Under the Arctic: Digging into Permafrost
Summary Evaluation Report

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Executive Summary

Under the Arctic: Digging into Permafrost, a 2,000 square foot museum exhibition, engaged visitors in real and simulated experiences related to the nature of permafrost, permafrost research, and the impact of climate change on permafrost. Development of the exhibition was part of a larger National Science Foundation Advancing Informal STEM Learning grant, *Hot Times in Cold Places: The Hidden World of Permafrost*, awarded to the University of Alaska Fairbanks in partnership with the Oregon Museum of Science and Industry.

Two related evaluation studies led us to our conclusions. First, we carried out a tracked visitor study of 99 family groups that included children between the ages of 9 and 14, which included three data collection methods: (1) cued visitor observations, (2) visitor audio recordings, and (3) written surveys. Second, we carried out a survey study using 625 written surveys completed by both children and adults.

We structured the evaluation findings around the three main questions we used to guide this *Under the Arctic* exhibition evaluation: (1) To what extent do visitors engage with *Under the Arctic* exhibition as planned? (2) To what extent do visitors understand the big idea: Thawing permafrost changes Arctic landscapes and our global climate? (3) In what ways does the exhibition affect visitors' perceptions of the ability of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts? We have integrated findings from the observations, recordings, and surveys.

To what extent do visitors engage with Under the Arctic exhibition as planned?

The first question guiding the evaluation is about how visitors engaged with the exhibition. We defined level of engagement in several ways, including the time spent in the exhibition overall, observed behaviors of engagement, observed emotional responses, and self-reported engagement.

- Using Serrell's (2010) Sweep Rate Index Average and Percent Diligent Visitors as a benchmark, the *Under the Arctic* exhibition was considered "thoroughly used" in terms of time and attention visitors gave to the content for the size of the exhibition.
    - The average time spent in the exhibition by visitors overall was 12 minutes and 28 seconds. The least time spent by a visitor was 3 minutes and 6 seconds, and the most time spent was 49 minutes and 38 seconds.
    - Of the 99 groups tracked, 48 (49%) stopped at more than one-half of the exhibition components.
- Visitors showed/expressed numerous behaviors indicative of engagement.

    - Behaviors indicative of engagement, such as pointing, calling someone over, touching, and using a bench or stool, were observed one or more times for every tracked visitor group.
    - The *Under the Arctic* exhibition included eight interactive components. Three of these components incorporated science process skills (Geology Workstation, Fossil Exploration Station, and Heat Trapping Blanket), three were games (Ice Bubble Researcher's Desk, Keeping Carbon in the ground, and Climate Action Card Game), and two allowed younger children to build and/or play with objects (Ice Age Landscape Station and Engineering for Permafrost). The majority of tracked visitors who stopped at these interactive components engaged as expected.
- 96% of the tracked visitor groups showed a positive emotional response to the exhibition. The most common emotional response was enjoyment, followed by awe or surprise, making a personal connection, naming an object with enthusiasm demonstrating excitement, or being disgusted. Disgust most often occurred in response to the smell button in the Tunnel Structure or the cooler at the Ice Bubble Research Station that showed food decaying.
    - Very few of the tracked visitor groups verbally voiced concern for or otherwise referred to northerners' lives.
- Of the tracked visitors, 81% gave the *Under the Arctic* exhibition an overall rating of 7 or higher (out of 10) on the written survey.
- The most engaging exhibition components were the Tunnel Structure, followed by the Heat Trapping Blanket and the components included in the Lab Area: Geology Workstation, Fossil Exploration Station, and Ice Bubble Researcher's Desk.

To what extent do visitors understand the big idea: Thawing permafrost changes Arctic landscapes and our global climate?

The second evaluation question addressed the extent to which visitors learned about the big idea: Thawing permafrost changes Arctic landscapes and our global climate. We defined learning in several ways, including observed behaviors that predict learning, observed statements of learning, and self-reported learning on the post-survey.

- Visitors extensively engaged in behaviors that are predictive behaviors for learning in exhibitions.
    - Reading Aloud: We observed 95 (96%) of the tracked visitor groups reading aloud at least one time, and an average of four times. In total, we observed 381 instances in which tracked visitors read panel information aloud. Of the instances in which tracked visitor groups read panel information aloud, about half of the readers were children in the group, indicating that the exhibition reading level was accessible for children.

    - Asking Questions: We also recorded 92 (93%) of the tracked visitor groups asking a question related to the *Under the Arctic* exhibition. In total, we recorded 241 questions.
    - Verbal Observations: We recorded 91 (92%) of the tracked visitor groups making a verbal observation. In total, we recorded 291 verbal observations.
    - Conversations: We recorded 68 (70%) of the tracked visitor groups having a conversation between adults and children, between children, and between adults. In total, we counted 160 conversations.
- Most of the tracked visitor groups and the survey study participants reported learning "some" or "a lot" about the topics we explicitly asked them about: problems caused by permafrost, relationship between permafrost/climate change, permafrost, methane and carbon dioxide release, how scientists are studying permafrost, and how people are adapting to thawing permafrost.
    - Tracked visitors who spent more time in the Lab Area (with the Geology Workstation, Fossil Exploration Station, Ice Bubble Researcher's Desk, and the Ice Age Landscape Station) were significantly ($p < 0.05$) more likely to report learning about permafrost, how people are adapting to permafrost, problems caused by thawing permafrost, and how scientists are studying permafrost.
- Twenty percent of the tracked visitors and 18% of the survey study participants captured the big idea—thawing permafrost changes Arctic landscapes and our global climate—when asked to describe what they would tell a friend about the *Under the Arctic* exhibition. The other two topics most visitors wrote about were permafrost and climate change. Twelve percent of the visitors wrote about all three ideas: permafrost, climate change, and the big idea.

In what ways does the exhibition affect visitors' perceptions of the ability of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts?

The third evaluation question addressed the extent to which the exhibition affected visitors' perceptions of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts.

- Twenty-seven percent of tracked visitors and 33% of the survey study participants **agreed more** after visiting the *Under the Arctic* exhibition that community efforts to address climate change have a positive effect.
- More than 30% of tracked visitors and survey study participants **agreed more** after visiting the *Under the Arctic* exhibition that climate scientists can be trusted to give full and accurate information on causes of climate change and that scientists understand very well whether climate change is occurring.

- Thirty-nine percent of tracked visitors and 46% of survey study participants **agreed more** after visiting the *Under the Arctic* exhibition that climate science is interesting.
- Thirty-three percent of tracked visitors and 42% of survey study participants **agreed more** after visiting the *Under the Arctic* exhibition that they want to learn more about climate change.
    - In the tracked visitor study, children were significantly ($p < 0.05$) more likely than adults to **agree more** that they want to learn more about climate change; however in the survey study adults were significantly ($p < 0.05$) more likely than children to agree more.

Contents

Introduction

Under the Arctic: Digging into Permafrost, a 2,000 square foot museum exhibition for families with children ages 9-14, engaged visitors in real and simulated experiences related to the nature of permafrost, permafrost research, and the impact of climate change on permafrost. Development of the exhibition was part of a larger National Science Foundation Advancing Informal STEM Learning (NSF AISL) grant, *Hot Times in Cold Places: The Hidden World of Permafrost*, awarded to the University of Alaska Fairbanks in partnership with the Oregon Museum of Science and Industry.

Learning goals included the following:

- Visitors will capture the big idea: thawing permafrost changes Arctic landscapes and our global climate.
- Visitors will increase their interest in exploring climate science principles that elucidate changes due to thawing permafrost.
- Visitors will increase their interest in talking about community actions that can support mitigation and/or adapting way of life to climate changes.
- Visitors will feel an emotional connection with northerners' lived experiences.
- Visitors will find personal relevance with the exhibition.

The *Under the Arctic* exhibition opened in November 2017 and ran through September 2018 at the Oregon Museum of Science and Industry (OMSI) in Portland, Oregon. OMSI installed the exhibition along the north wall of its 7,950 square foot Life Science Hall, adjacent to other exhibits and the Life Science Lab.

The exhibition will next travel to the Children's Science Explorium in Boca Raton, Florida, the Sam Noble Museum of Natural History in Norman, Oklahoma, and to other venues across North America during its eight-year tour.

Evaluation Methods

The purpose of the summative evaluation is to a) describe how visitors engaged with the exhibition, b) explore whether engagement helped visitors understand key concepts of permafrost and the important role it plays in global climate, and c) explore whether engagement and understanding affected visitors' perceptions of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts.

Question 1: To what extent do visitors engage with *Under the Arctic* exhibition as planned?

- What dwell time does the exhibition encourage? What dwell time do exhibition components encourage?
- Do visitors show/express behaviors indicative of engagement?

- How do visitors engage in learning behaviors?
- How do visitors respond emotionally to the exhibition?

Question 2: To what extent do visitors understand the big idea: Thawing permafrost changes Arctic landscapes and our global climate?

Question 3: In what ways does the exhibition affect visitors' perceptions of the ability of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts?

- Do visitors leave the exhibition more optimistic that community efforts to address climate change can have an impact?
- Do visitors leave the exhibition with greater trust in climate science/climate scientists?
- Do visitors leave the exhibition interested in learning more about the principles of climate change/climate science after engaging with the exhibition?

Question 4: What is the relationship among variables?

- Is there a relationship between visitor engagement (Question 1) and how much visitors learned (Question 2) or visitor engagement and perceptions of community solutions and/or policies (Question 3)?
- Is there a relationship between how much visitors learned and their perceptions of community solutions and/or policies? Are there differences in perceptions by age group? By time spent in the exhibition?

To answer these evaluation questions, we completed two related studies. First, we carried out a tracked visitor study of 99 family groups that included children between the ages of 9 and 14. This study included three data collection methods: (1) cued visitor observations, (2) visitor audio recordings, and (3) written surveys. Second, we carried out a survey study using 625 written surveys completed by both children and adults.

Data Collection Instruments

Following is a description of the data collection methods we used: cued visitor observations, visitor audio recordings, and written surveys.

Cued visitor observation: We used observations to assess dwell time and behaviors related to engagement and learning. The unit of analysis for behavioral "event" observations was a group. We coded for group behaviors because we assumed that engaging with the exhibition could occur not only by manipulating the exhibit component oneself, but also by watching others manipulate and/or interact with others through words and gestures (Hammerman, et al., 2013; Serrell and Associates, 2009). For the most part, we did not note who said or did something, just that it occurred while the group was around the exhibition.

Two evaluators conducted observations for six consecutive days from Wednesday March 28, 2018 through Monday April 2, 2018 to capture spring break visitors from both the Portland, Oregon area schools and the Vancouver, Washington area schools. Spring break traditionally has high rates of visitation. We completed an average of 16 observations per day.

Audio Recording: We used recordings of family groups during their exhibition visit to further assess engagement, learning, emotional responses, and personal connections to the exhibition content. In addition, we used recordings to assess whether family groups understood the exhibition's big idea and perceptions of community solutions and/or policies to address climate change. We provided each family who agreed to participate in the observation and audio recording with a wearable audio recording device.

Surveys: We administered paper surveys to gather information related to engagement (Question 1), understanding of the big idea (Question 2), and perceptions of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts (Question 3). Surveys also asked for demographic information. Surveys were offered to all individuals leaving the exhibition by an OMSI staff member.

Tracked Visitor Study Methods

We sampled family groups who visited the *Under the Arctic* exhibition and who had a child or children in the age range of 9 to 14. Some groups had younger children. Family group was defined as a multigenerational visiting unit of no more than six members, with at least one child between the ages of 9 to 14 and one adult age 19 or older (Borun et al., 1998). We limited family group size to six individuals to improve our ability to recognize group members on the audio recording.

