzle."* • Participant 167: *"The blocks had everyone participating. Child matched the craters, Grandpa saw the arrows, and Mom saw the words."* • Participant 174: *"I helped everyone to realize the sides need to be right side up and look at the letters on the blocks in a certain angle"* • Participant 179: *"Worked together to place [blocks.] Figured out we needed to line up arrows to read message"*

Table 9: *Adults responses with both a skill and an activity that were coded as the skill "Work with others" (n=38)*

Work with others (42%, n=38)
Challenge 1: Make a travel plan for your rover: • Participant 93: *"One child provided part of grid coordinates + other child provided 2nd part"* **Challenge 2: Match rover data to locations on the map:** • Participant 37: *"Worked and talked to complete the 2nd [challenge]. Tried different ideas and worked together"* • Participant 70: *"We all took pieces of the moon crater map and worked together"* • Participant 142: *"Worked as a team to solve problem two. Each person gave an idea on how to solve the puzzle."* • Participant 167: *"The blocks had everyone participating. Child matched the craters, Grandpa saw the arrows, and Mom saw the words."* • Participant 174: *"I helped everyone to realize the sides need to be right side up and look at the letters on the blocks in a certain angle"* • Participant 179: *"Worked together to place [blocks.] Figured out we needed to line up arrows to read message"* **Challenge 3: Extract water from frozen lunar material:** • Participant 85: *"Assisted on keeping claw straight for my injured team member."* • Participant 169: *"Used a cooperative assembly line for the ice mining station"* • Participant 186: *"When my teammate put an 'ice cube' in wrong and I helped"* **Challenge 5: Reconnect the power supply:** • Participant 106: *"Worked together to hold together circuit for #5"* • Participant 121: *"We had to work together to try and close the circuit. Everyone thought of ideas to try."* • Participant 175: *"we worked together to find multiple different conductive tools. everyone observed a different piece of the puzzle"* • Participant 212: *"Working as a team was important for challenge 5."* **Activity could not be identified:** • Participant 141: *"Working together to solve the puzzles"* • Participant 166: *"Kids worked together nicely to figure out all the clues"*

Table 10: *Adults responses with both a skill and an activity that were coded as the skill "Solve problems" (n=38)*

Solve problems (18%, n=38)
Challenge 1: Make a travel plan for your rover • Participant 94: *"Figuring out the code for the lock"* **Challenge 2: Match rover data to locations on the map** • Participant 136: *"To solve the rover location data, we had to problem solve what the overlays and cubes meant"* **Challenge 5: Reconnect the power supply** • Participant 54: *"Dad [snagged] a wire from the previous step. Some felt it was cheating [others] saw the need for the success of the mission"* • Participant 68: *"We had a hard time getting the power supply working [again], so we tried different configurations to get it to work. We talked amongst one another to solve the problem. It was a bit of trial and error."* • Participant 119: *"We talked out loud about how to solve the problems in a quick and efficient manner such as when we conducted electricity and decided to use the ruler"* • Participant 173: *"Figured out restoring the power"* • Participant 122: *"My son was able to figure out how to go longer by using a metal ruler instead of a smaller spinon (sp?) [sic]"*

Professionals' observations of visitors' use of 21st-century skills:

During the professional interviews, we asked professionals to share examples of and trends they had observed in visitors using 21st-century skills such as innovation, critical thinking, problem solving, and collaboration in playing the game. Professionals described observing visitors practicing these skills—particularly collaboration, problem solving, and critical thinking—highlighting how groups used these skills both throughout the game and in solving specific challenges.

Some professionals described how audiences had to use 21st century skills across all the game activities. One professional shared that they saw teamwork and critical thinking being used across stations in the game:

> *Definitely, as the family units came through, you could see the brother and sister, especially at my station like working together to figure out what did these cards mean and how do we put them in the right order… I think that's what the educators here like about this game is that it forces you to work as a team, it forces you to evaluate and think critically at almost every station. I could hear them next door at the electrical one and talking about why the pencil wasn't working and why the fork did work.*

Another professional described how the design of the game required visitors to collaborate and problem solve in each of the challenges, which was an exciting experience for visitors:

> *Fortunately, that's the way the moon game is set up, is that they have to collaborate, and they have to problem solve… for the most part, they are doing all of that investigating and learning and thinking about…each of the five stations as they work through them. And they get very excited about this stuff.*

These observations illustrate 21st-century skills, particularly collaboration and problem solving, may be practiced throughout the game, and that the game design supports visitors in practicing these skills.

Some professionals shared examples of how players used 21st-century skills in specific challenges. One talked about seeing problem solving and critical thinking being used both in Challenge 3 to extract water from frozen lunar material and in Challenge 5 to reconnect the power supply, saying:

> *I would definitely say critical thinking and problem solving. When they were trying to get that water sample to drop down, they were like, "We need more? Oh, maybe, if we add this cube here, or on that side it'll drop down better." And then the same thing for step five, the electricity one, trying to figure out why some carried electrical flow and why some didn't. They had to really think about that one.*

Other professionals shared examples about ways audiences used different skills in solving the same challenge. For example, one professional described how players problem solved to figure out how to match rover data to locations on the map in Challenge 2:

> *There was a lot of trying to problem solve, like "I'm pretty sure it's this one," but that would be off a map square and they were having to figure out exactly where the map square was for the rover. And then, it was oddly difficult for them at first to figure out [...] which way to put the block. Matching up the arrows and then also which color should be on top. They all got there in the end.*

And another professional talked about how players used critical thinking and collaboration to solve this same challenge, saying "There's this step in the game where they have to look at these blocks from a certain angle and...decode this message. You are definitely seeing them using some critical thinking there to do that. And collaboration for sure." These examples highlight specific activities in the game where visitors were observed practicing 21st-century skills, including how a range of skills were used in the activities.

Summary:

Both the public evaluation survey and professional interview data demonstrate that participants practiced 21st-century skills, while playing the game, related to collaboration, communication, problem-solving, innovation, and critical thinking. These skills were used in a variety of activities in the game, with example illustrating how skills such as collaboration were used across multiple activities in the game.

The public evaluation survey provided visitors' own perspectives on the extent to which they had used these skills and in what activities. Through these data, we saw visitors identifying that they had used these 21st-century skills. The professional interviews provided an additional avenue to understand how visitors practiced these 21st century skills in the game. Evidence from the professional interviews in many aspects mirrored and provided additional detail and context to what had been seen in the public evaluation survey. For example, professionals' observations provided additional examples highlighting where problem-solving and critical thinking were used by visitors. Professionals' observations helped illuminate how visitors used problem solving, such as in mapping rover data to locations on the map in Challenge 2 or across all challenges in the game. Additionally, most children and adults reported on the surveys having used critical thinking (thought about problems in different ways). But it was unclear in what activities critical thinking may have been used, as this skill was rarely identified in the adults'

examples on the public evaluation survey. The professional interviews provided another avenue to understand how critical thinking was being used. Professionals shared seeing critical thinking being used by visitors in working through mapping rover data to locations on the map (Challenge 2), extracting water from frozen lunar material (Challenge 3), and reconnecting the power supply (Challenge 5).

In summary, the Moon Adventure Game was designed to require the use of collaboration, communication, and problem solving in order to figure out the puzzles in the game, and it was effective in supporting practice and development of these 21st-century skills.

3.2 Professional Audiences

As outlined in Section 1.3, the evaluation questions guiding the professional summative evaluation work include:

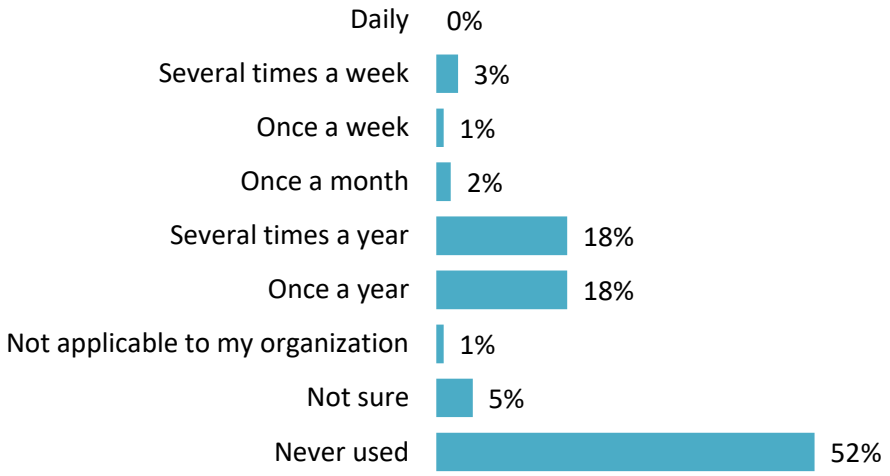
1) What kinds and how many professionals does the project reach?
2) What kinds of partnerships are formed between museums and community organizations through the project?
3) How do the educational products impact professionals' attitudes related to engaging the public in learning about space exploration, science, and engineering?

The following sections outline findings related to the above questions.

3.2.1 An estimated 414 professionals at 138 institutions used the Moon Adventure Game in 2021, and most were from small urban science centers and children's museums.

In 2021, the NISE Network team gathered toolkit reports from 327 institutions. As Figure 23 below shows, 138 of the 327 reporting institutions (42%) said they used the game in 2021. This number also represents 39% of the 355 organizations who received the game (since not all institutions complete their toolkit reports).

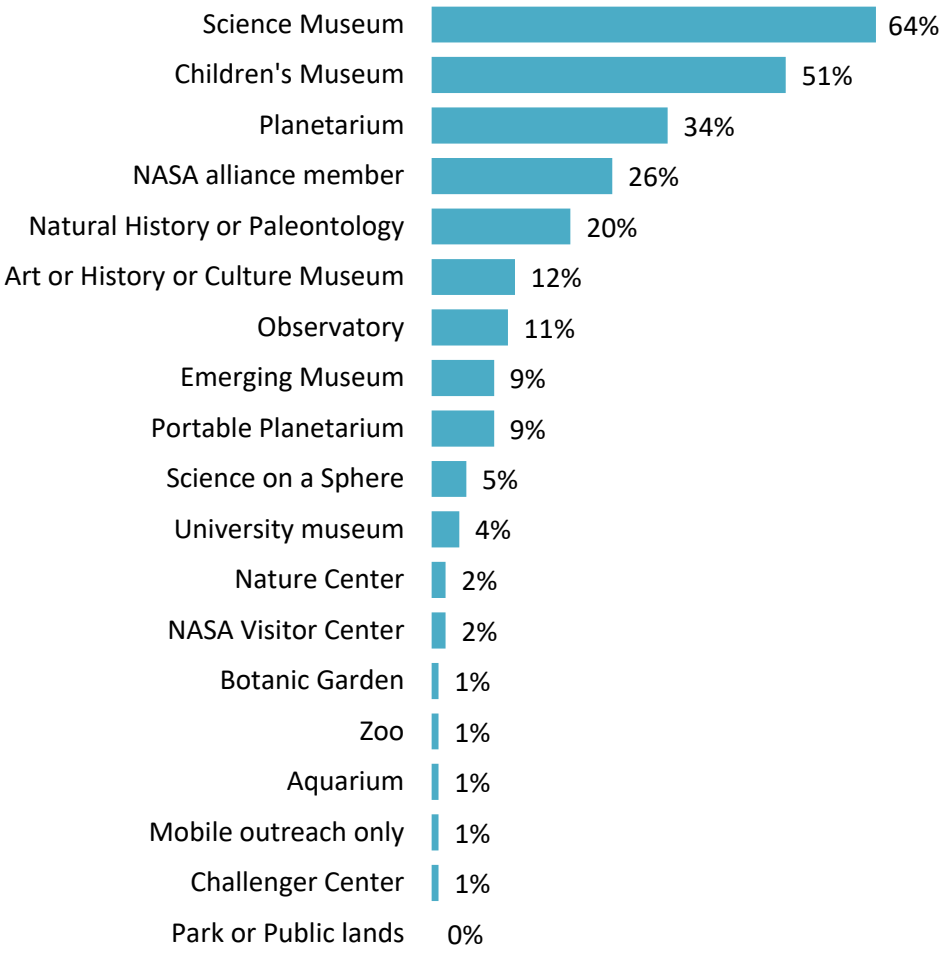
Figure 23: *Frequency of institutional use of the Moon Adventure Game in 2021 (n=327)*



