

Electric Space: The Sun-Earth Environment

Visitor Responses to a Front-end Evaluation

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INTRODUCTION AND PURPOSE OF THE STUDY

This report presents the results of a front-end evaluation for the upcoming exhibit entitled, “Electric Space: The Sun-Earth Environment” at the National Air and Space Museum. Front-end evaluation is often conducted to provide exhibit planners with information about their audience during the planning stages of an exhibit. This front-end evaluation was designed to determine visitors' familiarity with, knowledge of, and misconceptions about the make-up of space between the sun and the earth.

The goals of the evaluation, strongly influenced by the team's careful articulation of the exhibits' educational goals and objectives, are as follows:

To determine visitor knowledge about the four states of matter:

- Are visitors familiar with the four states of matter?
- Can visitors categorize everyday objects according to these four states?
- Do visitors know how one state of matter is transformed into another?

To determine visitors' prior knowledge of, or familiarity with astrophysical terms:

- How familiar are visitors with certain astrophysical terms?
- If they are familiar with some of the terms, what do they think they mean?

To determine how visitors interpret the concept of space as not being empty:

- Do visitors think of space as not being empty?
- What do visitors think exists in space?

To determine how familiar visitors are with an illustration of the magnetosphere that may be incorporated into the exhibit design:

- Do visitors recognize an illustration showing the magnetosphere?

To determine if visitors are familiar with the Sun's structure:

- Do they recognize a cross-section of the Sun?
- What visual clues are given to help visitors identify the Sun?

METHODOLOGY

The Questionnaire

A questionnaire, consisting of six questions and activities, was developed by the evaluator in consultation with the team. The questions and activities reflect the goals and objectives previously stated in the introduction.

Visitors were first given flashcards naming familiar objects such as “rock” or “water,” and asked to categorize them according to the four states of matter. The words on the flashcards were rock, florescent bulb, neon tube, water, tire, gas grill, book, and juice. The four states of matter were

named for the participant only upon request or if they named the four states of matter incorrectly. A fill-in-the-blank question was included at this point to determine whether visitors knew how one state of matter could be transformed to another.

Visitors were then given another stack of flashcards and asked to categorize them into words they “definitely knew,” “sort of knew,” or “did not know.” Upon completion of this task, visitors were asked to define those words they said they knew or “sort of knew.” For this section of the interview, twenty words were chosen by the evaluator and Museum staff to be identified. In order to keep the interview time as short as possible, the first 25 of the 50 respondents were asked to categorize and define half of the previously chosen words, and the last 25 interviewees were asked to categorize and define the remaining 10 words. The group of words shown to the first 25 people interviewed were space, plasma, aurora, solar wind, sun spots, radiation belts, electromagnetic spectrum, magnetic storms, northern lights, and radiation. The group of words shown to the remaining 25 interviewees were magnetic field, magnetosphere, solar flare, cosmic rays, comets, magnetic substorms, ionosphere, auroral oval, upper atmosphere, and corona. Each group of words was chosen to maintain a similar range of difficulty. This section of categorizing and defining words was the longest portion of the interview.

Lastly, visitors were asked to describe their thoughts about the statement “Space is not empty;” and to identify two illustrations: one showing the magnetosphere and the other a cross-section of the sun. If visitors could not identify the first illustration of the magnetosphere, they were shown another one that was labeled and more similar to a text-book illustration. Participants were then asked if they thought anything was wrong with the illustrations. (They were not drawn to scale.) Participants were shown the picture of a cross-section of the sun and asked to identify it. After identification of the drawing, participants were asked how they knew it was the sun--in other words, what visual clues did they use to identify the picture as the sun?

At the end of the interview, the interviewer recorded, by sight, the age, gender, and ethnicity of participants.

Since many of the questions were knowledge-based, the flash cards and visuals were used to relax interviewees. Visitors were also continually reassured that the interview was a test of the Museum's ideas, and not a test of their knowledge. Despite these efforts, many of the participants appeared uncomfortable when asked to give information beyond their expertise or knowledge, comparing the survey to a test. The spontaneous nature of the interview also caused interviewees to guess and to respond “off the top of their head.”