We approached every family who entered the exhibition area and crossed an imaginary line in front of the Title and Credit panel to participate in the observation. We asked all observed group members to wear a sticker with their group number and to complete a written survey. All families who agreed to participate in the observation and recording signed an informed consent form (Appendix B). Table 1 includes tracked visitor sample size for each instrument.

Table 1: Tracked visitor study sample size

Instrument	Sample Size
Tracked Visitor Group Observations	99
Tracked Visitor Group Recordings	97
Written Surveys (tracked visitor groups only)	133

All of the observed groups included children and adults. More than half of the observed visitors were female, a third of the observed visitors were children in the target age range of 9 to 14, and 86% of the observed visitors identified themselves as white.

Table 2: Tracked visitor study participant demographics[1,2]

	Percent of Visitors
Gender (n = 115)	
Female	57%
Male	43%
Age, in years (n = 117)	
6 to 8	8%
9 to 14	34%
15 to 17	4%
18 to 34	13%
35 to 54	34%
55 +	6%
Race/Ethnicity (n = 113)[3]	
Asian American	12%
Native American or Alaska Native	4%
White	86%
Black or African American	4%
Pacific Islander	1%
Hispanic or Latino/a	8%
Other	7%

[1] The total number of surveys is greater than 99 as surveys were disseminated to all members of tracked visitor groups.
[2] Visitor demographics do not represent the entire tracked visitor sample because many tracked visitors left the demographics section of the survey blank.
[3] Does not sum to 100% because visitors were able to select more than one race/ethnicity.

Analysis

We analyzed tracked visitor observations using IBM SPSS Statistics Version 21. Analyses included frequency distributions (e.g., percent of visitors to stop at a component, percent to engage in particular behaviors) and summary statistics (e.g., average time spent at a component). We analyzed survey data using IBM SPSS Statistics Version 21. Analyses included frequency distributions (e.g., percent of visitors who reported learning about a topic).

We used the Kruskal-Wallis test to see if there was a correlation in the amount of time that visitor groups spent in the exhibition (observation data) and their self-reported learning and satisfaction (survey data). We used the Kruskal-Wallis test, a nonparametric test, because we assumed that our data does not have a normal distribution.

- We tested to see if there was a correlation between the mean length of time that visitors spent in the exhibition and their satisfaction question responses reported on a scale of one to ten.

- We tested to see if there was a correlation between the mean length of time that visitors spent in the exhibition and their self-reported learning on a scale of one to four.
- We tested to see if there was a correlation between the mean length of time that visitors spent in the exhibition and their self-reported perceptions of climate change related topics on a scale of one to four.
- We tested to see if there was a correlation between the mean length of time that visitors spent in the exhibition and their understanding of the big idea.

We used chi-square analyses to test whether there were differences in tracked visitors' satisfaction question responses reported on a scale of one to ten, self-reported learning on a scale of one to four, and self-reported perceptions of climate change related topics on a scale of one to four by gender (male/female) and age (youth/adult). We also used chi-square analyses to test whether there were differences in tracked visitors' understanding of the big idea by gender (male/female) and age (youth/adult).

We transcribed audio recordings and coded the transcripts in several ways. First, we coded for expected behaviors (e.g., making an observation, participating in a conversation, asking/answering a question, calling someone over). Then we coded for:

- indicators of engagement and learning (e.g., asking a question, making a hypothesis, referring to other times/places, referring to other *Under the Arctic* components, referring to northerners' lives, making a personal connection);
- emotional responses (e.g., enjoyment, awe/surprise, excitement, hopefulness, sense of wanting to protect permafrost);
- observed learning (e.g., describe permafrost, problems caused by thawing permafrost, how people are adapting to thawing permafrost); and
- evidence of higher order thinking (e.g., making connections between previous knowledge or between exhibition components; comparing information; making a guess based on the information available).

Analysis of audio recordings included frequency distributions (e.g., percent of visitor group to read aloud) and summary statistics (e.g., total count of visitor groups that read aloud by exhibition component).

Survey Study Methods

From March 1 to April 30, 2018, OMSI staff surveyed individuals leaving the *Under the Arctic* exhibition. In total, OMSI staff collected 625 surveys from children and adults.

More than half of the survey participants were female, 19% percent of the survey participants were children in the target age range of 9 to 14, and 78% of the observed visitors identified themselves as white.

Table 3: Survey study participant demographics [1,2]

	Percent of Visitors
Gender (*n* = 558)	
Female	57%
Male	41%
Other or Blank Response	2%
Age, in years (*n* = 557)	
6 to 8	4%
9 to 14	19%
15 to 17	3%
18 to 34	32%
35 to 54	31%
55 +	8%
Other	3%
Race/Ethnicity (*n* = 551)[3]	
Asian American	8%
Native American or Alaska Native	4%
White	78%
Black or African American	5%
Pacific Islander	2%
Hispanic or Latino/a	10%
Other	7%

[1] Visitor demographics do not represent the entire survey sample because many participants left the demographics section of the survey blank.
[2] Does not sum to 100% because visitors were able to select more than one race/ethnicity.

Analysis

We analyzed the survey data using IBM SPSS Statistics Version 21. Analyses included frequency distributions (e.g., percent of visitors who reported learning about a topic) and summary statistics. We also used chi-square analyses to test whether there were differences in participants' satisfaction question responses reported on a scale of one to ten, self-reported learning on a scale of one to four, and self-reported perceptions of climate change related topics on a scale of one to four by gender (male/female) and age (youth/adult). We also used chi-square analyses to test whether there were differences in tracked visitors' understanding of the big idea by gender (male/female) and age (youth/adult).

Tracked Visitor Study Findings

We structured the tracked visitor study findings around the three main questions we used to guide this evaluation for the *Under the Arctic* exhibition. We integrated findings from the observations and surveys.

Observed Engagement

The first evaluation question is about how visitors engaged in the exhibition. We defined level of engagement in several ways, including the time spent in the exhibition overall, observed behaviors of engagement, observed emotional responses, and self-reported engagement.

First, we looked at the average time spent in the exhibition overall, which was 12 minutes and 28 seconds. The least time spent by a group was 3 minutes and 6 seconds, and the most time spent by a group was 49 minutes and 38 seconds.

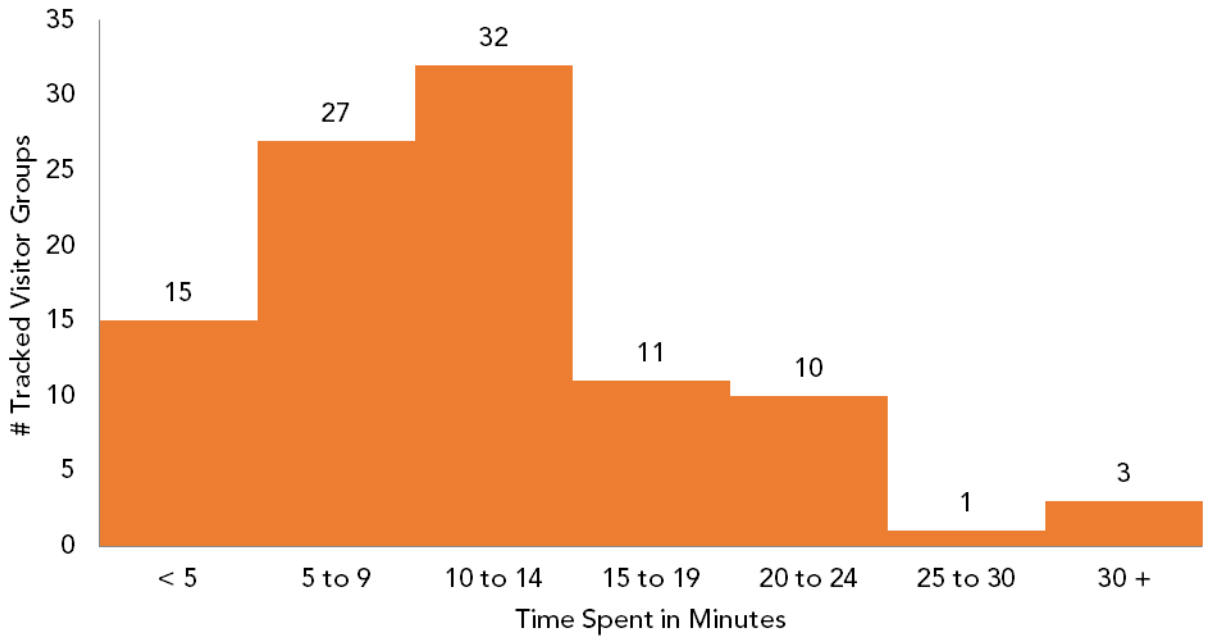

Figure 1: Histogram of time spent in the exhibition; average time spent was 12 minutes and 28 seconds.

We then compared *Under the Arctic* to other exhibitions using Serrell's Sweep Rate Index (2010). Sweep Rate Index is calculated by dividing the exhibition's square footage (2,000 square feet) by the average total time spent there for a tracked sample of casual visitors. A lower sweep rate means that visitors spent more time in the exhibition and were engaged in more learning-related behaviors. The Sweep Rate Index for *Under the Arctic* was 160.51, which is on the lower (and thus more positive) end of Serrell's scale of 0 to 1,000.

We then looked at the percentage of visitors in our sample of tracked visitor groups that stopped at more than half of the exhibition components. Serrell refers to this as the Percent Diligent Visitor (2010). We included 16 exhibition components in our observations. Of the 99 groups tracked, 48 (49%) stopped at more than one-half of the exhibition components.

The Tunnel Structure, the Heat-Trapping Blanket, and components located in the Lab Area (such as the Geology Workstation and Fossil Exploration Station), were clearly the most visited components. The table below illustrates visitor stop percentage and average time spent for all exhibit components.

Table 4: Percent of visitors who stopped; average time spent at each exhibit component

Exhibition Component	Percent of Tracked Visitors Who Stopped (n = 99)	Average Time Spent at Component (minutes:seconds)
Intro Panel	4%	00:12
Arctic Globe	48%	01:05
Welcome Video and Tunnel History	40%	01:03
Tunnel Structure Interior and Exterior	**95%**	**01:57**
Geology Workstation	**87%**	**01:28**
Ice Bubble Researcher's Desk	**63%**	**01:59**
Ice Age Landscape Station	37%	00:47
Fossil Exploration Station	**85%**	**01:11**
Microscope		01:56
Bison Skull		00:27
Heat Trapping Blanket	**88%**	**01:15**
Gear Photo Opportunity	29%	00:52
Keeping Carbon in the Ground	46%	02:17
Northern Stories Mini Theater	31%	02:19
Engineering for Permafrost	24%	03:22
Climate Action Card Game	33%	03:31
Stories of Change	29%	01:13

We then looked at the *Under the Arctic* Sweep Rate Index and Percent Diligent Visitors together to assess the "thorough use" of the exhibition as defined by Serrell (2010). Thoroughly used exhibitions are those in which visitors stay a long time and engage with a large proportion of the exhibit elements. The *Under the Arctic* scores are in the "stay engaged" quadrant of the "thorough use" graph (see Fig. 2) where visitors are interested and engaged long enough to learn something. Serrell calls exhibits with a Sweep Rate Index of less than 300 and a Percent Diligent Visitor of greater than 50% "exceptionally thoroughly" used. The *Under the Arctic* exhibition is just shy of the "exceptionally thoroughly" used criteria, and thus performs very competitively as compared to Serrell's exhibition database when looking at the "thorough use" metric.