Evaluators looked at NISE Network database information to learn about what types of institutions used the Moon Adventure Game. Institutions who used the game were primarily small urban science centers and children's museums, but also included many other types of institutions. As Figure 24 shows, nearly two-thirds of institutions who used the Moon Adventure

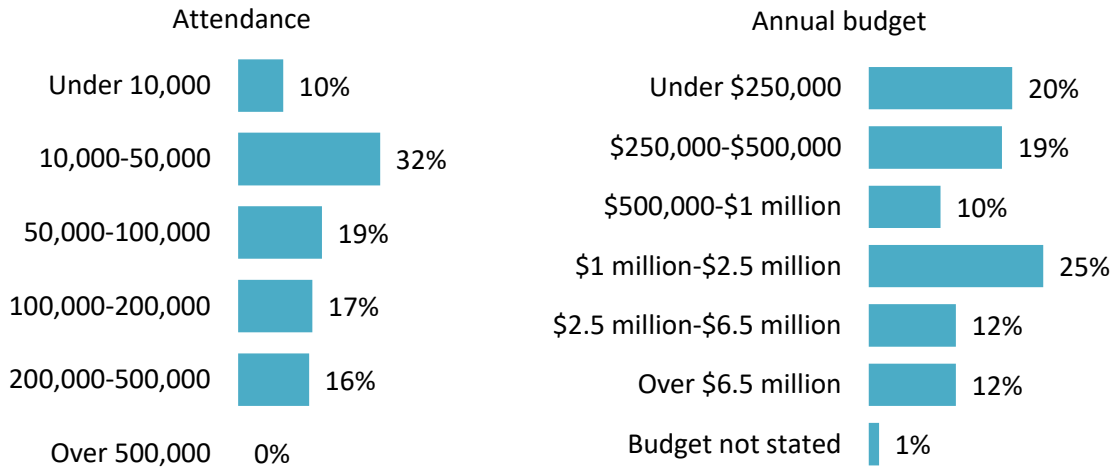
Game were science museums, just over half were children's museums, and there were 16 other institution types represented among sites using the Moon Adventure Game. Importantly, museums can be categorized as multiple institution types.

Figure 24: *Institutions using the Moon Adventure Game, by type (n=138)*



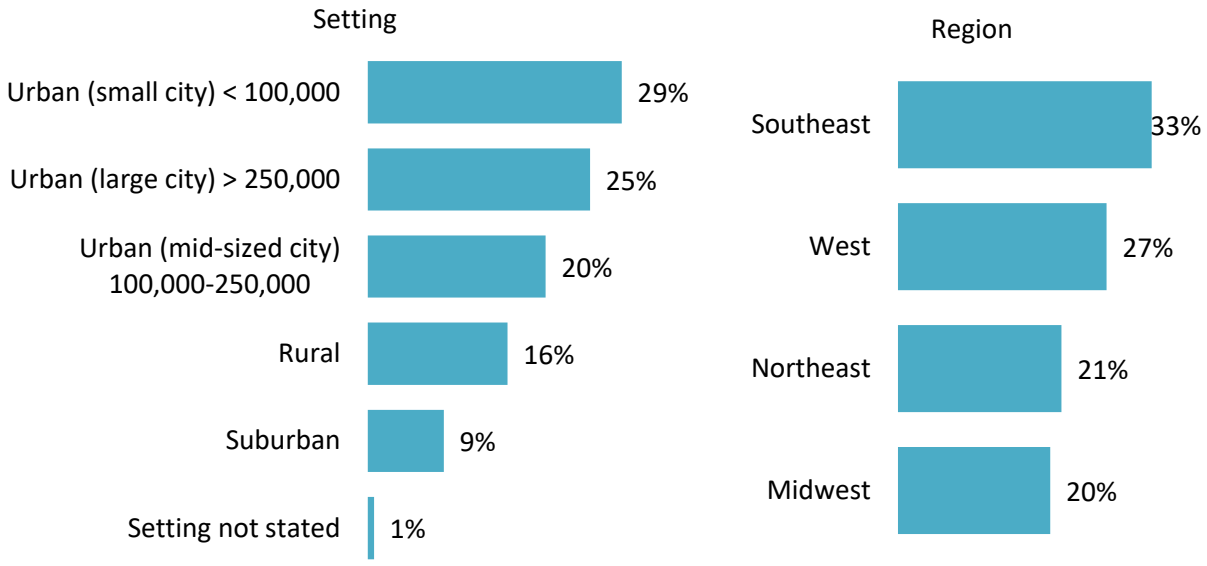
In terms of size, professionals using the Moon Adventure Game were generally situated at small- to medium-sized museums. The most common budget category for institutions using the game was the $1-2.5 million range, and the most common attendance category was the 10,000-50,000 range. While $1-2.5 million was the most common single budget category, 39% of museums had an annual budget under $500,000 (Figure 25).

Figure 25: *Institutions using the Moon Adventure Game, by attendance and annual budget (n=138)*



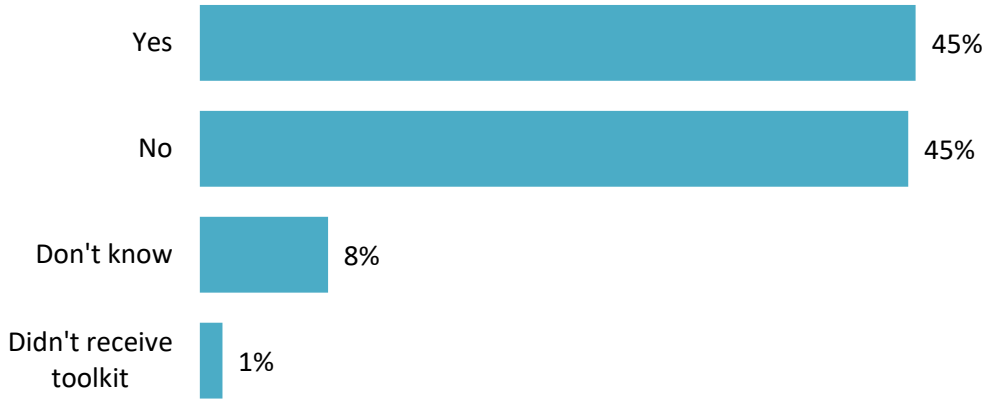
Finally, professionals using the Moon Adventure Game were located primarily in urban areas (most commonly small urban areas) in the Southeast region. As Figure 26 shows, three-quarters of institutions using the game were in urban areas, with 29% being in small cities (population under 100,000). While the Southeast was the most represented region at 33%, the least common region (Midwest) still represented 20% of institutions. See Figure 26 more detail.

Figure 26: *Institutions using the Moon Adventure Game, by setting and region (n=138)*



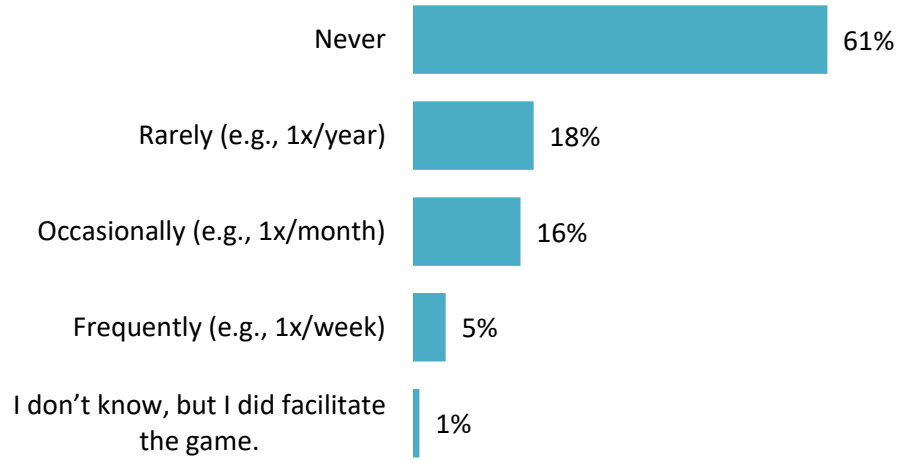
These toolkit report data mirror the data from the annual partner survey, in which professionals were asked about use of the game to filter them to the appropriate survey questions. Since the annual partner survey may be completed by multiple professionals at one institution, we use the toolkit report for reach estimates. However, as Figure 27 shows, just under half of professionals said their institution used the game, similar to what is seen on the toolkit report.

Figure 27: *Did your institution use the Moon Adventure Game with public audiences? (n=209)*



Annual partner survey respondents were also asked if they personally facilitated the Moon Adventure Game, since multiple people at one institution may facilitate the game. These data show that 39% of professionals personally facilitated the Moon Adventure Game, and that most commonly these professionals facilitated the game rarely (about once per year) or occasionally (about once per month) (Figure 28). Some interviewed professionals also shared that while they personally facilitated the game only a couple of times, they trained others to facilitate it.

Figure 28: *How often did you personally facilitate the Moon Adventure Game with public audiences? (n=209)*



The Moon Adventure Game leadership team estimates that three professionals per institution used the Moon Adventure Game. Therefore, if 138 institutions used the game in 2021, then it is estimated that a total of 414 informal science education professionals used the game in 2021. This number is lower than it could have been if not for the impact of COVID-19. For past toolkits prior to the COVID-19 pandemic, 98-100% of partners reported using toolkit materials. By contrast, on the 2021 reports, 88% of partners reported using toolkit materials. The pandemic forced science centers to close, furlough or lay off staff, and pivot to virtual programming, all of which reduced opportunities for professionals to facilitate the game.