SAMPLING PROCEDURE

A systematic sampling procedure was used to select visitors as potential participants. Every 15th visitor was approached if he or she passed a pre-determined line. Any visitor who was 15 years of age or older, and who could speak English or had a translator with him or her was eligible.

The interviewer approached visitors, telling them that the Museum was speaking with visitors about a new exhibit. They were asked to assist by answering a few questions. Agreeable visitors were

invited to sit down at a table during the interview. The average interview lasted 15 minutes, longer than anticipated. Coincidentally, at the time of the interviews, the Museum opened a popular exhibit requiring passes. As a consequence, many interviews were interrupted by passers-by requesting information. A total of 50 visitors were interviewed between Saturday, February 29 and Monday, March 2. Seventeen visitors were interviewed on Saturday, 20 on Sunday, and 13 on Monday. Interviews were conducted from 10:30 a.m. to 5:30 p.m. The testing was conducted on the main level of the Museum near the escalators in the “Hallmarks of Flight” gallery between the Independence Ave. and Mall entrances.

DATA ANALYSIS

Responses for defining astrophysical terms were scored for correctness using a key. The information-based questions were scored using the following scale:

- 3 = good, complete, acceptable answer
- 2 = relatively incomplete answer and / or close, but not really acceptable
- 1 = many misconceptions; not acceptable
- 0 = no answer

Verbatim responses from the scored and other questions were recorded whenever possible in order to provide qualitative as well as quantitative analysis. The exact responses of visitors were especially useful in the analysis of questions that required definitions from visitors. The resulting information has been grouped into categories accompanied by written observations and overall impressions noted by the interviewer.

Results

Demographics

A total of 50 visitors comprised the sample. Eighty-seven visitors were approached, 36 refused to participate, and 1 did not finish the interview in its entirety. Thus, refusal rate (including the interviewee who did not finish the interview) was 43 percent. Refusals were mostly due to time limitations; however, another frequent reason cited was an inability to speak English (six refusals). Table 1 summarizes the demographic characteristics of respondents.

Table 1.
Demographics
(n=50)

Characteristics	
Gender	
Male	26
Female	24
Age	
15-20	4
21-30	14
31-40	13
41-50	10
51-60	4
61+	5
Ethnicity	
White	43
African American	3
Hispanic	0
Asian	3
Other	1

Interview Results

Can visitors identify the four states of matter, and can they categorize everyday objects according to these four states?

In the first part of the interview, respondents were given eight flashcards, each listing the name of a familiar object. The words chosen for this activity were as follows: rock, florescent bulb, neon tube, water, inflated tire, gas grill, book and juice. Visitors were asked to categorize the flashcards according to the four states of matter (solid, liquid, gas, plasma). Respondents were told the four states of matter ONLY if they asked or if they named the four states of matter incorrectly.

Confusion resulted from the use of combination words such as “inflated tire” and “gas grill.” Participants were unsure whether to categorize the container, (tire) or its contents, (air).

Seventy-eight percent of the interviewees (39 out of 50) did not know the four states of matter. However, it should be noted that many participants were able to name solid, liquid, and gas, but not plasma. Those who did not ask what the states of matter were often did not categorize any of the objects as plasma. Therefore, plasma appeared to be the most unfamiliar term to the participants. (Plasma was also a word visitors were asked to define in another section of the interview. For comparison, refer to Table 3). A few respondents named earth, wind, fire, and rain as the four states.

Twenty-two percent of respondents (11 out of 50) correctly identified all of the terms. All visitors knew the state of matter of the rock, water, and book. The florescent bulb and neon tube were correctly labeled as plasma by thirty-six percent of the respondents (18 out of 50) and by thirty percent of the respondents (15 out of 50), respectively. Almost all of the participants hesitated when categorizing florescent bulb and neon tube. They seemed to know there was something different about them even if they eventually categorized them incorrectly.

Table 2 summarizes the number of correct responses given by participants for each term.

Table 2.
Identification Of Terms By Four States of Matter
(n=50)

Term	Number of Correct Responses
Rock	50/50
Water	50/50
Book	50/50
Juice	49/50
Gas grill	47/50
Inflated tire	41/50
Florescent bulb	18/50
Neon tube	15/50

Did visitors know what is added or taken away to change the state of matter?