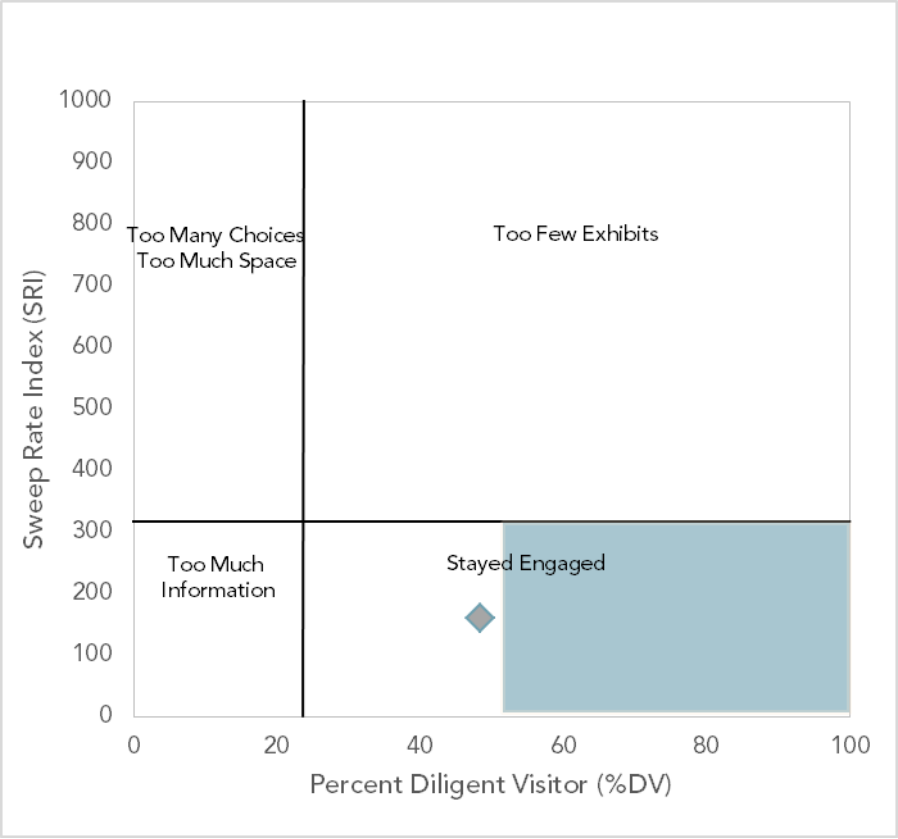

Figure 2: "Thorough Use" metric, or Percent Diligent Visitors vs. Sweep Rate by Serrell (2010); Under the Arctic *score indicated by grey diamond, blue shaded area is considered "exceptionally thoroughly" used*

Behaviors Indicative of Engagement

During observations, we also looked for physical actions indicative of engagement, including manipulating interactive exhibits, touching objects, calling someone over, pointing, and using a bench or stool. We observed one or more of these behaviors for **every tracked visitor group**. Groups were most likely to point while at the Fossil Exploration Station and the Stories of Change components; most likely to call someone over to look at the Tunnel Structure, the Fossil Exploration Station, and the Gear Photo Opportunity; most likely to touch or engage manipulatives at the Heat Trapping Blanket, Bison Skull, and Arctic Globe components; and most likely to sit at the Ice Bubble Researcher's Desk, Northern Stories Mini Theater, and Climate Action Card Game.

Table 5: Percent of tracked visitor groups that showed physical behaviors indicative of engagement, organized by Under the Arctic *component*

Exhibition Component	Point	Call Someone Over	Touch	Use Bench Stool
Intro Panel (*n* = 4)	0%	0%	0%	N/A[5]
Arctic Globe (*n* = 48)	56%	8%	81%	N/A[5]
Welcome Video and Tunnel History (*n* = 40)	0%	13%	5%	N/A[5]
Tunnel Structure (*n* = 94)	53%	39%	38%	N/A[5]
Geology Workstation (*n* = 86)	33%	21%	74%[1]	N/A[5]
Ice Bubble Researcher's Desk (*n* = 62)	32%	26%	47%[2]	76%
Ice Age Landscape Station (*n* = 37)	26%	3%	N/A[4]	35%
Fossil Exploration Station				
Microscope (*n* = 69)	58%	28%	48%[3]	51%
Bison Skull (*n* = 45)	20%	24%	82%	N/A[5]
Heat Trapping Blanket (half planets) (*n* = 78)	10%	26%	N/A[4]	N/A[5]
Heat Trapping Blanket (molecules) (*n* = 79)	15%	6%	N/A[4]	N/A[5]
Gear Photo Opportunity (*n* = 29)	0%	31%	N/A[4]	N/A[5]
Keeping Carbon in the Ground (*n* = 45)	16%	13%	N/A[4]	27%
Northern Stories Mini Theater (*n* = 31)	7%	3%	N/A[4]	55%
Engineering for Permafrost (*n* = 24)	4%	0%	N/A[4]	50%
Climate Action Card Game (*n* = 33)	12%	6%	N/A[4]	52%
Stories of Change (*n* = 29)	62%	7%	14%	N/A[5]

[1] The number refers to the percent of tracked visitor groups who were observed touching some part of the Geology Workstation (e.g., the core drill).
[2] This number refers to the percent of tracked visitor groups who were observed touching some part of the Ice Bubble Researcher's Desk (e.g., the coffee cup).
[3] This number refers to the percent of tracked visitor groups who were observed touching a part of the Fossil Exploration Station (e.g., the mammoth tooth case).
[4] Touching these exhibits was coded as part of the activity or game.
[5] No stool was available during the observations.

The *Under the Arctic* exhibition included eight interactive components. Three of these components incorporated science process skills (Geology Workstation, Fossil Exploration Station, Heat Trapping Blanket), three were games (Ice Bubble Researcher's Desk, Keeping Carbon in the Ground, and Climate Action Card Game), and two allowed younger children to build and/or play with objects (Ice Age Landscape Station and Engineering for Permafrost). The majority of tracked visitors who stopped at these interactive components engaged as expected. The Heat Trapping Blanket had the highest rate of engagement with its interactive components, with 97% of the visitor groups who stopped at the component putting their hands in the half planets and 86% picking up and handling the molecules. The Fossil Exploration Station Microscope had the next highest rate of engagement with interactive components, with 86% of those who stopped adjusting the microscope, and 84%

spinning the tray. More than half also used the field notebook to explicitly find the objects included in the spin tray.

Table 6: Percent of tracked visitor groups that used interactives, organized by Under the Arctic *component*

Exhibition Component	Percent of Visitor Groups who Stopped at Component
Geology Workstation (*n* = 86)	
Weighed core samples	77%
Lifted panels to check hypothesis	65%
Fossil Exploration Station Microscope (*n* = 69)	
Adjusted the microscope	**86%**
Read field notebook	59%
Spin tray	**84%**
Used field notebook	51%
Heat Trapping Blanket	
Half planets (*n* = 78)	**97%**
Molecules (*n* = 79)	**86%**
Ice Bubble Researcher's Desk (*n* = 62)	
Played video game	65%
Watched video (either after game or in cooler)	76%
Keeping Carbon in the Ground (*n* = 45)	
Played game	67%
Read reward screen	69%
Played game 2nd time	40%
Read screen 2nd time	36%
Climate Action Card Game (*n* = 33)	
Put cards in sensors	64%
Read instructions	58%
Read reward screen	73%
Engineering for Permafrost (*n* = 24)	
Build a structure	63%
Thaw the permafrost	50%
Build a second structure	25%
Thaw the permafrost a second time	25%
Ice Age Landscape Station (*n* = 37)	
Touched/played with wooden animal shapes	78%

The Tunnel Structure also provided a meaningful interactive opportunity. The numbered panels encouraged visitors, primarily children, to find the numbered objects in the tunnel walls. Groups tended to start on the left side of the tunnel with the smell button, then read

the "Time travel underground panel," then find some of the objects listed on the panel, then read the "Ice Wedge" panel, and then leave the tunnel or look at the panels on the right hand side of the tunnel, often making connections between the "Ice Wedge" panel and the "Ancient Sinkhole" panel. The "Ice Wedge" panel in particular elicited extensive conversations among visitors, which we documented in the Visitor Learning Section of this report.

Table 7: Percent of tracked visitor groups that read panels and found objects in the Tunnel Structure walls, organized by panel

Tunnel Structure Panel	Percent of Visitor Groups
Read panel: *The permafrost tunnel is freezing cold, frozen solid, and funny smelling*	73%
Used the smell button	73%
Read panel: *Time travel underground*	65%
Found *Time travel underground* objects	50%
Read Panel: *Ice wedge*	**94%**
Read Panel: *Inside old, dirty ice*	61%
Found *Inside old, dirty ice* objects	42%
Read Panel: *Ancient sinkhole*	62%
Found *Ancient sinkhole* objects	45%

Emotional Responses

We observed 483 instances of emotional responses, coming from from 95 of the 99 total visitor groups tracked. The most common emotional response was enjoyment (e.g., smiling, laughing, verbal comments that indicated enjoyment such as "this is fun"), followed by awe or surprise (e.g., verbal comments that indicated surprise such as "I didn't know that!"). Many of the tracked visitor groups were also observed making a personal connection, naming an object with enthusiasm (e.g., verbal comments that indicated enthusiasm about a specific object such as "that's a mammoth tusk!"), or demonstrating excitement (e.g., running to the next component, or verbal comments that indicated excitement such as "I want to do that again!"). The yuck-factor (e.g., verbal comments such as "eew!") most often occurred in response to the smell button in the Tunnel Structure or the cooler at the Ice Bubble Research Station that showed food decaying.

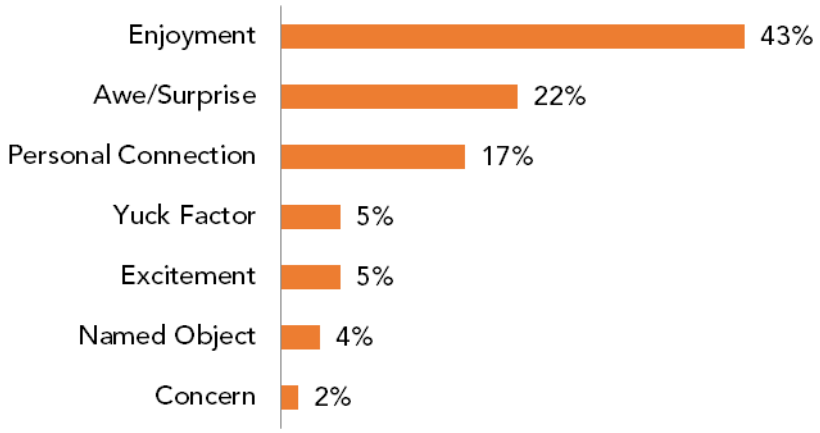

Figure 3: Percent of observed emotional response tracked visitor groups verbalized organized by type of emotion (n = *483)*

Overall, the Fossil Exploration Station, the Tunnel Structure, and the Ice Bubble Researcher's Desk had the most occurrences of emotional responses.

Table 8: Percent of tracked visitor groups that stopped at an exhibition component ***and*** *voiced a positive emotional responses, organized by* Under the Arctic *component*

Exhibition Component	Count of Observed Emotions	Count of Groups that Stopped	Percent of Groups that Stopped
Fossil Exploration Station (*n* = 69)	54	69	78%
Tunnel Structure (*n* = 94)	70	94	74%
Ice Bubble Researcher's Desk (*n* = 62)	39	62	63%
Heat Trapping Blanket (*n* = 79)	47	79	59%
Climate Action Card Game (*n* = 33)	16	33	48%
Welcome Video and Tunnel History (*n* = 40)	17	40	43%
Engineering for Permafrost (*n* = 24)	10	24	42%
Northern Stories Mini Theater (*n* = 31)	13	31	42%
Keeping Carbon in the Ground (*n* = 45)	19	45	42%
Geology Workstation (*n* = 86)	34	86	40%
Arctic Globe (*n* = 48)	18	48	38%
Bison Skull (*n* = 45)	16	45	36%
Gear Photo Opportunity (*n* = 29)	10	29	34%
Stories of Change (*n* = 29)	7	29	24%
Ice Age Landscape Station (*n* = 37)	7	37	19%

Tracked visitor groups who verbally voiced concern for or otherwise referred to northerners' lives, did so at the at the Stories of Change component, the Engineering for Permafrost component, the Geology Workstation, and the Keeping Carbon in the Ground. Following are several examples.