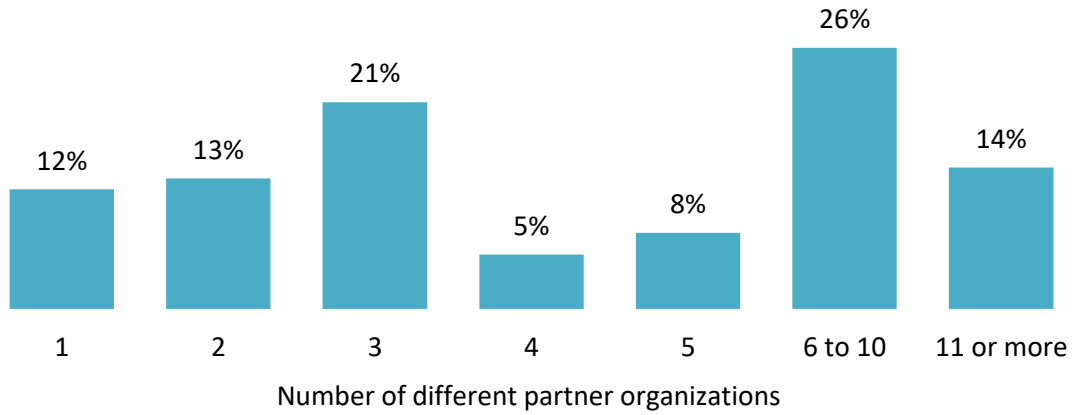
Summary:
As with public reach (see Section 3.1.1 The Moon Adventure Game reached an estimated 17,470 members of the public across the US in 2021.the Moon Adventure Game reached a moderate number of professionals, mostly at science centers and children's museums. Unlike public reach, the game was not as limited by its format in terms of engaging professionals. The game required staff to run it, and several institutions trained multiple staff members to facilitate the game. Unfortunately, one large factor for the moderate reach is the COVID-19 pandemic. Many sites were not able to implement the game at all, and others had limited visitation which also meant fewer opportunities for facilitation. Of the 335 organizations that received the game, 39% were able to implement it. This would almost certainly have been higher if not for COVID.

3.2.2 About two-thirds of institutions who used that Moon Adventure Game collaborated with external partners in 2021, most often forming partnerships with 6-10 organizations.

Professionals filling out their 2021 toolkit report were asked to describe any collaborations or partnerships formed in 2021 (not specific to the Moon Adventure Game). They were asked if they participated in any collaborations, and if so, how many and with whom. Of the 134 professionals answering on behalf of their institution, 87 (66%) said they did collaborate with external partners in 2021. When asked how many different organizations they collaborated with (with answer options of 1, 2, 3, 4, 5, 6-10, and 11 or more), the most common answer was 6-10, followed by three organizations and 11 or more organizations. See Figure 29 below.

To estimate the total number of collaborations, we multiplied each category for "number of partner organizations" by the number of NISE Net partners selecting that category. For example, three NISE Net partners reporting two collaborations equals six total unique collaborations. For the "6-10" category, an estimate of eight organizations was used (since 8 is the midpoint between 6 and 10). For organizations partnering with 11 or more organization, an estimate of partnerships with 15 organizations was used, recognizing that some will have partnered with fewer than 15 and some will have partnered with more. Using this method, an estimate of partnerships with 534 different organizations in 2021 is reached.

Figure 29: *Number of organizations involved in 2021 collaborations among institutions who used the Moon Adventure Game. (n=134)*



Though these collaborations may not have involved the Moon Adventure Game, in the professional interviews, professionals were asked specifically about any partnerships that formed or centered around the game. Among the 11 institutions represented by the 12 professionals interviewed, five described some type of partnership around the game.

In some cases, institutions partnered with organizations by bringing the Moon Adventure Game to their locations (e.g., libraries, community centers). Then, as one professional described, "Youth come in and use the game there." In other cases, the partner organizations would provide volunteers to facilitate the game. For example, one institution partnered with a local astronomical society and an observatory. "They came and volunteered at a bigger event," one professional from this institution explained, "leading activities for us." Still others described potential or lapsed partnerships, for example, hoping to partner with teachers for professional learning opportunities or a previous partnership with a university that slowed due to communication challenges.

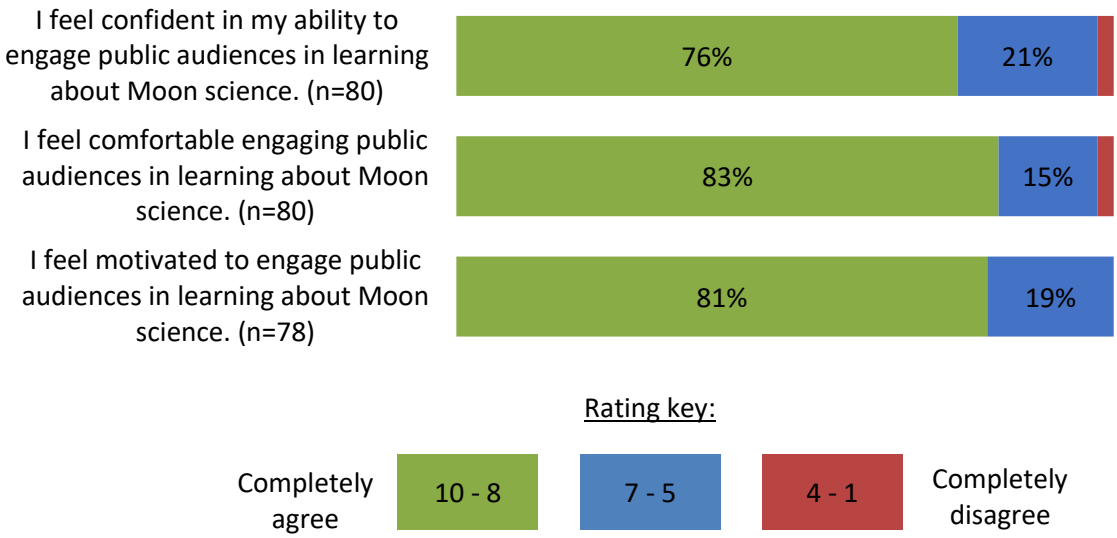
COVID-19 also limited the potential for partnerships for institutions. On the toolkit report, one professional shared an example of this situation: "Although we took a few programs to summer camps and programs, because the museum was closed, we did not really collaborate with others for programming. If the museum was open, it would have worked with several organizations." In some cases, official COVID policies prevented the kind of partnerships that institutions hoped to do. For example, in the interviews, one professional described this happening with a local Civil Air Patrol, and another described the same situation with local public libraries. It is not known how many partnerships would have been formed if not for COVID, but several institutions stated that it was a limiting factor for them.

3.2.3 Overall, professionals reported high levels of confidence, comfort, and motivation to engage publics in learning about Moon science and space exploration, and about half said that the Moon Adventure Game had a strong influence on these attitudes.

On the annual partner survey, professionals were asked to rate their confidence, comfort, and motivation around engaging public audiences in learning about Moon science, and then were asked the same about space exploration. They answered the questions using a 1-10 rating scale, where 1 was "Completely disagree" and 10 was "Completely agree." For summary purposes, in the charts below, professionals' ratings are categorized as high, medium, or low on this scale. "Low" ratings range from 1 to 4, "medium" ratings from 5 to 8, and "high" ratings from 8 to 10.

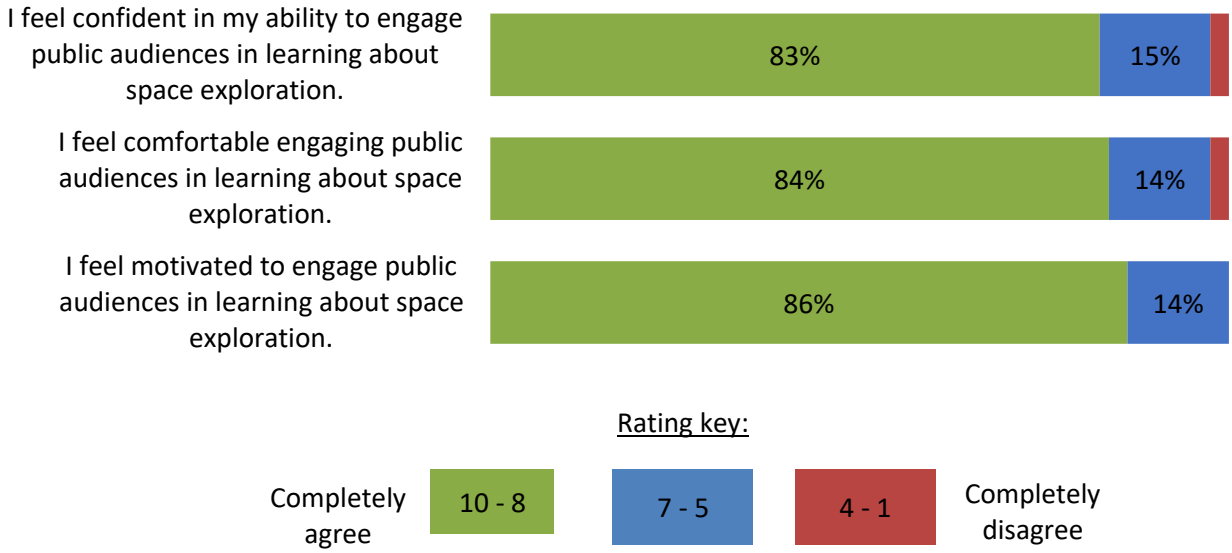
As seen in Figure 30, after using the game, professionals' ratings of their confidence, comfort, and motivation around engaging publics in learning about Moon science were generally high. For the topic of Moon science, between 76% and 83% of professionals gave high ratings to the statements, indicating strong agreement. More professionals gave high ratings for their *comfort* than for their confidence or motivation. However, no professionals gave low ratings to the statement about their *motivation* to engage publics in learning about Moon science.

Figure 30: *Professionals' ratings of their comfort, confidence, and motivation to engage publics in learning about Moon science (n varies)*



For space exploration, the ratings were even slightly higher, with 83% to 86% of professionals giving high ratings to the three statements (Figure 31). In the case of science exploration content, more professionals expressed strong agreement that they were *motivated* engaging publics in learning about space exploration than they were confident or comfortable—but all ratings were high. Again, no professionals gave low ratings to the statement about their *motivation* to engage publics in learning about space exploration.

Figure 31: *Professionals' ratings of their comfort, confidence, and motivation to engage publics in learning about space exploration (n=80)*

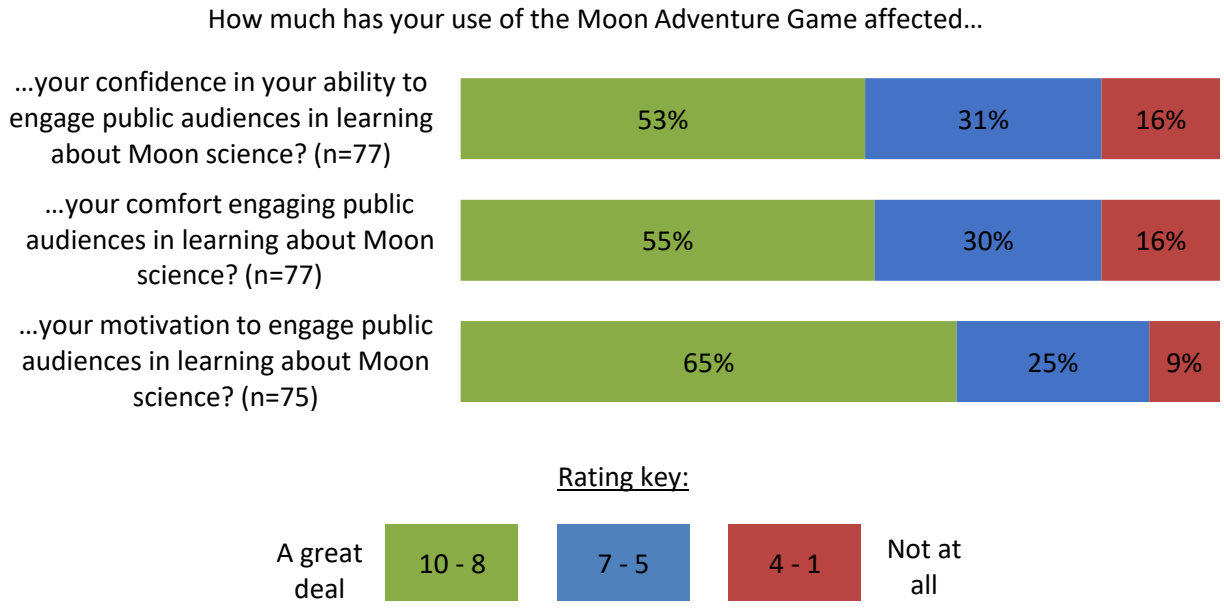


After answering questions about their overall confidence, comfort, and motivation to engage publics in learning about Moon science and space exploration, professionals were asked to rate how much their use of Moon Adventure Game affected those attitudes. They again answered the

questions using a 1-10 rating scale, where in this case 1 was "Not at all" and 10 was "A great deal."

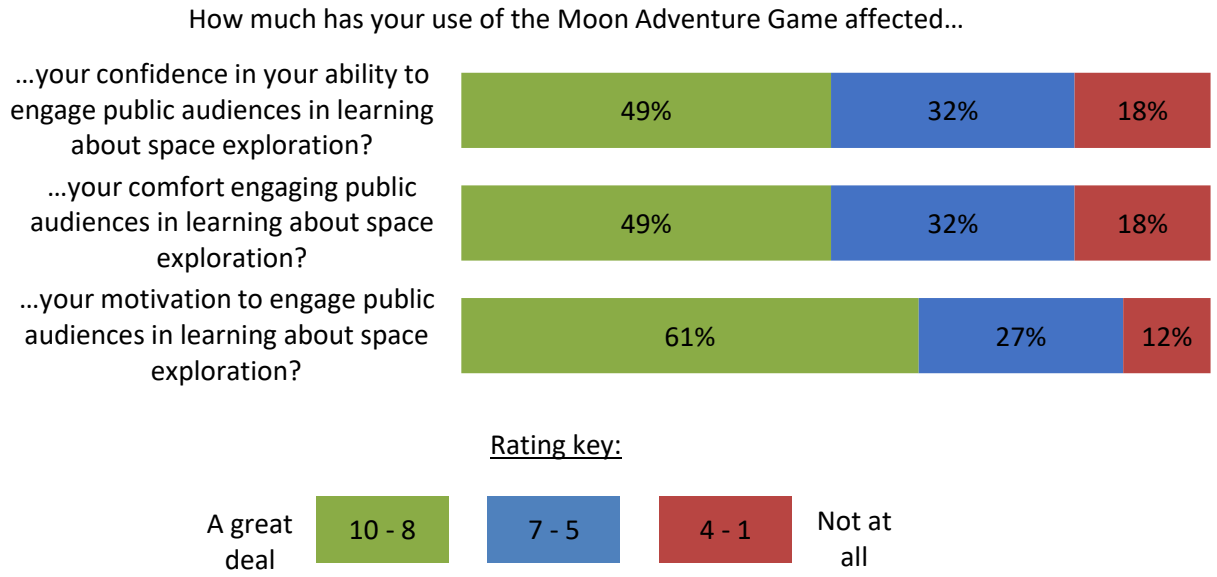
Overall, about half of professionals said that the Moon Adventure Game had strong effects on their confidence and comfort in engaging publics in learning about Moon science, indicated via high ratings. Professionals reported that the game had even stronger effects on their motivation, with 65% of professionals giving high ratings to the motivation statement (Figure 32).

Figure 32: *Professionals' ratings of how much their use of the Moon Adventure Game affected their confidence, comfort, and motivation to engage publics in learning about Moon science (n varies)*



For space exploration, the trend was similar, with just under half of professionals saying the game affected their confidence and comfort a great deal, and slightly more (61%) saying that the game affected their motivation a great deal (Figure 33).

Figure 33: *Professionals' ratings of how much their use of the Moon Adventure Game affected their confidence, comfort, and motivation to engage publics in learning about space exploration (n=77)*



3.2.4 Although many professionals stated that their confidence, comfort, and motivation were already high prior to using the Moon Adventure Game, they still said the game's style/format and outcomes affected these attitudes.

To help learn more about why and how the game affected professionals' comfort, confidence, and motivation, respondents to the annual partner survey were asked to reflect on what aspects of the Moon Adventure Game most affected those attitudes in an open-ended question. As seen in

Table **11**, about half of professionals (48%, n=60) said that something related to the format or style of the game most affected their attitudes. The second most common aspect, cited by 23 professionals, was the general outcome of the game for participants.

Table 11: *Code categories for professionals' responses to the question, "What aspects of the Moon Adventure Game most affected your confidence, comfort, or motivation in engaging public audiences in learning about Moon science or space exploration?" (n=60)*

Code	Frequency
Format/style *	29
Outcomes *	23
Components *	11
Nothing/don't know/didn't use	7
Prior Knowledge	6
Content/topic	5
Other	4
Accurate and authentic science	3

*Code contains subcodes

By "format" or "style," professionals most often meant the structure and presentation of the information in the game. For example, one professional explained, "I like how there are little science concepts peppered in each station." Another cited "the simplicity with which the space explorations are illustrated." Professionals also cited many other aspects of the game format or style that contributed to their attitudes toward engaging publics. Table 12 shows the further breakdown of codes within "Format/style," along with examples.

Table 12: *Subcodes for the "Format/style" main code (n=29)*

Code	Frequency	Response Examples
Format/style (subcodes below)	**29**	
Information structure/ presentation	8	*"The game is set up so the facilitator has the information needed to lead the groups in a comprehensive way."*
Easy to use	4	*"This game was great because it was a nice pre-packaged activity that took little work for me to set up…"*
Engaging	4	*"The format of the game is engaging for kids, so it's fun to facilitate with different audiences. …"*
Stations	4	*"… The different stations effectively introduce different topics related to the moon/space exploration, in a way that's approachable for people, even if they don't have much background knowledge about the subject."*
Roleplay/ storytelling	4	*"The storytelling aspect invites people to get more involved in the process which has aided in the way I think about facilitating space exploration content."*
Facilitator support	4	*"I really appreciate the great detail that is provided in the game manuals and instructions, it made learning the activities fairly easy and it also made teaching volunteers to facilitate the activities very easy."*

Pre-packaged	4	*"I think that knowing that I had a complete kit and the training and background videos helped me feel confident presenting this program."*
Other format aspects	4	*"… I think the game is a great way for audiences to experience the importance of 'soft skills' (e.g., cooperation, teamwork, planning, precision, method, creative thinking, etc.) in addition to scientific background knowledge."*
Hands-on/ interactive	3	*"It gives students a hands-on approach to learning about Moon exploration…"*

After format and style, professionals said the *outcomes* of the game for themselves or the public most contributed to their attitudes about it. In other words, trying the game and seeing how much fun it was to facilitate and how much public audiences enjoyed it made professionals more comfortable, confident, and motivated to keep using it. For example, one professional said, "Learning more information about the moon and working with students has impacted my thoughts about facilitating moon activities." Another explained, "They really enjoyed seeing the oxygen and hydrogen bubbles—made it feel like an 'aha' moment." Table 13 shows the further breakdown of codes within "Outcomes," along with examples.

Table 13: *Subcodes for the "Outcomes" main code (n=23)*

Code	Frequency	Response Examples
Outcomes (subcodes below)	**23**	
Fun	7	*"The resources give a fun way to talk about science. …"*
Positive visitor feedback/success facilitating	6	*"We used the game as a base to make a science themed murder mystery game that our middle schoolers loved."*
Facilitator learning	6	*"My feedback includes building the capacity of my teen facilitators most of which were new. The content was completely new to them and encompassed aspects of the moon that were not familiar to them."*
Impacts on practice	2	*"The game inspired me to suggest we reimagine our existing space station exhibit into a Moon or Mars habitat."*
Other outcomes	2	*"The practice of finding and then delving into details through conversations during the mission—which being longer than most—created both a challenge and an opportunity for an even deeper dive. Participant focus could shift from mission to meaning."*

In addition to format/style and outcomes, professionals cited things like specific game components, prior knowledge, and the content/topic of the game as aspects that affected their comfort, confidence, and motivation to engage publics in learning about Moon science and space exploration. A full table of codes with examples can be found in Appendix E.

In the interviews, professionals were asked to explain more about their responses for the rating statements about comfort, confidence, and motivation and the game's effect on each attitude. For example, professionals might be asked more about the reasons why they said the game did

or did not affect their comfort, confidence, and motivation. Interviewers typically read professionals' ratings back to them to give them full context and remind them what they said.

Some shared that their high comfort, confidence, and motivation stemmed from longtime personal interest in the subject matter. For example, one professional said, "I've taken astronomy classes…I've always been, you know, a nerdy girl. I'm not an astronomer, I'm an enthusiast." Other professionals had not only personal interest but deep professional expertise in the subject matter. As one professional shared, "For me personally…I'm a professor of physics and astronomy, and I've been doing outreach since I was a teenager." This professional shared that she had high comfort, confidence, and motivation around this subject matter due to her academic training.

Though professionals generally had high comfort, confidence, and motivation, some chose to explain why their ratings for one attitude were lower than others. For example, some professionals had personal interest or experience in other areas of science and thus got less experience with astronomy or space science-related activities at their institutions. As one professional shared,

> *I think in terms of my confidence around space science… My background is in biology, and in my organization, we cover a lot of areas of STEM, but space science is not my area of expertise. And I have other people on my staff where it is their area of expertise, so a lot of times, things related to [space science] fall to them.*

However, even for professionals without astronomy backgrounds, the quality of the game and its support material for facilitators promoted confidence, comfort, and motivation for engaging publics in learning about Moon science and space exploration. As one professional put it, "Space science in general is not my background, but I also feel that a good teacher can teach what they're given. So given something like this, that is high quality, and the kinks are worked out, it makes that engagement with the students easier."

As outlined in Section 3.2.2 About two-thirds of institutions who used that Moon Adventure Game collaborated with external partners in 2021, most often forming partnerships with 6-10 organizations., many professionals already felt comfortable, confident, and motivated when it came to engaging with publics around Moon science and space exploration, leaving less space for the game to increase these attitudes. For example, one professional shared how much programming her institution had already been doing around space-related content:

> *We have the Earth and Space exhibit, and then we did a rollout theme around the anniversary of the Apollo mission, and at that time we did a heavy programming emphasis and did stuff with that. I had already researched, and I've been doing programming about Moon science and Moon exploration. For me, it's because I already felt like I knew a lot of these things personally, and I've already had some confidence.*

Even so, many professionals did still state that the game positively affected their attitudes or those of others. For example, the professional who shared that she was a professor of physics and astronomy added, "I can say that I think it does really help my college students that I train to run the game, because they have a script right there that they can just follow, and they don't have to worry about knowing anything in general."