Girl: *[At Northern Stories Mini Theatre] "Crazy" [after Esau's story about his uncle falling g through the ice] (Group A20)*

Girl: *[At Climate Action Card Game] I am scared for climate change. (Group A38)*

Girl: *[At Northern Stories Mini Theatre] What are they doing with that poor fish!*
AM: *They are going to eat it for food. (Group A45)*

Girl: *[At Stories of Change] Mm, hilly. [pause] what? This is sad. (Group KK13)*

Boy: *[at Stories of Change] Oh whooah... that's not good. and that happens all the time. [when permafrost thaws])*
Girl: *Wouldn't it be awful if you had a house that you built and it eroded like that? I would be so mad. That'd be so sad. (KK29)*

Unfortunately, most of these exhibition components were not well trafficked; less than a third of the tracked visitor groups stopped at the Engineering for Permafrost (24% stopped), the Northern Stories Mini Theater (31% stopped), or the Stories of Change (29% stopped). Tracking data do not indicate why the tracked visitor groups did not stop at these exhibit components as frequently as others did, but observer debriefing notes suggest that these components were at the end of the exhibition in an area not clearly demarcated from other engaging stations nearby that were not part of the permafrost exhibit (see the *Under the Arctic* Life Hall layout in Appendix A).

Self-Reported Engagement

The post-written surveys also reflect positive engagement. Of the tracked visitors, 81% gave the *Under the Arctic* exhibition an overall rating of 7 or higher on a 10-point scale.

Table 9: Tracked visitors satisfaction ratings

Rating	Interesting (n = 130)	Liked (n = 133)	Recommend (n = 132)	Overall Rating (n = 129)
7 to 10	73%	74%	62%	**81%**
9 to 10	22%	31%	26%	37%
7 to 8	52%	44%	36%	44%
1 to 6	27%	27%	39%	18%

We used a Kruskal-Wallis test to examine the relationship between time in the exhibition and satisfaction. The relationship between time in the exhibition overall and satisfaction was significant. Tracked visitors who spent more time in the exhibition overall (χ^2 [df, 7, N = 129] = 17.8; p = .013), and those who spent more time in the Living with Climate Change area (χ^2 [df, 7, N = 126] = 17.0; p = .018), rated the overall exhibition higher. We used a chi-square test of independence to examine the relationship between gender and satisfaction and age and satisfaction. Female visitors were more likely to report that they would recommend the exhibition to their family or friends than male visitors were (χ^2 [df, 9, N = 114] = 19.2; p = .024).

Observed and Reported Learning

The second evaluation question addressed the extent to which visitors learned about the big idea: Thawing permafrost changes Arctic landscapes and our global climate. We used evidence of learning from observed learning behaviors, recorded statements of learning, and self-reported learning on the post-survey.

Observed Behaviors that Indicate Learning

First, we tracked behaviors that are indicative of learning, such as reading aloud, asking/answering questions, making a verbal observation or explanation, making a personal connection, or having a conversation about the exhibition.

Reading Aloud

We observed 95 (96% of the tracked visitor groups) of the tracked visitor groups reading aloud at least one time, and an average of four times. In total, we observed 381 instances in which tracked visitors read panel information aloud. The Heat Trapping Blanket prompted the most reading aloud, followed by the Tunnel Structure. Most of those who stopped at the Climate Action Card Game also read the reward screens aloud. Of the instances in which tracked visitor groups read panel information aloud, about half of the readers were children in the group, indicating that the exhibition reading level was accessible for children.

*Table 10: Percent of tracked visitor groups that stopped at an exhibition component **and** read aloud, by Under the Arctic exhibition component*

Exhibition Component	Count of Read Aloud	Count of Groups that Stopped	Percent of Groups that Stopped
Heat Trapping Blanket (*n* = 79)	68	79	86%
Tunnel Structure (*n* = 94)	67	94	71%
Climate Action Card Game (*n* = 33)	20	33	61%
Geology Workstation (*n* = 86)	51	86	59%
Bison Skull (*n* = 45)	25	45	56%
Intro Panel (*n* = 4)	2	4	50%
Ice Bubble Researcher's Desk (*n* = 62)	29	62	47%
Arctic Globe (*n* = 48)	21	48	44%
Fossil Exploration Station (*n* = 69)	29	69	42%
Keeping Carbon in the Ground (*n* = 45)	18	45	40%
Stories of Change (*n* = 29)	11	29	38%
Ice Age Landscape Station (*n* = 37)	11	37	30%
Engineering for Permafrost (*n* = 24)	5	24	21%
Welcome Video and Tunnel History (*n* = 40)	4	40	10%

Asking Questions

We also recorded 92 (93%) of the tracked visitor groups asking a question related to the *Under the Arctic* exhibition. In total, we recorded 241 questions. More than half (54%) of the questions were factual in nature, such as the following:

- *What is that?*
- *What kind of tooth is that?*
- *What's a molecule?*
- *Is that real?*

Another 18% of the questions were comparative, evaluative, or inferential, such as:

- *Which one is more stable?*
- *Why do you think the ice is frozen in a crisscross pattern?*
- *Can you feel the difference?*

Eleven percent were about the exhibit, such as:

- *What's the goal here?*
- *What do you have to do here?*

Finally, 16% of the questions were about a personal connection or about the person being asked the question, such as:

- *Can you imagine seeing that?*

- *Where do you want to go next?*

Almost half of the visitors who stopped at the Tunnel Structure and the Fossil Exploration Station asked a question. In the Tunnel Structure, a few of the questions were specifically about whether the bones in the wall were real. At the Fossil Exploration component, about 10% of the tracked visitors who stopped were curious whether the gold they found in the tray was real. Of those who stopped at the Bison Skull, 36% asked a question, but only a handful of the questions were about whether the Bison Skull was real.

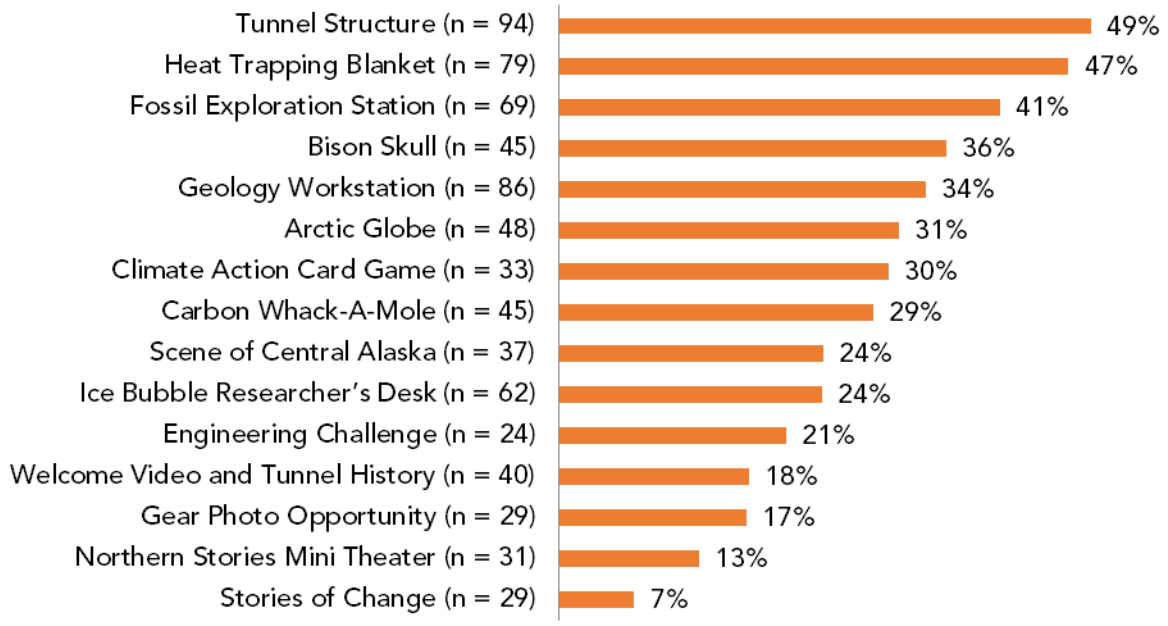

Figure 4: Percent of tracked visitor groups who stopped at an exhibition component ***and*** *had a question, by* Under the Arctic *exhibition component (n=241)*

Verbal Observations

We recorded 91 (92%) of the tracked visitor groups making a verbal observation. In total, we recorded 291 verbal observations.

- Sixty-one percent were descriptive observations, such as "That's a woolly mammoth tooth," or an explanation of an object or component, such as "If you put your hands inside the two cylinders, it will show you what it feel like with and without an atmosphere."
- Seventeen percent of the observations were about a personal connection or a connection to previous knowledge, such as "I think I've heard how they might be able to bring animals frozen in permafrost back to life by taking their DNA" and "I had a buddy who went to ... college who went to Antarctica and would drill for ice core samples like this."

- Eleven percent of the observations were related to learning, including the significance of methane and carbon dioxide, problems caused by thawing permafrost, permafrost's relationship to climate change, and references to northerners' lives.
- Seven percent of the observations were about the exhibit itself.

The Heat Trapping Blanket prompted numerous verbal observations; 89% of the tracked visitors who stopped at the Heat Trapping Blanket made an observation about the component. The following observations were typical.

Boy:	*Feel the air--jeez, this is really hot. Oh. This is like holding the heat...it's like in the chemistry lab...when you were doing that one experiment with the gasses.*
AF:	*A little gas goes a long way...*
Boy:	*So these are trapping ones...the methane...[read out loud...these are solid and so when heat hits a symmetrical gas it just bounces.] These are greenhouse gasses so they are also part of global warming.*

The Fossil Exploration Station and the Geology Workstation also prompted numerous observations.

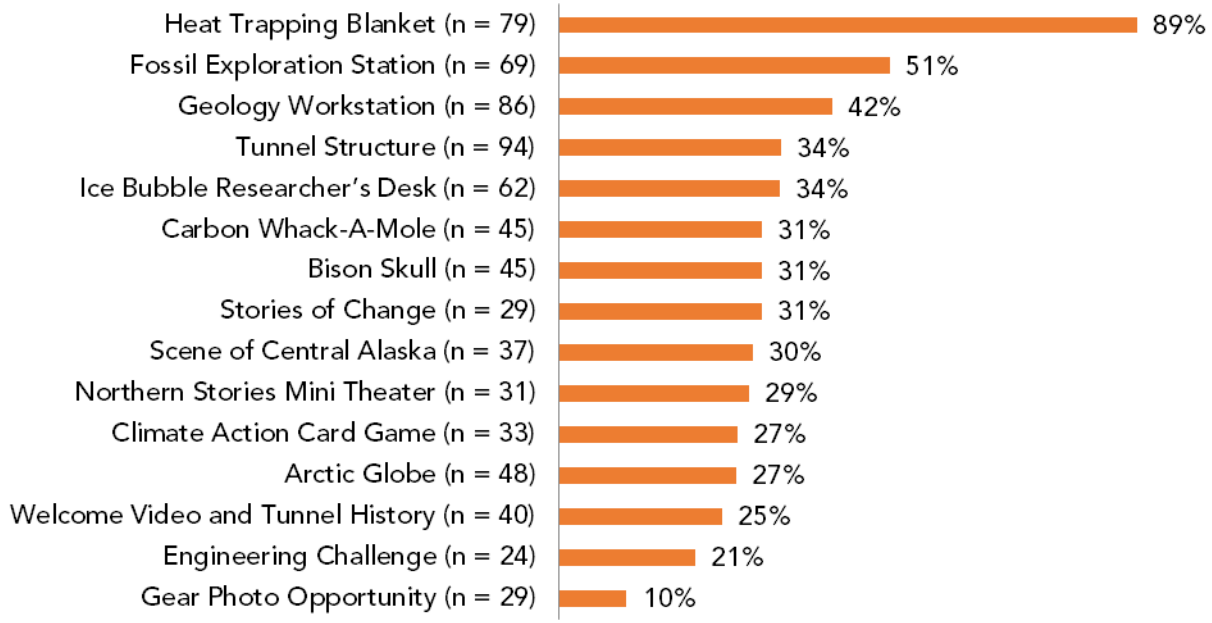

Figure 5: Percent of tracked visitor groups who stopped at an exhibition component ***and*** *made a verbal observation, by* Under the Arctic *exhibition component (n = 291)*

Conversations

We recorded 68 (70%) of the tracked visitor groups having a conversation between adults and children, between children, and between adults. In total, we counted 160 conversations.