Other professionals, who felt less comfortable with Moon science and space exploration, found the game helped support them in engaging with publics around these topics. One professional, explaining how the game affected her attitudes, found the game helped her reconnect with a dormant interest in space and astronomy:

> *Well, I've always liked science in general. Space, at one point I thought, "Oh, I want to be an astronomer"…but [I] have kind of gotten away from that. … It just kind of motivated and inspired me to get going again. I hadn't done that for a while. So that was fun and to realize, and although I am not an astronomer, and that is not my area—I like the nature kind of things—no, I did know enough of that that I can teach people some of that stuff. And having it laid out like that in the kits, with all the information for presenters and facilitators, and some background information, and knowing some common misconceptions to watch for, that made me more confident to work with adults that came with the kids.*

Explaining why she felt particularly *motivated* to engage audiences, she expressed feeling motivated by the importance of the topic. This professional added, "I just think that's important to do, but it's my weakest area probably."

Another professional who gave the highest ratings to *motivation* explained his ratings by saying the game itself was motivational. He explained, "Yeah, I thought it was a motivational game. … That was one of the best pieces from that 2nd year of Space and Earth Science [kits], because of its deeper involvement." In his view, the depth of engagement that the game offered made it especially motivational.

Finally, at the end of the annual partner survey's Moon Adventure Game questions, professionals were asked an open-ended question about anything else they wanted to add about the game. As shown in Table 14, a total of 51 professionals answered the question, and over half used the space to share additional praise about the game or share something they liked about it.

Table 14: *Code categories for professionals' responses to the question "Is there anything else you would like to add about the impact the Moon Adventure Game had on you, your visitors, or your institution?" (n=51)*

Code	Frequency	Response examples
Praise	25	*"Just so much fun!"*
Kit use	15	*"We did a Space Camp and it well supported that programming."*
Likes	8	*"I love how interactive it is! …My favorite part is watching kids actually make oxygen using hydrolysis…"*
Context explanation	8	*"We rarely used it because our museum was closed due to the pandemic, then we had limited opportunities for facilitated activities once we re-opened. We look forward to using the game more in the future!"*
N/A	8	*"na"*
Dislikes/critique	4	*"The number and components and setup requirements was difficult for teen facilitators initially."*
Impacts of using the kit	4	*"…I have become more engaged than I probably otherwise would have been in the upcoming Moon missions as well as the JWST."*
Other	3	*"It gave me a great sense of accomplishment as I took on the project (building, organizing, etc.) and championed it in my organization."*

*Response mentioned more than one category

Professionals shared praise about many aspects of the game, including the game's built-in opportunities to collaborate, its narrative elements, its novelty, and the amount of information it was able to communicate. For example, one professional said, "Guests loved the game and were impressed with how much they learned about Moon exploration." Another said, "People really enjoyed it—I think it felt like a mini escape room which is something very different from our normal exhibits." Another shared, "I was impressed with the level of cooperation and teamwork the children exhibited while working on the game, especially since they didn't know each other." These comments echo some of the responses from the previous finding, namely that the game's style, format, and outcomes had strong effects on professionals' comfort, confidence, and motivation to engage publics in learning about Moon science and space exploration.

A few professionals mentioned that the learning from the game would carry into other aspects of their programming. One professional said, "The children loved the role-playing aspect of this program. They were much more excited and engaged than the sit-down-and-follow-these-directions type of programs. I will try to use this format more in programs I design." Another professional whose institution had designed other escape room-style activities explained, "The design of the game influenced how we approached designing other escape rooms (which we use in a variety of our programs) - including more hands-on activities/challenges, rather than just puzzles to solve." These comments suggest that the game has affected professionals' practices as well as their attitudes.

Though professionals shared a great deal of praise for the game, a few shared minor critiques in this final question. Two comments centered on the number of components and time required for setup. One professional noted that "The number and components and setup requirements was difficult for teen facilitators initially." Another said, "It's fun, but it is hard to use every day for

science demos because their [sic] are so many components and is difficult to set up." A third professional shared that while the game was a personal favorite, "I just wish it could have been done with larger audiences at once!" All of these comments point to a key drawback of the game's style of interactive, sequential puzzle stations: that it limits the number of people who can participate at any given time. According to professionals, the game was highly engaging and educational, but it is important to recognize the natural tradeoff of depth of engagement with fewer visitors versus shallower engagement with more.

Summary

However, despite the game limitations (time required to set up, small throughput of players, small group sizes), it is clear that professionals greatly enjoyed the game and found its in-depth, hands-on, puzzle-oriented format encouraged learning and collaboration. They also identified this style as particularly influential on their comfort, confidence, and motivation to engage publics in learning about Moon science and space exploration. As seen in interview responses, they also noted why this format was motivational in particular. The cases where the game was not as supportive were cases where the professionals already had deep subject matter expertise and/or educational experience. Even in these cases, professionals had positive feedback about the game, they just recognized that it did not affect their own attitudes toward engaging publics in learning about Moon science and space exploration.

Conclusion

Overall, even though the Moon Adventure Game was distributed to sites at a particularly challenging time, it appears to have achieved many of its goals. Public audiences enjoyed the game and wanted play again, and survey results showed that they learned about Moon science and space exploration, increased their confidence to learn more, felt a greater sense of science identity, and practiced 21st-century skills. Similarly, professional audiences shared a great deal of praise about the game and said it had at least some effect on their comfort, confidence, and motivation to engage publics in learning about Moon science and space exploration.

One of the game's great strengths was its challenge-based format, inspired by escape rooms. This format appeared to support both public and professional audiences in their learning and skill-building. First, this format guided participants toward practicing 21st century skills by building opportunities for collaboration, communication, problem-solving. Both public and professional participants strongly agreed that participants practiced these skills (see Section 3.1.5). Professionals also named the game format as the aspect that most affected their confidence, comfort, and motivation to engage publics in learning about Moon science and space exploration (see Section 3.2.4).

In addition, the game appeared to have affected professionals' motivation in particular. The ease of use and high quality of support materials combined with the engaging activities made professionals motivated to use the game with public audiences (see Section 3.2.3). Working with enthusiastic professionals likely contributed to participants' interest in the game and their feeling that it was engaging and fun, as 86% of children agreed it was. Professionals were able to engage visitors while supporting their learning. The oxygen-making activity was especially effective, with many participants and professionals specifically mentioning it.

The format of the game did create some drawbacks that were exacerbated by the context of COVID-19. For one, the game was relatively low throughput by design, and required a lot of staff time for setup and facilitation. This can be challenging in normal circumstances, but COVID-19 made it even more difficult. Sites found themselves short on staff with layoffs and furloughs. Some sites likely chose not to use the game because it required close contact, in-person facilitation, which many sites eliminated or reduced during early COVID. While lower throughput activities will not reach as many people in general, this format plus the context of COVID-19 meant that the game was not able to reach as many people as it might have with a different format or different contextual situation.

However, it appears that those who were reached were especially engaged because of the format. Not only did the format present ample opportunities for practicing 21st-century skills, but this format also created a context that allowed visitors to have realistic scientific experiences. Public and professional audiences alike had no shortage of praise. Overall, the Moon Adventure Game, though hampered by contextual challenges, appears to have been successful at engaging public audiences in learning about Moon science and space exploration and at encouraging professionals to do more of this engagement.

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Appendix A: Data Collection Instruments

Moon Adventure Game – Child Consent and Assent Forms

Dear Parent/Guardian,

Thank you for participating in the Moon Adventure Game! As part of the evaluation of the Moon Adventure Game, game facilitators are helping the Museum of Science, Boston collect important information about participants' experiences with the game.

I am inviting you and your minor to participate in an approximately 10-minute survey about their experience interacting with the game. There is one survey for those age 13 and up and a different survey for those age 12 and under. Your minor's participation is voluntary, and they can skip any survey questions they do not want to answer and stop taking the survey at any time if they choose to. Participation should not make you or your minor uncomfortable.

The surveys will be used as data for evaluation purposes only. Information from the surveys may be published in evaluation reports or used in conference settings with other professionals. Your minor's name will never be associated with his or her information unless you and your minor request that we do so. You and your minor will not receive monetary compensation for participating in this evaluation. Information collected about your minor as part of this research may be used for future research or evaluation studies, but identifying information will be removed.

By providing the requested information and signing below, you indicate that you are the parent/guardian of this minor participant, and that you provide consent for your minor to participate in the evaluation of the Moon Adventure Game, sponsored by NASA. If you do not consent to your child's participation, you may return this form to the game facilitator without signing.

If you have any concerns or questions about this project, you may contact Liz Kunz Kollmann at the Museum of Science at ekollmann@mos.org or 617-589-0467.

Your Minor's Name: _____ **Your Minor's Age:** _____

Your Minor's Gender (check all that apply to your minor):

☐ Male ☐ Female ☐ Non-binary ☐ Prefer to self-describe: _____

Your Minor's Race/Ethnicity (check all that apply to your minor):

☐ American Indian or Alaskan Native ☐ Asian or Asian American ☐ Black or African American

☐ Hispanic or Latino ☐ Native Hawaiian or Pacific Islander ☐ White

☐ Prefer to self-describe: _____

Your Name: _____

Your Signature: _____
Date: _____

Thank you for your help!

Sincerely,
Liz Kunz Kollmann
Manager, Research and Evaluation

--

Hello,

Thank you for trying the Moon Adventure Game! We are doing a survey to find out if you enjoyed playing this game. We are asking you to be in the study because you have played the game and your opinion is important to us!

If you agree, you will fill out a short survey that should take you no longer than 10 minutes to complete. You can choose to skip any questions you want to. Your parent has said that it is okay for you to do this, but you can choose if you want to fill out the survey, and you may quit at any time.

❑ **Yes**, I agree to do the survey.

❑ **No**, I do not agree to do the survey.

We will use your answers to make the game better! Your name will not be used, and no one will know what answers you give. Please ask us any questions you have.

Please check one box below. If you do not want to do the survey, please hand this form back to the game facilitator.

Thank you for your help!

Sincerely,
Liz Kunz Kollmann
Manager, Research and Evaluation
Museum of Science, Boston

Moon Adventure Game – Child Survey, Ages 8-12

1. Did you finish the game? Circle **YES** or **NO**

2. How fun was the game? Circle your answer below.

No fun at all A little fun A lot of fun!

3. How much did you learn about the Moon? Circle your answer below.

Nothing at all A little bit A lot!

4. Would you want to play again? Circle **YES** or **NO**

5. Would you want to play a game like this about Mars? Circle **YES** or **NO**

6. Did you do anything in the game that was like what a scientist does? Circle **YES** or **NO**

7. Did you do any of these things in the game? Circle your answer below.

Work with others	**YES**	**NO**	**DON'T KNOW**
Talk with others	**YES**	**NO**	**DON'T KNOW**
Think of new ideas to try	**YES**	**NO**	**DON'T KNOW**
Think about the problem in different ways	**YES**	**NO**	**DON'T KNOW**
Solve problems	**YES**	**NO**	**DON'T KNOW**

8. After playing the game today…

I am MORE interested in the Moon or space exploration than I was before.	**YES**	**NO**	**DON'T KNOW**
I know MORE about the Moon or space exploration than I did before.	**YES**	**NO**	**DON'T KNOW**
I am MORE confident I can learn about the Moon or space exploration in the future.	**YES**	**NO**	**DON'T KNOW**
I feel MORE like a "science person" than I did before.	**YES**	**NO**	**DON'T KNOW**

Moon Adventure Game – Evaluation Survey for Ages 13+ and 18+

1. Did you finish the game? Circle **YES** or **NO**
   If NO: Which challenge were you on when time ran out? Circle: **1 2 3 4 5**

Please select one answer for each of the following:

	Not at all	A little	Moderately	Very much
2. How fun was the game?	☐	☐	☐	☐
3. How interested are you in playing again?	☐	☐	☐	☐
4. How interested are you in playing a similar game about Mars?	☐	☐	☐	☐

How much did you do the following things to help your team solve the challenges?

	Not at all	A little	Moderately	Very much
5. Work with others	☐	☐	☐	☐
6. Talk with others	☐	☐	☐	☐
7. Think of new ideas to try	☐	☐	☐	☐
8. Think about the problem in different ways	☐	☐	☐	☐
9. Solve problems	☐	☐	☐	☐

10. Please share an example of how you used one of the skills above:

11. What did you learn about Moon science or space exploration from playing the game?

12. **BEFORE** trying the game today, how would you have rated your agreement with the following statements?

	Strongly disagree	Disagree	Agree	Strongly agree
I am interested in Moon science or space exploration.	☐	☐	☐	☐
I am knowledgeable about the Moon or space exploration.	☐	☐	☐	☐
I am confident I can learn more about Moon science or space exploration in the future.	☐	☐	☐	☐
I consider myself a "science person."	☐	☐	☐	☐

13. Now, **AFTER** trying the game, how would you rate your agreement with the following statements?

	Strongly disagree	Disagree	Agree	Strongly agree
I am interested in Moon science or space exploration.	☐	☐	☐	☐
I am knowledgeable about the Moon or space exploration.	☐	☐	☐	☐
I am confident I can learn more about Moon science or space exploration in the future.	☐	☐	☐	☐
I consider myself a "science person."	☐	☐	☐	☐

Annual Partner Survey - Moon Adventure Game Section

The following questions are specific to the Moon Adventure Game, part of the Explore Science: Earth & Space Science 2020 Part B toolkit. The premise of the game is a fictional story grounded in actual NASA science and research about what people might need in the future to live and work on the Moon. In the game, players work together to solve a series of challenges about living and doing research on the Moon.

As part of our research study of the Moon Adventure Game, we are inviting you to fill out a survey about your experiences facilitating the game. We're interested in learning more about what facilitating the game was like for you and how it affected your thoughts and feelings about engaging the public in learning about Moon science and space exploration.

We understand that several people may have facilitated the Moon Adventure Game at your institution. We will ask you to provide email addresses for anyone else at your institution who has facilitated the Moon Adventure Game so that we can invite them to fill out the survey as well.

1. Since receiving the Explore Science: Earth & Space 2020 toolkit, did your institution use the Moon Adventure Game with public audiences (i.e. visitors, camp groups, schools, etc.)?
    a. Yes
    b. No

2. How often did you personally facilitate the Moon Adventure Game with public audiences?
    a. Never
    b. Rarely – e.g., 1x/year
    c. Occasionally – e.g., 1x/month
    d. Frequently – e.g., 1x/week
    e. I don't know

3. Who else at your institution has facilitated the Moon Adventure Game with public audiences? We would like to send them this survey as well. Please enter their email addresses below:

4. Is your institution having any public programming or information related to the James Webb Space Telescope launch, which is scheduled for December 2021?
    a. Yes, we have already held educational programming.
    b. Yes, we are planning to have educational programming in the future.
    c. No, and we don't have plans to have any educational programming.
    d. I don't know.

For the next section, please use a scale of 1-10, where 1 = "Completely disagree" and 10 = "Completely agree."

5. For each statement below, please rate your level of agreement or disagreement with the statements about public audiences in learning about **Moon science**.

	1 = Completely disagree	**...**	**10 = Completely agree**
I feel **confident** in my ability to engage public audiences in learning about Moon science.	( )	( )	( )
I feel **comfortable** engaging public audiences in learning about Moon science.	( )	( )	( )
I feel **motivated** to engage public audiences in learning about Moon science.	( )	( )	( )

6. For each statement below, please rate your level of agreement or disagreement with the statements about engaging public audiences in learning about **space exploration.**

	1 = Completely disagree	**...**	**10 = Completely agree**
I feel **confident** in my ability to engage public audiences in learning about space exploration.	( )	( )	( )
I feel **comfortable** engaging public audiences in learning about space exploration.	( )	( )	( )
I feel **motivated** to engage public audiences in learning about space exploration.	( )	( )	( )

For the next section, please use a scale of 1-10, where 1 = "Not at all" and 10 = "Completely agree."

7. The following questions ask you to reflect on engaging public audiences in learning about **Moon science.** How much has your use of the Moon Adventure Game affected…

	1 = Not at all	**…**	**10 = A great deal**
…your **confidence** in your ability to engage public audiences in learning about Moon science?	( )	( )	( )
…your **comfort** engaging public audiences in learning about Moon science?	( )	( )	( )
…your **motivation** to engage public audiences in learning about Moon science?	( )	( )	( )

8. The following questions ask you to reflect on engaging public audiences in learning about **space exploration.** How much has your use of the Moon Adventure Game affected…

	1 = Not at all	**…**	**10 = A great deal**
…your **confidence** in your ability to engage public audiences in learning about space exploration?	( )	( )	( )
…your **comfort** engaging public audiences in learning about space exploration?	( )	( )	( )
…your **motivation** to engage public audiences in learning about space exploration?	( )	( )	( )

9. What aspects of the Moon Adventure Game most affected your confidence, comfort, or motivation in engaging public audiences in learning about Moon science or space exploration?

10. Is there anything else you would like to add about the impact the Moon Adventure Game had on you?

Professional Interview Questions

1. Please tell me about how your institution used the Moon Adventure Game. [Review survey answers and ask any applicable]
    a. When did you start using the game?

    b. How often did or does your institution run the game?

    c. With what types of audiences have you used it? [Probe for public vs. camp, age groups, any other demographics, especially from the underrepresented categories]

    d. Have you made any modifications to it? If so, what are they?

2. Did you partner with any external groups (e.g., libraries, youth-serving organizations) using the Game in any way?

    a. If so, were those collaborations new partnership(s) or established ones?

    b. What did those partnership(s) around the Game look like?

3. Did you observe Game participants learning new things about Moon science and/or space exploration? If so, please share an example or a common theme of what they learned and how you observed it.

4. Did you observe Game participants engaging in 21st century skills, such as innovation, critical thinking, problem solving, and collaboration? If so, please share an example or a common theme of what skills they engaged in and how you observed it.

5. On the survey, I see you selected [rating] with the statements about **confidence** engaging publics in Moon science and space exploration. You also said that the Game affected your confidence [rating]. Can you explain more about why and how the Game [did/did not] affect your confidence in this area?

6. Is there anything else you would like to add about the Game?

Appendix B: Arizona Science Center Compared to Other Sites, Test Statistics

Results in order of survey questions:

Survey Question	Number of Categories (survey)	Number of Categories (χ^2)	N	df	$\chi 2$	*p*-value
Q2: How fun was the game?	4	2	132	1	0.075	0.784
Q3: How interested are you in playing again?	4	3	131	2	4.064	0.131
Q4: How interested are you in playing a similar game about Mars	4	2	130	1	1.562	0.211
Q5-9: How much did you do the following things to help your team solve the challenges?						
• Q5: Work with others	4	2	132	1	0.558	0.455
• Q6: Talk with others	4	2	131	1	0	0.986
• Q7: Think of new ideas to try	4	3	130	2	1.238	0.538
• Q8: Think about the problem in different ways	4	3	131	2	5.308	0.070
• Q9: Solve problems	4	2	130	1	0.027	0.868
Q12: BEFORE trying the game, how would you have rated your agreement with the following statements?						
• 12A: I am interested in Moon science or space exploration.	4	2	132	1	0.047	0.829
• 12B: I am knowledgeable about the Moon or space exploration.	4	3	132	2	2.405	0.300
• 12C: I am confident I can learn more about Moon science or space exploration in the future.	4	2	132	1	0.145	0.703
• 12D: I consider myself a "science person."	4	3	132	2	2.802	0.246
Q13: AFTER trying the game, how would you rate your agreement with the following statements?						
• 13A: I am interested in Moon science or space exploration.	4	2	132	1	1.75	0.186
• 13B: I am knowledgeable about the Moon or space exploration.	4	2	132	1	1.421	0.233
• 13C: I am confident I can learn more about Moon science or space exploration in the future.	4	2	132	1	1.474	0.225
• 13D: I consider myself a "science person."	4	3	132	2	0.951	0.622

Appendix C: Topics adults learned about in the game

Themes identified in adults' responses on the public evaluation survey to the question: *What did you learn about Moon science or space exploration from playing the game?* (n=105)

Topics	Frequency	Response Examples
Content message categories:		
What do you need to live on the Moon? Shelter, food, water, energy, communication, and teamwork! [Welcome]	9	*"I think for my 8-year-old, she learned some of the basic needs of an astronaut on the Moon."* *"You need water, oxygen, and food to survive."* *"Need air"*
Moon craters [Challenge 1]	10	*"I learned about [its] craters"* *"Craters are huge."* *"TEMP OF CRATERS"**
Permanently shadowed areas [Challenge 2]	0	
Frozen lunar materials in craters [Challenge 3]	8	*"That we can harvest ice on the moon to make oxygen, water, energy"** *"MOON ICE!!"* *"How to extract water"*
Splitting water molecules into hydrogen and oxygen [Challenge 4]	40	*"Create oxygen"* *"How to make oxygen from water"* *"I learned about Electrolysis."*
Using conductive materials to close an electrical circuit [Challenge 5]	13	*"How to make electricity"* *"The difference between insulators + conductors"* *"Humans are a good conductor"*
NASA exploration of the Moon [Wrap-up/Reflection]	2	*"Artemis"* *"The coldest part of the moon is the south pole. That is the first place humans will go since water is stored there in the form of ice."**
Skill message categories:		
Interpreting maps and data [Challenges 1, 2]	1	*"Learned coordinates and water [molecules]"*
Teamwork [Challenges 1, 5]	3	*"... help ~~with~~ from Blue crew"* *"Working with each other to solve problems"** *"...How important teamwork is."*
Sorting material [Challenge 3]	0	
Measuring [Challenge 4]	0	

Topics	Frequency	Response Examples
Additional categories:		
Rovers [Challenge 2 background]	0	
Moonquakes [Challenge 2 background]	2	*"There are moon quakes…"* *"That there is seismic activity on the moon…"*
South Moon facts	2	*"South moon facts"* *"The coldest part of the moon is the south pole. That is the first place humans will go since water is stored there in the form of ice."**
Moon temperatures	13	*"The diff temps of the crater"** *"Temperature"* *"…And there are extremely cold places on the moon."*
Generic recognition of the scale of the challenge	6	*"How to use different tools to succeed"* *"Lots of skills required"* *"Not as easy as it looks"*
Topography	1	*"Temperature and topography"*
Suggestions for improving the game	1	*"Wish the answers we explained better. For example, the kids saw bubbles but didn't realize they were oxygen"*
Other content	2	*"It involves a lot of chemistry and Physics"* *"8 planets (~~9~~)"*
Other skills	4	*"Must follow directions"* *"How to work on the fly"* *"You have to be clam when things go wrong"*
Other	8	*"I enjoyed watching my son (age 7.5) p interact with the other kids!"* *"It's exciting."* *"[Somewhat] knowledgeable."*
Nothing	5	*"-"* *"nothing"* *"x"*

*Response mentions multiple categories

Appendix D: 21st century skills and activity coding

Summary of intersection of skill and activity codes:
Thirty-eight responses were identified as including both a skill and an activity. The intersection of these categories is summarized in the table below. Following the summary table are tables displaying the responses coded the intersectional category, first by skill and then by activity category.