Of the conversations, 91 (57% of all the conversations) were explanatory in nature, often starting with an inferential question from either an adult or a child. These conversations clearly facilitated children's learning. The following conversation between an adult female (AF) and a 10-year-old girl (Girl) occurred while the group was in the Tunnel Structure looking at the panel about sinkholes:

AF:	*…everything stayed frozen, what would happen if every summer was unusually warm…everything would melt and sink, what would that do to the ground around it?*
Girl:	*It would pull in the ground.*
AF:	*It would make it all very unstable; think about all the structures around that rely on the permafrost to be almost like a kind of foundation.*
Girl:	*Like concrete.*
AF:	*It would all start to sink in.*
Girl:	*That would be scary. Thousands of people could die. That is why Alaska is very cold (Group A17).*

Another 34 conversations (21% of all conversations) were factual in nature, but still explanatory and also clearly facilitated learning. The following conversation occurred at the Fossil Exploration Station between an adult male (AM) and a 10-year-old boy (Boy):

AM:	*Hey [kid name], look at this, this is a tooth.*
Boy:	*From what?*
AM:	*Back from the time of the dinosaurs, more or less? There were huge elephants and they were called woolly mammoth. And this is the tooth.*
Boy:	*That's so big.*
AM:	*That's so big, right?*
Boy:	*But like how did they find all these things?*
AM:	*They found them in the ground and then they dug them up. And then they try to save them and they study them to learn more about the animals from before. (Group A33)*

Fourteen of the conservations (9% of all the conversations) were about a personal connection. For example, the following conversation took place at the Arctic Globe between an adult female (AF) and a 14-year-old girl (Girl):

Girl:	*Mom, would you want to travel up here by Russia?*
AF:	*I don't have much interest in going north.*
Girl:	*I really want to go to Iceland -- do you know why they named it Iceland? They wanted to trick pirates. (Group A29)*

The remaining 19 conversations (12% of conversations) we recorded were about the exhibit in general. Most of these were related to manipulating an interactive component, such as zooming in to find gold at the Fossil Exploration Station or talking about the weight of the core samples at the Geology Workstation. There were also several conversations related to whether the Bison Skull, gold, or bones were real. For example, the following conversation took place between an adult female (AF) and a 12-year-old boy (Boy).

Boy:	*Is that a real skull?*
AF:	*It might be a cast of one? I'm not sure.*
Boy:	*Is that an ancient skull or a modern one?*
AF:	*That's probably from the ice age... yeah. (Group K22)*

Three of the *Under the Arctic* components had the most conversations: the Geology Workstation, the Heat Trapping Blanket, and the Fossil Exploration Station. All three of these components were designed to inspire discussion. The Geology Workstation and the Fossil Exploration Station also incorporated an "investigator role" which further expanded the opportunities for visitor groups to engage in conversation.

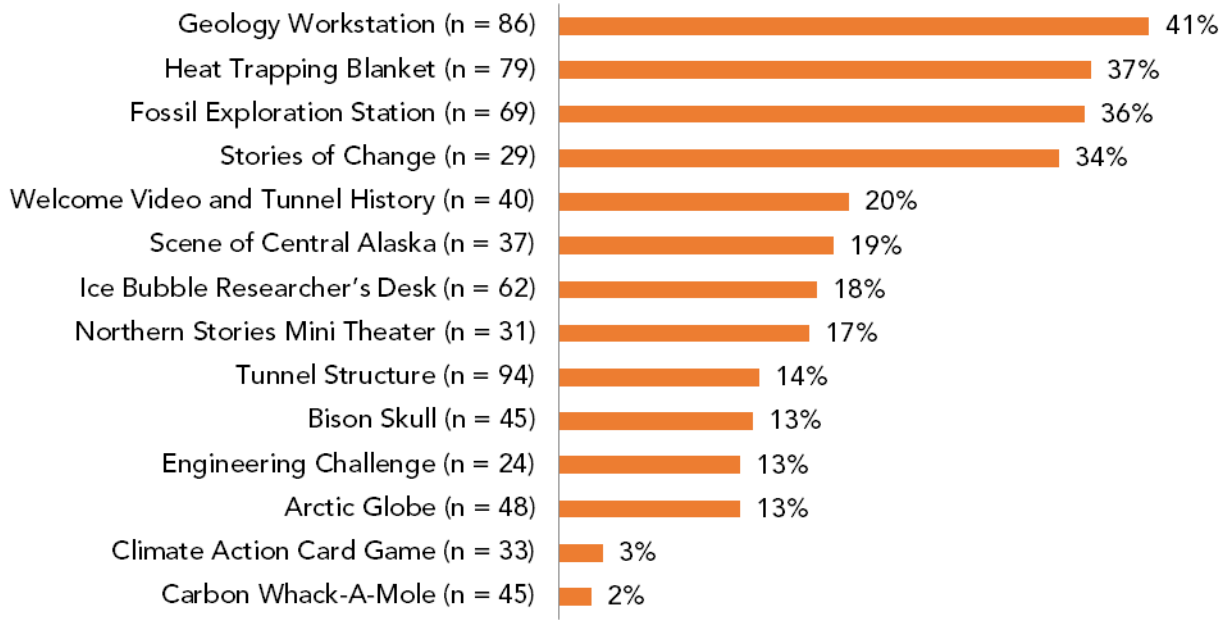

Figure 6: Percent of tracked visitor groups who stopped at an exhibition component ***and*** *had a conversation, by* Under the Arctic *exhibition component (n = 160)*

Reported Learning

Overall, most of the tracked visitor groups reported learning "some" or "a lot" about the topics we explicitly asked them about: problems caused by permafrost, the relationship

between permafrost/climate change, permafrost, methane and carbon dioxide release, how scientists are studying permafrost, and how people are adapting to thawing permafrost.

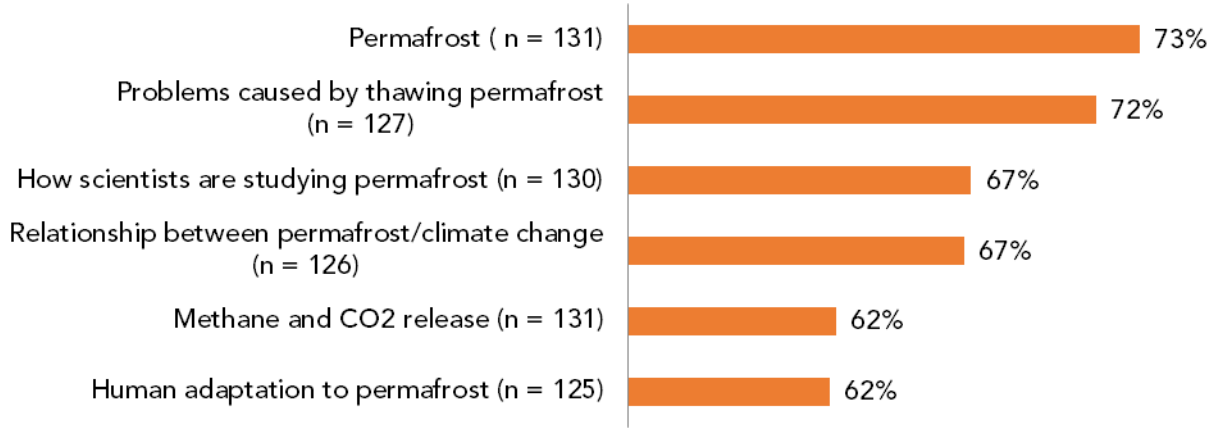

Figure 7: Percent of tracked visitors who reported learning "some" or "a lot" about Under the Arctic *topics*

We used a Kruskal-Wallis test to examine the relationship between time in the exhibition and self-reported learning. Time spent in the exhibition overall and in different part of the exhibition affected the self-reported learning of tracked visitors. Tracked visitors who spent more time in the exhibition **overall** were more likely to report learning about the following:

- permafrost (χ^2[df, 3, N = 131] = 16.5, p =.001)
- problems caused by thawing permafrost (χ^2 [df, 3, N = 127] = 12.2, p = .007)

Tracked visitors who spent more time in the **Lab Area** (with the Geology Workstation, Fossil Exploration Station, Ice Bubble Researcher's Desk, and the Ice Age Landscape Station) were more likely to report learning about the following:

- permafrost (χ^2 [df, 3, N = 131] = 18.1, p < .000)
- how people are adapting to permafrost (χ^2[df, 3, N = 125] = 11.4, p = .010)
- problems caused by thawing permafrost (χ^2 [df, 3, N = 127] = 12.9, p = .005)
- how scientists are studying permafrost (χ^2 [df, 3, N = 130] = 10.5, p = .015)

Tracked visitor who spent more time in the **Living with Climate Change Areas** were more likely to report learning about the following:

- problems caused by thawing permafrost (χ^2 [df, 3, N = 125] = 10.1, p = .018)

We used a chi-square test of independence to examine the relationship between overall satisfaction and self-reported learning. Visitors who rated the *Under the Arctic* exhibition highly overall were more likely to report learning about the following:

- problems caused by thawing permafrost (χ^2 [df, 21, N = 123] = 41.0; p = .006)
- the relationship between permafrost and climate change (χ^2 [df, 21, N = 122] = 41.5; p = .005)

- how scientists are studying permafrost (χ^2 [df, 21, N = 127] = 55.5; p < .001).

We also used a chi-square test of independence to examine the relationship between gender and self-reported learning. Female visitors were more likely to report learning about the following:

- how people are adapting to thawing permafrost (χ^2 [df, 3, N = 107] = 8.1; p = .044)
- relationship between permafrost and climate change (χ^2 [df, 3, N = 110] = 10.2; p = .017).

We also used a chi-square test of independence to examine the relationship between age and self-reported learning. Adults were more likely than children were to report learning about the following:

- relationship between permafrost and climate change (χ^2 [df, 3, N = 110] = 13.8; p = .003).

Big Idea

Twenty percent of the tracked visitors captured the big idea—thawing permafrost changes Arctic landscapes and our global climate—when asked to describe what they would tell a friend about the *Under the Arctic* exhibition. The other two topics most visitors wrote about were permafrost and climate change. Twelve percent of the visitors wrote about all three ideas: permafrost, climate change, and the big idea.