	Activities						
Skills	Make a travel plan for your rover (n=3)	Match rover data to locations on map (n=10) *	Extract water from frozen lunar material (n=5)	Fill your oxygen tanks (n=1)	Reconnect the power supply (n=13) *	Other activities within the game (n=1)	Activity could not be identified (n=5)
Work with others (n=16)	1	6	3	0	4	0	2
Talk with others (n=10)	1	2	0	0	4	1	2
Think of new ideas to try (n=8)	0	4	0	1	3	0	0
Think about the problem in different ways (n=2)	0	0	0	0	2	0	0
Solve problems (n=7)	1	1	0	0	5	0	0
Other skills (n=3)	0	0	2	0	0	0	1

*Some responses for these activities mention multiple skills

Skill code tables for responses with both a skill and an activity:

Work with others (n =16):

Activity	Frequency	Responses
Challenge 1: Make a travel plan for your rover	1	• Participant 93: *"One child provided part of grid coordinates + other child provided 2nd part"*
Challenge 2: Match rover data to locations on the map	6	• Participant 37: *"Worked and talked to complete the 2nd [challenge.] Tried different ideas and worked together"** • Participant 70: *"We all took pieces of the moon crater map and worked together"* • Participant 142: *"Worked as a team to solve problem two. Each person gave an idea on how to solve the puzzle."** • Participant 167: *"The blocks had everyone participating. Child matched the craters, Grandpa saw the arrows, and Mom saw the words."* • Participant 174: *"I helped everyone to realize the sides need to be right side up and look at the letters on the blocks in a certain angle"* • Participant 179: *"Worked together to place [blocks.] Figured out we needed to line up arrows to read message"*
Challenge 3: Extract water from frozen lunar material	3	• Participant 85: *"Assisted on keeping claw straight for my injured team member."* • Participant 169: *"Used a cooperative assembly line for the ice mining station"* • Participant 186: *"When my teammate put an 'ice cube' in wrong and I helped"*
Challenge 4: Fill your oxygen tanks	0	
Challenge 5: Reconnect the power supply	4	• Participant 106: *"Worked together to hold together circuit for #5"* • Participant 121: *"We had to work together to try and close the circuit. Everyone thought of ideas to try."** • Participant 175: *"we worked together to find multiple different conductive tools. everyone observed a different piece of the puzzle"* • Participant 212: *"Working as a team was important for challenge 5."*
Other activities within the game	0	
Activity could not be identified	2	• Participant 141: *"Working together to solve the puzzles"* • Participant 166: *"Kids worked together nicely to figure out all the clues"*

*Response mentioned multiple skills

Talk with others (n=10):

Activity	Frequency	Responses
Challenge 1: Make a travel plan for your rover	1	• Participant 39: "Talked with kids to map out rover"
Challenge 2: Match rover data to locations on the map	2	• Participant 37: *"Worked and talked to complete the 2nd [challenge.] Tried different ideas and worked together"** • Participant 91: "Talking about which way the blocks should go on the map in order to get the correct message."
Challenge 3: Extract water from frozen lunar material	0	
Challenge 4: Fill your oxygen tanks	0	
Challenge 5: Reconnect the power supply	4	• Participant 68: *"We had a hard time getting the power supply working [again,] so we tried different configurations to get it to work. We talked amongst one another to solve the problem. It was a bit of trial and error."** • Participant 118: *"Talking about what conductors do vs insulated items"* • Participant 119: *"We talked out loud about how to solve the problems in a quick and efficient manner such as when we conducted electricity and decided to use the ruler"** • Participant 181: *"We talked together to figure out new ideas on the last challenge."**
Other activities within the game	1	• Participant 83: *"Playing w/ my daughter we communicated about all the tools and following instructions and calling mission control"*
Activity could not be identified	2	• Participant 80: *"Discussed each challenge"* • Participant 116: *"We talked with each other about the problems"*

*Response mentioned multiple skills

Think of new ideas to try (n=8):

Activity	Frequency	Responses
Challenge 1: Make a travel plan for your rover	0	
Challenge 2: Match rover data to locations on the map	4	Participant 37: *"Worked and talked to complete the 2nd [challenge.] Tried different ideas and worked together"** Participant 43: *"Tried a new code for lock"* Participant 105: *"With the blocks -- matching arrow-to-arrow (new ideas to try)"* Participant 142: *"Worked as a team to solve problem two. Each person gave an idea on how to solve the puzzle."**
Challenge 3: Extract water from frozen lunar material	0	
Challenge 4: Fill your oxygen tanks	1	Participant 69: *"We couldn't get bubbles in the oxygen separation experiment. We tried adding more salt and checked connections. We finally found that we needed to change batteries."*
Challenge 5: Reconnect the power supply	3	Participant 113: *"Suggested a different implement to use to conduct electricity"* Participant 121: *"We had to work together to try and close the circuit. Everyone thought of ideas to try."** Participant 181: *"We talked together to figure out new ideas on the last challenge."**
Other activities within the game	0	
Activity could not be identified	0	

*Response mentioned multiple skills

Think about the problem in different ways (n=2):

Activity	Frequency	Responses
Challenge 1: Make a travel plan for your rover	0	
Challenge 2: Match rover data to locations on the map	0	
Challenge 3: Extract water from frozen lunar material	0	
Challenge 4: Fill your oxygen tanks	0	
Challenge 5: Reconnect the power supply	2	Participant 38: *"Though of different ways to arrange conductive pieces"* Participant 68: *"We had a hard time getting the power supply working [again,] so we tried different configurations to get it to work. We talked amongst one another to solve the problem. It was a bit of trial and error."**
Other activities within the game	0	
Activity could not be identified	0	

*Response mentioned multiple skills

Solve problems (n=7):

Activity	Frequency	Responses
Challenge 1: Make a travel plan for your rover	1	• Participant 94: *"Figuring out the code for the lock"*
Challenge 2: Match rover data to locations on the map	1	• Participant 136: *"To solve the rover location data, we had to problem solve what the overlays and cubes meant"*
Challenge 3: Extract water from frozen lunar material	0	
Challenge 4: Fill your oxygen tanks	0	
Challenge 5: Reconnect the power supply	5	• Participant 54: *"Dad [snagged] a wire from the previous step. Some felt it was cheating [others] saw the need for the success of the mission"* • Participant 68: *"We had a hard time getting the power supply working [again], so we tried different configurations to get it to work. We talked amongst one another to solve the problem. It was a bit of trial and error."* • Participant 119: *"We talked out loud about how to solve the problems in a quick and efficient manner such as when we conducted electricity and decided to use the ruler"* • Participant 173: *"Figured out restoring the power"* • Participant 122: *"My son was able to figure out how to go longer by using a metal ruler instead of a smaller spinon (sp?) [sic]"*
Other activities within the game	0	
Activity could not be identified	0	

Activity code tables for responses with both a skill and an activity:

Challenge 1: Make a travel plan for your rover (n=3):

Skill	Frequency	Responses
Work with others	1	• Participant 93: *"One child provided part of grid coordinates + other child provided 2nd part"*
Talk with others	1	• Participant 39: *"Talked with kids to map out rover"*
Think of new ideas to try	0	
Think about the problem in different ways	0	
Solve problems	1	• Participant 94: *"Figuring out the code for the lock"*
Other skills	0	

Challenge 2: Match rover data to locations on the map (n=10):

Skill	Frequency	Responses
Work with others	6	• Participant 37: *"Worked and talked to complete the 2nd [challenge.] Tried different ideas and worked together"** • Participant 70: *"We all took pieces of the moon crater map and worked together"* • Participant 142: *"Worked as a team to solve problem two. Each person gave an idea on how to solve the puzzle."** • Participant 167: *"The blocks had everyone participating. Child matched the craters, Grandpa saw the arrows, and Mom saw the words."* • Participant 174: *"I helped everyone to realize the sides need to be right side up and look at the letters on the blocks in a certain angle"* • Participant 179: *"Worked together to place [blocks.] Figured out we needed to line up arrows to read message"*
Talk with others	2	• Participant 37: *"Worked and talked to complete the 2nd [challenge.] Tried different ideas and worked together"** • Participant 91: *"Talking about which way the blocks should go on the map in order to get the correct message."*
Think of new ideas to try	4	• Participant 37: *"Worked and talked to complete the 2nd [challenge.] Tried different ideas and worked together"** • Participant 43: *"Tried a new code for lock"* • Participant 105: *"With the blocks -- matching arrow-to-arrow (new ideas to try)"* • Participant 142: *"Worked as a team to solve problem two. Each person gave an idea on how to solve the puzzle."**
Think about the problem in different ways	0	
Solve problems	1	• Participant 136: *"To solve the rover location data, we had to problem solve what the overlays and cubes meant"*
Other skills	0	

*Response mentioned multiple skills

Challenge 3: Extract water from frozen lunar material (n=5):

Skill	Frequency	Responses
Work with others	3	• Participant 85: *"Assisted on keeping claw straight for my injured [team member.]"* • Participant 169: *"Used a cooperative assembly line for the ice mining station"* • Participant 186: *"When my teammate put an "ice cube" in wrong and I helped"*
Talk with others	0	
Think of new ideas to try	0	
Think about the problem in different ways	0	
Solve problems	0	
Other skills	2	• Participant 1: *"Fine motor skills while [sic] catch the blue cubes."* • Participant 18: *"Graber to drop blocks – Many tries."*

Challenge 4: Fill your oxygen tanks (n=1):

Skill	Frequency	Responses
Work with others	0	
Talk with others	0	
Think of new ideas to try	1	• Participant 69: *"We couldn't get bubbles in the oxygen separation experiment. We tried adding more salt and checked connections. We [finally] found that we needed to change batteries."*
Think about the problem in different ways	0	
Solve problems	0	
Other skills	0	

Challenge 5: Reconnect the power supply (n=13):

Skill	Frequency	Responses
Work with others	4	• Participant 106: *"Worked together to hold together circuit for #5"* • Participant 121: *"We had to work together to try and close the circuit. Everyone thought of ideas to try."** • Participant 175: *"we worked together to find multiple different conductive tools. everyone observed a different piece of the puzzle"* • Participant 212: *"Working as a team was important for challenge 5."*
Talk with others	4	• Participant 68: *"We had a hard time getting the power supply working [again,] so we tried different configurations to get it to work. We talked amongst one another to solve the problem. It was a bit of trial and error."** • Participant 118: *"Talking about what conductors do vs insulated items"* • Participant 119: *"We talked out loud about how to solve the problems in a quick and efficient manner such as when we conducted electricity and decided to use the ruler"** • Participant 181: *"We talked together to figure out new ideas on the last challenge."**
Think of new ideas to try	3	• Participant 113: *"Suggested a different implement to use to conduct electricity"* • Participant 121: *"We had to work together to try and close the circuit. Everyone thought of ideas to try."** • Participant 181: *"We talked together to figure out new ideas on the last challenge."**
Think about the problem in different ways	2	• Participant 38: *"Though of different ways to arrange conductive pieces"* • Participant 68: *"We had a hard time getting the power supply working [again,] so we tried different configurations to get it to work. We talked amongst one another to solve the problem. It was a bit of trial and error."**
Solve problems	5	• Participant 54: *"Dad snagged a wire from the previous step. Some felt it was cheating others saw the need for the success of the mission"* • Participant 68: *"We had a hard time getting the power supply working again, so we tried different configurations to get it to work. We talked amongst one another to solve the problem. It was a bit of trial and error."** • Participant 119: *"We talked out loud about how to solve the problems in a quick and efficient manner such as when we conducted electricity and decided to use the ruler"** • Participant 122: *"My son was able to figure out how to go longer by using a metal ruler instead of a smaller spinon (sp?) [sic]"* • Participant 173: *"Figured out restoring the power"*
Other skills	0	

*Response mentioned multiple skills

Other activities within the game (n=1):

Skill	Frequency	Responses
Work with others	0	
Talk with others	1	• Participant 83: *"Playing w/ my daughter we communicated about all the tools and following instructions and calling mission control"*
Think of new ideas to try	0	
Think about the problem in different ways	0	
Solve problems	0	
Other skills	0	

Activity could not be identified (n=5):

Skill	Frequency	Responses
Work with others	2	• Participant 141: *"Working together to solve the puzzles"* • Participant 166: *"Kids worked together nicely to figure out all the clues"*
Talk with others	2	• Participant 80: *"Discussed each challenge"* • Participant 116: *"We talked with each other about the problems"*
Think of new ideas to try	0	
Think about the problem in different ways	0	
Solve problems	0	
Other skills	1	• Participant 101: *"Come up w/ a plan"*

Appendix E: Aspects of the game that affected professionals' confidence, comfort, or motivation

Below are tables for the coding for professionals' responses on the annual partner survey to *What aspects of the Moon Adventure Game most affected your confidence, comfort, or motivation in engaging public audiences in learning about Moon science or space exploration?* (*n*=60).

Many responses mentioned multiple aspects of the game that affected their confidence, comfort, or motivation and thus were coded to each of the appropriate categories based on co-occurring excerpts. In the tables below, bold text in the response examples represent the sections relevant to the indicated code.

Table of codes:

Code	Frequency	Response examples
Format/Style*	29	*"The **format of the game is engaging for kids**, so it's fun to facilitate with different audiences. The **different stations** effectively introduce different topics related to the moon/space exploration, in a way that's **approachable for people**, even if they don't have much background knowledge about the subject."* *"As with all [NISE Net] materials, the content, **facilitator support, and quality of materials** made it very comfortable to engage our audiences."*
Outcomes*	23	***"Learning more information about the moon and working with students has impacted my thoughts about facilitating moon [activities.]"*** *"We used the game as a base to make a science themed murder mystery game **that our middle schoolers loved**."*
Components*	11	***"The grabbers, the oxygen kit, the pictures"*** ***"The training videos were great."***
Nothing/Don't know/Didn't use	7	***"Nothing. It's a very well put together game, although we did tweak it a bit for our use."*** ***"Don't know. I am not on the education team."***
Prior Knowledge	6	***"Content knowledge"***

Code	Frequency	Response examples
		"We have a team member who worked on the [Hubble] Telescope for NASA and is very well qualified."
Content/Topic	5	*"My background with lunar science through attending seminars regarding exploration and lunar science. From this knowledge throughout the years,* ***this has been one of my favorite subjects to present****. Also, we include Moon observation usually at First Quarter with telescopes ranging in size from 24" to 8"."* *"My feedback includes building the capacity of my teen facilitators most of which were new.* ***The content was completely new to them and encompassed aspects of the moon that were not familiar to them****."*
Other	4	***"Since we weren't able to engage in a public way, I don't really have the ability to answer this very well. It wasn't a highly checked out component of the lending library, either****."* ***"I enjoyed setting up a pregame orientation which included asking people what they already knew about Apollo and Artemis missions, a brief video from NASA about the Artemis mission.*** *I liked guiding players without giving away solutions, and then engaging with them after the game to answer any questions while someone in the group would be taking the survey."*
Accurate and Authentic Science	3	*"It gave me great pleasure* ***to present real NASA science*** *to our visitors."* *"The resources give a fun way to talk about science. Additionally,* ***I feel confident in the scientific accuracy of what I'm teaching,*** *since my background is in ecology rather than Moon science or space exploration."*

*These codes contain subcodes. Tables of the subcodes with examples are included below.

Tables of subcodes:

Format/Style subcodes (n=29):

"Format/Style" subcode	Frequency	Response examples
Information structure/ presentation	8	*"It's a fun way to get guests engaged with the idea of space science. I like* ***how there are little science concepts peppered in each station."*** *"The science was* ***very clearly written and understandable****, which made it easier to put into simpler terms for younger audiences."*
Easy to use	4	*"This game was great because it was a nice pre-packaged activity that* ***took little work for me to set up*** *and motivated me to engage with audiences."* *"The kit was* ***easy to assemble and use****."*
Engaging	4	*"That the activities are fun and* ***engaging*** *for children as well as being educational."*
Facilitator support	4	*"As with all [NISE Net] materials, the content,* ***facilitator support****, and quality of materials made it very comfortable to engage our audiences."* *"I really appreciate the great detail that is provided in the game manuals and instructions,* ***it made learning the activities fairly easy and it also made teaching volunteers to facilitate the activities very easy****."*
Pre-packaged kit	4	*"I love having the tools to actually show kids things that astronauts are thinking about. [It's] one thing to talk about how the astronauts will move and explore the moon, [it's] another thing to do hands-on activities about it. I could probably have come up with a super cool activity to enhance my lessons on the moon, but these write ups gave me and my staff great confidence and comfort during a time when staffing and hours were limited.* ***It was amazing to have something already [assembled] (mostly) already written up with clear directions on what we needed to do.*** *We all knew the background content, but the ease of using the game brought relief to myself and the staff."* *"This game was great because it was a* ***nice pre-packaged activity*** *that took little work for me to set up and motivated me to engage with audiences."*

"Format/Style" subcode	Frequency	Response examples
Role-play/ Storytelling	4	*"I loved that the children started the game by **playing the role of scientists performing tasks when 'disaster struck.**' They immediately became very serious and worked together to solve problems. Instead of just following directions of a task, they were in charge and led their own adventure."* *"The **storytelling aspect** invites people to get more involved in the process which has aided in the way I think about facilitating space exploration content."*
Stations	4	*"Hands-on involvement **different stations** leading to a conclusion"* ***"Each station focuses on different aspects of Moon/space exploration**. The Moon game is well balanced and guests can role play different scenarios that astronauts would face in space. The Moon game is a good tool for guests to use their STEM skills while learning about space exploration."*
Other format aspects	4	*"As with all [NISE Net] materials, the content, facilitator support, and **quality of materials** made it very comfortable to engage our audiences."* *"I enjoyed setting up a pregame orientation which included asking people what they already knew about Apollo and Artemis missions, a brief video from NASA about the Artemis mission. **I liked guiding players without giving away solutions,** and then engaging with them after the game to answer any questions while someone in the group would be taking the survey."*
Game/Play	3	*"The **interaction aspect**. That it was a game while learning."* ***"Play-based learning** is an excellent way to "trick" people into learning. The Moon Adventure Game has had a lot of positive feedback from our visitors and encouraged us to use some of the resources in our STEM Nights."*
Hands-on/ interactive	3	***"Hands-on** involvement different stations leading to a conclusion"* *"It gives students a **hands-on approach** to learning about Moon exploration and it became easier to talk with them about it."*

"Outcomes" subcodes (n=23):

"Outcomes" subcode	Frequency	Response examples
Fun	7	*"The format of the game is engaging for kids,* ***so it's fun to facilitate with different audiences****. The different stations effectively introduce different topics related to the moon/space exploration, in a way that's approachable for people, even if they don't have much background knowledge about the subject."* *"That the* ***activities are fun*** *and engaging for children as well as being educational."*
Facilitator Learning	6	***"Learning more information about the moon and working with students has impacted my thoughts about facilitating moon [activities****.]"* ***"I learned some things that I didn't know about the moon what made me more comfortable teaching it.*** *I also find this activity to be a little more engaging than the other activities about processes on the moon. Somehow adding in the human factor (like the things in the game are actually happening to you) makes it more engaging"*
Positive visitor feedback/success facilitating	6	*"We used the game as a base to make a science themed murder mystery game* ***that our middle schoolers loved****."* ***"I was able to successfully and confidently engage with a family participating in the game where I was the facilitator****. The basic premise is what was exciting to me and I was able to convey that."*
Impacts on Practice	2	***"The game inspired me to suggest we reimagine our existing space station exhibit into a Moon or Mars habitat****."* *"The storytelling aspect invites people to get more involved in the process* ***which has aided in the way I think about facilitating space exploration content****."*
Other Outcomes	2	*"It gives students a hands-on approach to learning about Moon exploration and* ***it became easier to talk with them about it****."* *"The practice of finding and then delving into details through conversations during the mission - which being longer than most- created both a challenge and an opportunity for an even deeper dive.* ***Participant focus could shift from mission to meaning****."*

"Components" Subcodes (n=11):

"Components" subcode	Frequency	Response examples
Training Materials	7	*"I really appreciate the great detail that is provided in **the game manuals and instructions**, it made learning the activities fairly easy and it also made teaching volunteers to facilitate the activities very easy."* ***"The kit provides wonderful resources**. As a retired Earth Science and Astronomy teacher, I am familiar with most of the information being presented."* *"I think that knowing that I had a complete kit and **the training and background videos** helped me feel confident presenting this program."*
Activity Materials	4	***"The grabbers, the oxygen kit,** the pictures"* *"They really enjoyed **seeing the oxygen and hydrogen bubbles-** made it feel like an 'aha' moment"* *"Love **the script** that draws in the crowd and sets a good scene and flow between stages."*
Other Materials	1	*"The grabbers, the oxygen kit, **the pictures"***