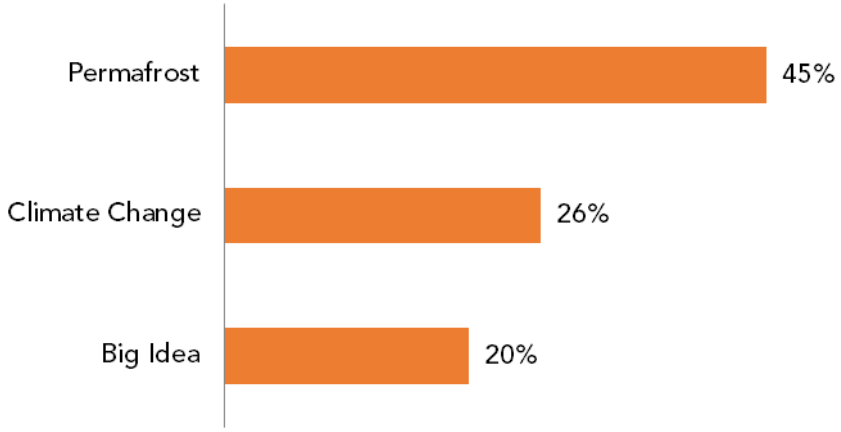

Figure 8: Under the Arctic *tracked visitor groups' self-reported summary of what the exhibition was about (*n = *133 surveys)*

Understanding the big idea was not correlated with satisfaction or with overall time in the exhibition. Tracked visitors were more likely to understand the big idea the longer they spent in the exhibition overall (χ^2 [df, 1, N = 133] = 7.9; p = .005), and the longer they spent in the Tunnel Structure (χ^2 [df, 1, N = 127] = 12.1; p = .001). There were no differences by

gender in whether a visitor wrote about the big idea. Adults were significantly more likely to capture the big idea than children were (χ^2 [df, 1, N = 115] = 5.4; p = .017).

Climate Change Perceptions

The third evaluation question addressed the extent to which the exhibition affected visitors' perceptions of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts. Audio data collection only captured a handful of visitor groups talking about solutions or actions to address climate change, a sense of urgency to do something, personal or community action, agreement with actions illustrated in the exhibition, or interest in further exploring climate science principles. Following are several examples (AF = adult female, AM = adult male):

AF: *Climate change is changing when the fish run and when things happen, when the caribou move. The question is like, "how do you change that?" how do you stop it? (Group A05)*

AF: *It's telling us we need to keep the permafrost frozen by reducing fossil fuels. We saved today by riding our bikes, didn't we? (Group A12)*

AF: *Las Vegas runs its municipal facilities on 100% renewable energy… I didn't know that did you?*
Boy: *No.*
AM: *We changed to LEDs and saved hundreds of bucks. (Group A22)*

However, the post-survey results strongly indicate that tracked visitor groups increased their positive perceptions of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts. Approximately a third of the tracked visitor groups reported **agreeing more** that community effort to address climate change will have a positive impact, that scientists understand whether climate change is occurring and that climate scientists can be trusted, and that they are interested in climate science and want to learn more about climate change.

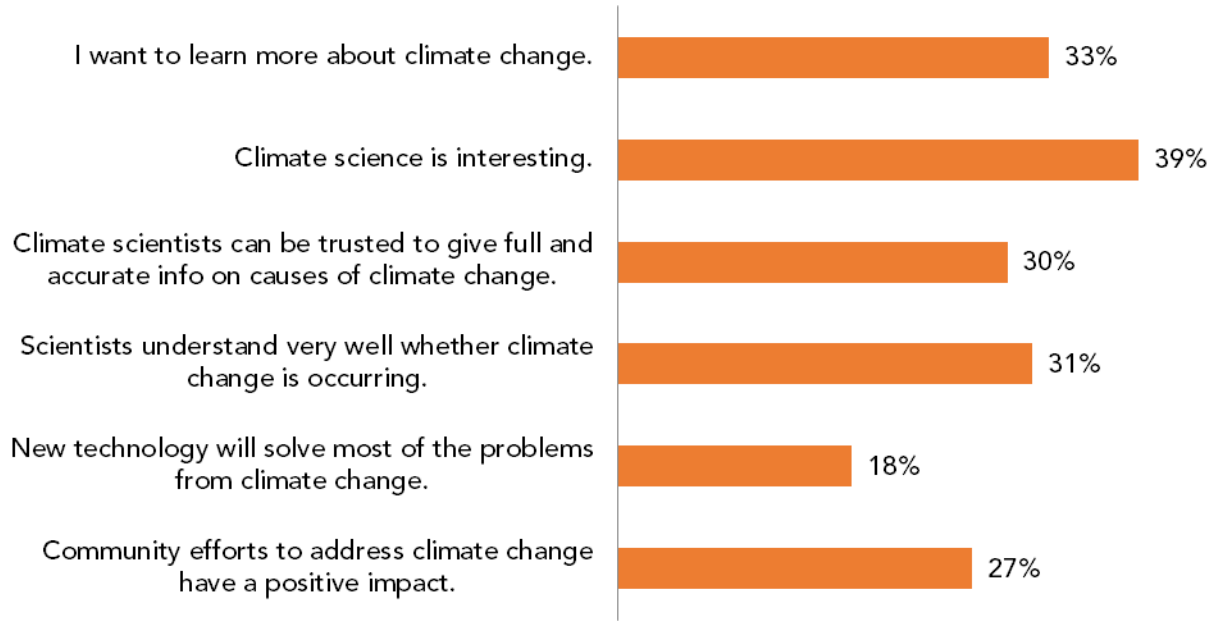

Figure 9: Percent of individuals from tracked visitor groups who, after visiting the Under the Arctic *exhibition, agree more about climate change ideas (*n = *133)*

We used a Kruskal-Wallis test to examine the relationship between time in the exhibition and agreement with climate change ideas after visiting the *Under the Arctic* exhibition. Total time in the exhibition or in different areas of the exhibition did not affect whether tracked visitors were more likely to agree about climate change ideas.

We used a chi-square test of independence to examine the relationship between gender, age, and satisfaction and agreement with climate change ideas after visiting the *Under the Arctic* exhibition. Female visitors were more likely than males to "agree more" after visiting the exhibition that scientists understand very well whether climate change is occurring (χ^2 [df, 3, N = 100]= 10.0; p = .018). Children were more likely than adults were to "agree more" after visiting the exhibition that they want to learn more about climate change (χ^2 [df, 3, N = 106] = 13.8; p = .003).

The higher visitors rated the overall exhibition, the more likely they were to "agree more" after visiting the exhibition that climate change scientists can be trusted a lot to give full and accurate information on causes of climate change (χ^2 [df, 21, N = 102]= 42.4; p = .004), that climate science is interesting (χ^2 [df, 21, N = 102] = 88.0; p < .001), and that they want to learn more about climate change (χ^2 [df, 21, N = 104] = 64.6; p < .001).

Survey Study Findings

We structured the tracked visitor study findings around the three main questions we used to guide this evaluation for the *Under the Arctic* exhibition: engagement, learning outcomes and understanding about the big idea, and effects on visitors' perceptions of the ability of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts.

Visitor Engagement

We asked participants to circle a whole number, ranging from one to 10, for four questions that gauged their overall response to the *Under the Arctic* exhibition; one was a negative response, five was neutral, and 10 was a positive response towards the exhibit. The highest average response was for the overall rating of the exhibit with a 7.58 rating. The lowest response was for the likelihood that the participants would recommend the *Under the Arctic* exhibition, with an average of 6.97—although, while this was the lowest average response, it was still a positive response. For all four questions, the average response was around a seven, which showed an overall positive reaction to the exhibit.

Table 11: Average Under the Arctic *engagement responses by survey question*

Question	*n*	Average
How interesting was the *Under the Arctic* Exhibition? (1=not at all interesting, 10=extremely interesting)	612	7.20
How much did you like the *Under the Arctic* exhibition? (1=did not like it at all, 10=liked it a lot)	613	7.38
How likely is it that you would recommend the *Under the Arctic* exhibition to a friend or family member? (1=not likely at all, 10=extremely likely)	619	6.97
Overall, how would you rate the *Under the Arctic* exhibition? (1=poor, 10=fantastic)	611	7.58

We used a chi-square test of independence to examine the relationship between gender and engagement and age and engagement. There were no statistical differences between female and male participants related to engagement. Adults were more likely to report that they would recommend the exhibition to their family or friends than children were ($\chi 2$ [df, 9, N = 541] = 22.9; p = .006), and adults rated the overall exhibition higher than children did ($\chi 2$ [df, 8, N = 533] = 18.8; p = .016).

Learning Questions and Understanding of the Big Idea

We also asked participants to assess how much they learned from the exhibit about the causes and effects of thawing permafrost. For each question, we asked participants to circle a whole number between one and four, with one being that they learned nothing and four being that they learned a lot. Participants reported learning the most about permafrost and the least about methane and carbon dioxide (CO_2) release. Well over 50% of participants reported learning at least "some" about each of the six topics.

Table 12: Percent of Under the Arctic *survey participants by question and level of self-reported learning*

Question	*n*	learned nothing	learned little	learned some	learned a lot	Total learned some and a lot
Permafrost	618	4%	20%	49%	27%	76%
Methane and CO_2 release	614	11%	31%	41%	18%	58%
Human adaptation to permafrost	599	11%	25%	42%	22%	64%
Problems caused by thawing permafrost	596	8%	19%	44%	28%	72%
Relationship between permafrost and climate change	597	8%	21%	42%	29%	71%
How scientists are studying permafrost	605	9%	22%	39%	30%	69%

In addition, 564 visitors (90% of all survey participants) wrote about what they would tell a friend about the *Under the Arctic* exhibition. Of those, 407 wrote about the content of the exhibition (72% of survey participants). A total of 56% of those who wrote that they would tell a friend about content indicated they would tell about permafrost[1], 34% would tell about climate change, and 18% (72 participants) referenced the exhibition's big idea "Thawing permafrost changes Arctic landscapes and our global climate." The following table lists the themes that emerged.

[1] Most responses included more than one idea or concepts, so results do not sum to 100%.

Table 13: Ideas or concepts participants wrote about when asked what they would tell a friend about the Under the Arctic exhibition (n = 407 participants who wrote a comment about an idea or concept)

Idea/Concept	Count	Percent[1]
Permafrost	226	56%
Climate Change	137	34%
Big Idea	72	18%
Arctic	56	14%
Research	52	13%
Human Impact	47	12%
Ice	30	7%
Bones/Fossils	20	5%
Importance of Permafrost	19	5%
Under Ground	17	4%
Historical context/Timeframe	15	4%
Named a specific element of the exhibition	11	3%
Gases	10	2%
Smell	9	2%
Sink holes	7	2%
Energy	5	1%
Don't Know	5	1%
Tunnel	4	1%
Anti-climate change	3	1%

[1]Most responses included more than one ideas or concept so results do not sum to 100%

We used a chi-square test of independence to examine the relationship between gender and self-reported learning and age and self-reported learning. There were no statistical differences between female and male respondent relate to their self-reported learning. Adults were more likely to self-report learning about the topics we explicitly asked them about than children were.

- permafrost ($\chi 2$ [df, 3, N = 539] = 8.0; p = .046)
- methane and carbon dioxide release ($\chi 2$ [df, 3, N = 535] = 8.5; p = .037)
- how people are adapting to thawing permafrost ($\chi 2$ [df, 3, N = 524] = 11.3; p = .010)
- problems caused by thawing permafrost ($\chi 2$ [df, 3, N = 524] = 8.5; p = .037)
- the relationship between permafrost and climate change ($\chi 2$ [df, 3, N = 526] = 21.3; p < .000)
- how scientists are studying permafrost ($\chi 2$ [df, 3, N = 531] = 8.5; p < .000)

Climate Science and Efforts to Address Climate Change

We also asked participants six questions to assess whether the *Under the Arctic* exhibition had an impact on their opinions about climate science and efforts to address climate change. Approximately 530 participants answered each question. Almost half of the

participants agreed more that climate science is interesting and that they want to learn more about climate change.

Table 14: Percent of participants who disagree or agree more or about the same about climate change statements

Question	*n*	disagree more	disagree about the same	agree about the same	agree more
Community efforts to address climate change have a positive impact.	536	3%	6%	59%	33%
New technology will solve most of the problems from climate change.	528	4%	23%	56%	17%
Scientists understand very well whether climate change is occurring.	513	2%	9%	58%	31%
Climate scientists can be trusted to give full and accurate info on causes of climate change.	530	4%	9%	55%	32%
Climate science is interesting.	532	2%	6%	47%	45%
I want to learn more about climate change.	529	3%	9%	46%	42%

We used a chi-square test of independence to examine the relationship between gender and opinions about climate change science and age and opinions about climate change science. Male participants were more likely than female participants to "disagree about the same" that scientists know very well whether climate change is occurring ($\chi 2$ [df, 3, $N = 499$] = 13.1; $p = .004$). Adults were more likely than children to "agree more" with the following:

- community efforts to address climate change will have a positive impact ($\chi 2$ [df, 3, N = 519] = 20.9; p < .000)
- new technology will solve most of the problems form climate change ($\chi 2$ [df, 3, N = 511] = 12.7; p = .005)
- climate scientists can be trusted a lot to give full and accurate info on causes of climate change ($\chi 2$ [df, 3, N = 512] = 13.0; p = .005)
- climate science is interesting ($\chi 2$ [df, 3, N = 514] = 27.7; p < .000)
- they want to learn more about climate change ($\chi 2$ [df, 3, N = 512] = 23.4; p < .000)

Discussion

Under the Arctic scored very high in terms of the time and attention visitors gave the content in relation to the size of the exhibition. More importantly, though, while in that space, tracked visitors truly engaged with most of the exhibition components. Visitor groups who stopped at the interactive exhibition components participated in the activities as designed—weighing core samples at the Geology Workstation, using the field notebook to find samples at the Fossil Exploration Station, building a structure and thawing the permafrost at the Engineering for Permafrost component, or playing the Climate Action Card Game and reading the reward screens. In the Tunnel Structure, most of the tracked visitor groups also used the lists provided on two panels to find objects embedded in the tunnel walls.

Almost all of the tracked visitor groups verbalized a positive emotional response while viewing the exhibition. These responses included smiling, laughing, awe, surprise, and even disgust after pushing the smell button in the Tunnel Structure or looking in the cooler of rotting fruits and vegetables on the Ice Bubble Researcher's Desk. Only a few of the tracked visitor groups verbalized concern for or otherwise referred to northerners' lives. Those that did, did so at the at the Stories of Change component, the Engineering for Permafrost component, the Geology Workstation, and the Keeping Carbon in the Ground component.

Overall, the most frequently visited exhibition component was the Tunnel Structure. This finding is not surprising given the layout of the exhibition and the design of the tunnel entrance intentionally drawing visitors to the tunnel. After the Tunnel Structure, the Heat Trapping Blanket and the components included in the Lab Area were the most frequently visited: Geology Workstation, Fossil Exploration Station, and Ice Bubble Researcher's Desk. However, although fewer visitors visited the Living with Climate Change Area (less than a third of the tracked visitor groups), visitors spent more time with components there, on average, than other components elsewhere. The Living with Climate Change components included Keeping Carbon in the Ground, Northern Stories Mini Theater, Engineering for Permafrost, and Climate Action Card Game. It is unclear if visitors were less likely to stop at the Living with Climate Change components because were less inviting than those in the Lab Area. It may be that the exhibition's layout made it unclear that the exhibition included the Living with Climate Change area, so visitors continued through the Living with Climate Change area without stopping, not knowing they were missing *Under the Arctic* exhibition components. Alternatively, it may be that the location of the exhibition within OMSI's 7,950 square foot Life Science Hall, adjacent to other exhibits and the Life Science Lab, simply drew visitors away to something new after they had completed the Lab Area.

In general, the Tunnel Structure and the components included in the Lab Area also elicited the most emotional responses. The components in the Lab Area prompted tracked visitor

groups to read aloud to one another more than other parts of the exhibition (except the Climate Action Card Game). More than half of the readers observed were children in the group. Likewise, more questions were asked, more observations, and more conversations occurred in the Lab Area.

The *Under the Arctic* exhibition provided extensive opportunities for children and adults to have conversations, ask and answer questions, and to make observations. Many of the conversations were explanatory or factual in nature, often starting with an inferential question from either an adult or a child. These conversations clearly facilitated children's learning. Many of the conversations made a personal connection to the exhibition. A few conversations were about the realness of the objects in the exhibition, particularly the bones in the Tunnel Structure, the Bison Skull, and the gold in the microscope tray.

Evidence of Learning

Time spent paying attention is a prerequisite for learning, and studies have shown a positive relationship between the amount of time spent in an exhibition and learning (Borun et al., 1998). Spending more time overall, talking about the exhibits, and reading label texts aloud to each other are three highly predictive behaviors for learning in exhibitions. We saw evidence of this relationship in the evaluation.

About **two-thirds** of the tracked visitor group members who completed a survey, and survey study participants, **reported learning** about the topics that were explicitly asked about. These topics were problems caused by permafrost, the relationship between permafrost and climate change, permafrost itself, methane and carbon dioxide release, how scientists are studying permafrost, and how people are adapting to thawing permafrost. Of tracked visitor groups who completed surveys, those who spent greater time in the Lab Area were more likely to report learning about four of these topics. The Heat Trapping Blanket, the Geology Workstation, and the Fossil Exploration station also facilitated a higher percentage of the highly predictive behaviors for learning in exhibitions—more than a third of the visitor groups who stopped at these components engaged in a conversation. Also, more than 40% of the visitor groups who stopped at these three components made a verbal observation—describing something about the component, making a personal connection, or describing something they were learning. More than a third of the visitor groups that stopped at these components asked a question related to the component.

The post-survey results also strongly indicate that tracked visitor groups and survey study participants **increased their positive perceptions of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts**. Approximately a third of the tracked visitor groups reported agreeing more that community effort to address climate change will have a positive impact, that scientists understand whether climate change is occurring and that climate scientists can be trusted, and that they are interested in climate science and want to learn more about climate

change. However, we only recorded a handful of visitors talking about community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts. These observations were made primarily in the Living with Climate Change area. We expect that we would have heard additional comments had more of the tracked visitor groups visited this part of the exhibition. More traffic to this area of the exhibition may also increase the percent of visitors who increase their positive perceptions of community solutions and/or policies to reduce carbon emissions and mitigate and/or adapt to climate change impacts.

The evaluation provided evidence that **the *Under the Arctic* exhibition achieved, to some extent, many of its learning goals**. About 20% of the tracked visitors and 18% of the survey study participants captured the big idea—thawing permafrost changes Arctic landscapes and our global climate—when asked to describe what they would tell a friend about the *Under the Arctic* exhibition. The other two topics most visitors wrote about were permafrost and climate change. Twelve percent of the visitors wrote about all three ideas: permafrost, climate change, and the big idea. Adults were more likely to capture the big idea than children were.

While only a handful of tracked visitors appeared to increase their feelings of emotional connection with northerners' lived experiences, many more found personal relevance with the exhibition from knowing someone in Alaska, to feeling worried about sinkholes that might occur in their own neighborhood, to thinking about ways to save energy. There is also evidence that the exhibition increased interest in exploring climate science principles that elucidate changes due to thawing permafrost for both adults and children, but more so for children who reported that they want to learn more about climate change after visiting the exhibition.

Finally, *Under the Arctic* targeted children ages 9 to 14 and their families. Both the tracked visitor study and the survey study strongly indicated that both adults and children enjoyed the exhibition and were engaged in learning activities. However, the survey study indicated adults were more likely to self-report learning about the topics we explicitly asked them about than children were, and both studies found that adults were more likely to report understanding of the big idea. In addition, the survey study found that while both children and adults reported visit to the exhibition affected their opinions about climate science and efforts to address climate change, adults were more likely than children were to report a positive effect.

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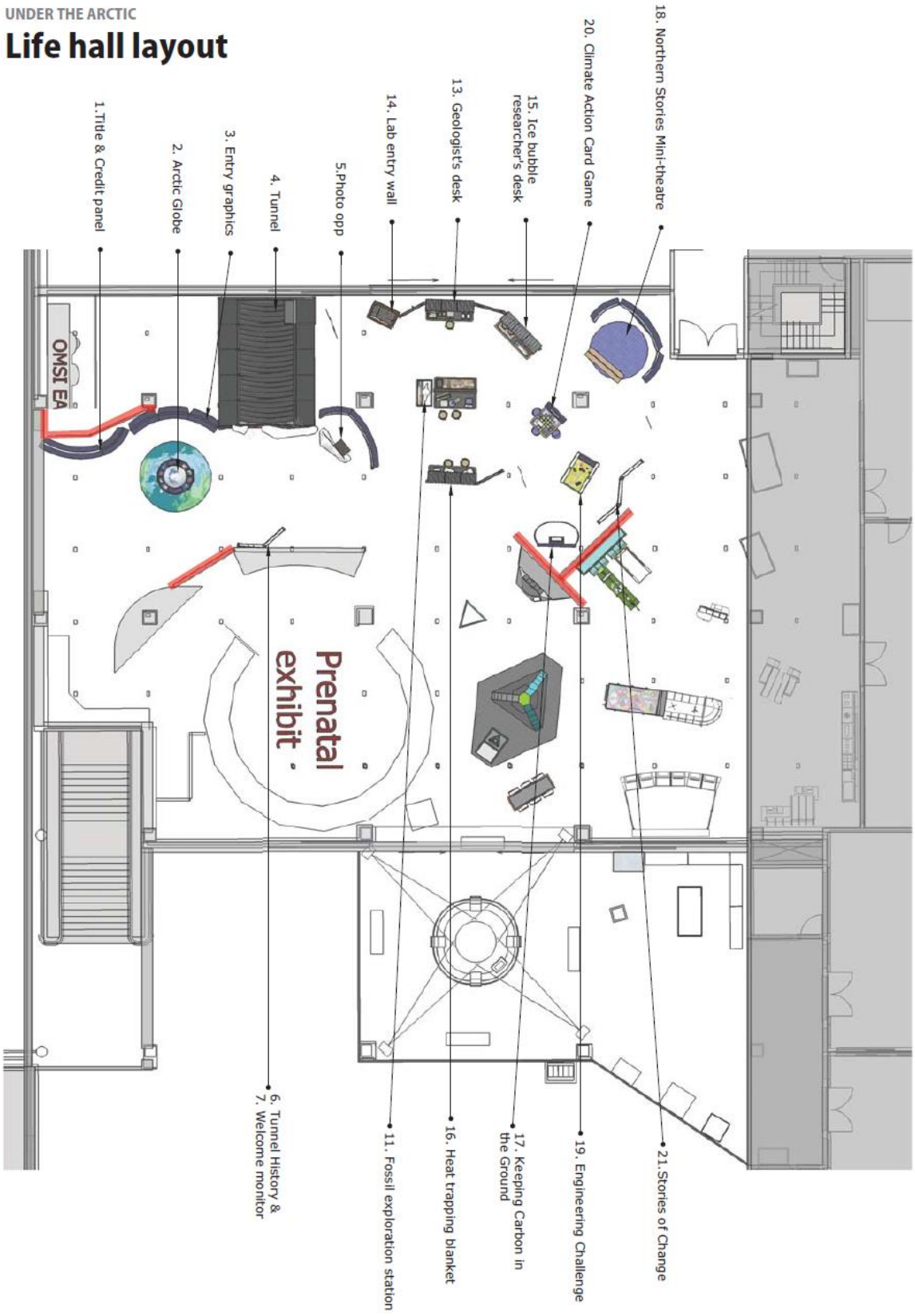
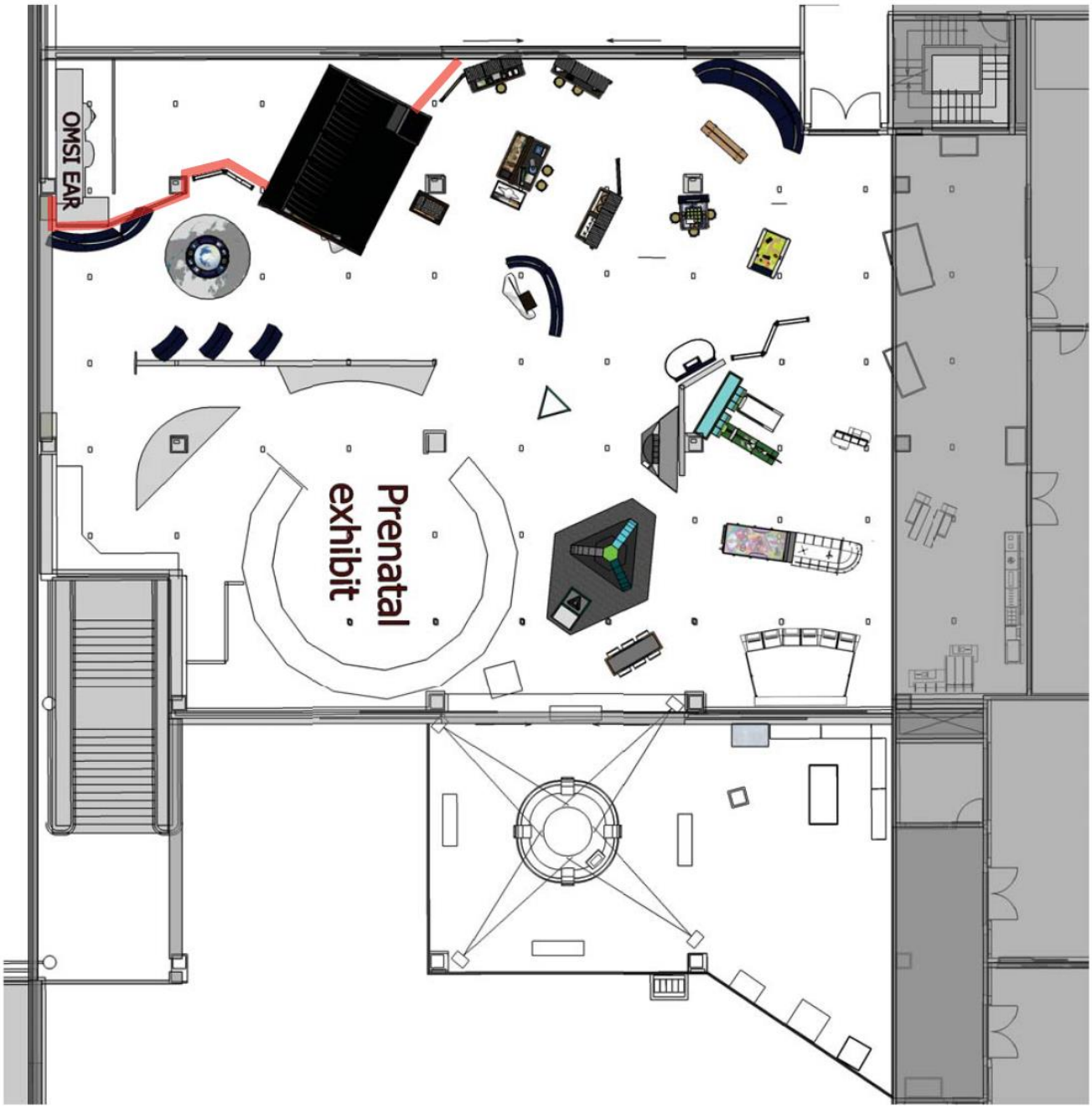
Appendix A: *Under the Arctic* Exhibition Layout





DRAWN BY: Joe Bartley

DATE: August 22, 2017

Permafrost

PROJECT # 075

WORKING CONCEPT

NOT FOR PRODUCTION

1945 SE WATER AVENUE
PORTLAND, OREGON
97214-3354
PH. (503) 797-4000
FAX (503) 797-4800

OMSI

Appendix B: Tracked Visitor Study Informed Consent

***Under the Arctic* Evaluation Information Sheet and Consent**

What is *Under the Arctic*: *Under the Arctic* is a 2,000 square foot museum exhibit. Development of the exhibit was part of a larger National Science Foundation Advancing Informal STEM Learning grant, *Hot Times in Cold Places: The Hidden World of Permafrost*, awarded to the University of Alaska Fairbanks in partnership with the Oregon Museum of Science and Industry (OMSI). The Goldstream Group is conducting the evaluation. Angela Larson, Principal is leading the evaluation.

Why are we doing the evaluation? The purpose of the summative evaluation is to describe how visitors engage with the exhibit and to explore whether engagement helped visitors learn about permafrost.

What happens in the evaluation?

- You (and your child or children) will visit the exhibit as you normally would. You can stay for as long or as little as you want.
- Evaluators will take notes as they watch what you do and say while in the exhibition. This helps us understand how people engage with the exhibition.
- You or your child will wear an audio recorder, which will record what you say while in the exhibition. This helps us understand how people react to the exhibition.
- When you are done, you (and your child or children) will be asked to fill out a survey about what you learned and what you thought of the exhibit.

What we do with the information? Only evaluation staff will see the raw date. We will not record any personally identifying information about you. We will write about what we learn for OMSI and University of Alaska Fairbanks exhibition developers and our funders. We may publish in journals or online.

Are there any benefits or risks? There are no direct benefits to you, though you may feel good about helping us improve the exhibit. You might be embarrassed by something you say or do. Because we don't record your identity, there are no further risks.

Do I have to take part? No.

What if I have more questions? The evaluator or OMSI staff may be able to answer your questions. You may call the lead evaluator, Angela Larson at 907-452-4365 or by email at alarson@goldstreamgroup.com. You can also call Chris Cardiel on OMSI's Research and Evaluation Team at 503-797-4584 or by email at ccardiel@omsi.edu.

YES. I understand the *Under the Arctic* evaluation and agree for me and/or my child/children to be part of the study and survey.

Signature **Date**

Group # _____

Appendix C: *Under the Arctic* Post Survey

OMSI GOLDSTREAM group, inc.

Under the Arctic Evaluation

Please tell us about your experience visiting the *Under the Arctic* exhibition today!

1. If a friend asked you what the *Under the Arctic* exhibition was about, what would you say?

2. How interesting was the *Under the Arctic* exhibition? Circle the number closest to your opinion.

Not at all interesting	1	2	3	4	5	6	7	8	9	10	Extremely interesting

3. How much did you like the *Under the Arctic* exhibition? Cicle the number closest to your opinion.

Did not like it at all	1	2	3	4	5	6	7	8	9	10	Liked it a lot

4. How likely is it that you would recommend the *Under the Arctic* exhibition to a friend or family member? Circle the number closest to your opinion.

Not at all Likely	1	2	3	4	5	6	7	8	9	10	Extremely likely

5. Overall, how would you rate the *Under the Arctic* exhibition? Circle the number closest to your opinion.

Poor	1	2	3	4	5	6	7	8	9	10	Fantastic

6. How much did you learn about...

	Learned nothing	Learned a little	Learned some	Learned a lot
permafrost?	☐	☐	☐	☐
methane and CO_2 release?	☐	☐	☐	☐
how people are adapting to thawing permafrost?	☐	☐	☐	☐
problems caused by thawing permafrost?	☐	☐	☐	☐
the relationship between permafrost and climate change?	☐	☐	☐	☐
how scientists are studying permafrost?	☐	☐	☐	☐

7. Is there anything else you would like to share about your learning?

8. After seeing the *Under the Arctic* exhibition, how much do you agree or disagree with these ideas compared with how you felt before you visited the exhibition?

	Disagree more	Disagree about the same	Agree about the same	Agree more
Community efforts to address climate change will have a positive impact.	☐	☐	☐	☐
New technology will solve most of the problems from climate change.	☐	☐	☐	☐
Scientists understand very well whether climate change in occurring.	☐	☐	☐	☐
Climate scientists can be trusted a lot to give full and accurate info on causes of climate change.	☐	☐	☐	☐
Climate science is interesting.	☐	☐	☐	☐
I want to learn more about climate change.	☐	☐	☐	☐

9. About how many times have you been to a museum in the last 12 months? _____

10. About you?

What is your gender? _____

What is your age? _____

What is your zip code? _____

11. What is your race/ethnicity? You may select more than one.

- ☐ Asian American
- ☐ Native American or Alaska Native
- ☐ White
- ☐ Black or African American
- ☐ Pacific Islander
- ☐ Hispanic/Latino/a
- ☐ Other

12. How much school have you finished? Check your highest completed education level.

- ☐ Some elementary school
- ☐ Some middle school
- ☐ Some high school
- ☐ High school diploma/GED
- ☐ Some college
- ☐ 2-year college degree (AA, AS)
- ☐ 4-year college dgree (BA, BS)
- ☐ Master's degree
- ☐ Doctoral degree
- ☐ Professional degree
- ☐ Other/different system

13. If you have completed a college degree, is your degree in a science, technology, engineering, or math field?

- ☐ Yes
- ☐ No
- ☐ Haven't completed a college degree or higher

Thank you!

Appendix D: *Under the Arctic* Tracking and Timing Instrument

exhibit component	01_Title and Credit	02_Arctic Globe	03_Entry Graphics (Right)	04_Margaret's video panel	05_Tunnel	06_lab entry wall	07_geologists desk	08_ice bubbles	09_scene of central AK	10_bison fossil
Start										
End										
look at images										
read text/labels										
read aloud										
call someone over										
point										
verbal obs										
verbalize enthusiasm										
ask question										
answer question										
touch exhibit items										
took picture										
sit down										
watched others										
Watched video										
Read Panel R1										
Found Panel R1 objects										
Read Panel R2										
found panel R2 objects										
Read Panel L1										
Used smell button										
Read Panel L2										
found panel L2 objects										
Read Panel L3										
Found panel L3 objects										
weigh core samples										
lift panels										
play video game										
watch other play game										
adjust microscope										
spin tray										
look at monitor										
read field notebook										
use field notebook to ID										
play game										
read reward screen										
play game again										
read rewards again										
look at large screen										
build										
melt permafrost										
rebuild										
melt permafrost again										
read instructions										
play game										
put cards in sensors										
read reward screens										
front										
back										
Field Notes										

exhibit component	11a_microscope	11b_bison tooth	12a_1/2 planets	12b_molecules	13_photo op	17_keeping carbon in the ground	18_northern stories theatre	19_engineering challenge	20_climate action card game	21_stories of change	22_aurora projection
Start											
End											
look at images											
read text/labels											
read aloud											
call someone over											
point											
verbal obs											
verbalize enthusiasm											
ask question											
answer question											
touch exhibit items											
took picture											
sit down											
watched others											
Watched video											
Read Panel R1											
Found Panel R1 objects											
Read Panel R2											
found panel R2 objects											
Read Panel L1											
Used smell button											
Read Panel L2											
found panel L2 objects											
Read Panel L3											
Found panel L3 objects											
weigh core samples											
lift panels											
play video game											
watch other play game											
adjust microscope											
spin tray											
look at monitor											
read field notebook											
use field notebook to ID											
play game											
read reward screen											
play game again											
read rewards again											
look at large screen											
build											
melt permafrost											
rebuild											
melt permafrost again											
read instructions											
play game											
put cards in sensors											
read reward screens											
front											
back											
Field Notes											