Thirty-eight percent (19 out of 50) correctly responded that heat is added or taken away to change one state of matter to another. Ten percent (5 out of 50) gave no response, and 52 percent (26 out of 50) responded incorrectly. Table 3 lists the six most common wrong answers.

Table 3.
Six Most Common Wrong Answers

Term	
Matter	10/50
Energy	10/50
Molecules/atoms	4/50
Water	2/50
Oxygen	2/50
Space/dimension	2/50

How familiar are visitors with astrophysical terms, and what do they think the terms mean?

This portion of the interview, asking respondents to identify and define astrophysical terms with which they were familiar, appeared to be the most challenging and frustrating. Respondents often took much time to think about the definitions, or said things they thought they knew about the terms, rather than defining them. Many felt frustrated, and one left the interview during this part.

However, some respondents enjoyed this part, and were curious about the terms they were unsure of or did not know. Three participants came by the table later during the day after having read the take-home information sheet, and said they were looking forward to the exhibit and were pleased to have been part of the survey.

Table 4 summarizes the results of and discrepancies between what terms the visitors think they know the meanings of and those of which they actually do know the meanings. The highlighted columns compare what visitors said they definitely knew with the number of definitions that rated a score of 3. Many discrepancies came when visitors originally placed words they merely recognized or words that looked familiar to them in the “know” and “sort of know” piles. When asked to define these words, participants often asked to change piles from the “know” and “sort of know” to the “don't know” or stated that they were only recognizable, not definable terms. Described below are some of the responses which exhibited discrepancies between terms visitors thought they knew and terms they actually knew. These words may have been studied in school, as indicated by respondents who said, “It's been awhile since I've been in school,” or “I used to study this in high school.” If learned, those words had since been forgotten.

Table 4.
Familiarity and Actual Knowledge of Astrophysical Terms
(n=25)

Terms	Do Not Know	Sort of Know	Know	Score 3	Score 2	Score 1	Score 0	Average Score
Comets	0	2	23	10	9	6	0	2.16
Upper Atmosphere	2	5	18	9	9	5	2	2.00
Space	0	2	23	6	19	0	0	2.28
Solar Flare	6	4	15	5	9	5	6	1.48
Electromagnetic Spectrum	10	7	8	5	4	6	10	1.16
Aurora	7	9	9	4	8	8	7	1.44
Northern Lights	2	5	18	4	14	4	3	1.76
Ionosphere	12	4	8	3	11	0	11	1.24
Corona	12	4	9	3	7	4	11	1.08
Sun spots	3	8	14	3	7	12	3	1.36
Solar Wind	6	8	5	1	7	4	13	.84
Magnetic Field	7	7	11	1	6	10	8	1.00
Cosmic rays	8	8	9	1	10	5	9	1.12
Radiation	0	8	17	1	12	10	2	1.44
Radiation Belts	15	5	5	0	5	4	16	.56
Magnetic storms	5	6	8	0	7	11	7	1.00
Magnetosphere	15	6	4	0	3	8	14	.56
Magnetic substorm	16	6	3	0	6	2	17	.52
Plasma	7	4	14	0	5	12	8	.84
Auroral Oval	18	5	2	0	0	7	18	.28

Most respondents did not actually define the terms, rather named associations with, and/or appearances and effects of them. For example, comets were defined as “a streak of light,” and “light flashing across the sky.” Many people named Haley's comet and knew that comets were “on an orbit.” However, one participant said that comets “burn as they descend to Earth,” implying that they did not know comets were on an orbit. Few listed ice as one of the components of a comet. Most described it as a “chunk of planet,” “a rock” or “fragments of an exploding star, moon, or astroid.” Some of the incorrect responses given defined comet as “one of our planets,” and “a star with a tail.”

Upper atmosphere was often described in terms of distance. “Greater than 110,000 feet,” “over six miles up,” “slightly below where satellites are,” “about as high as balloons used to go,” were some of the answers given. Few actually stated that it was a layer of earth's atmosphere, but seemed to be understood as a given by respondents.

Respondents also had a difficult time providing definitions for some of the words they thought they knew, such as space. Many motioned with their hands in attempts to describe space, and many others, who had come to see an exhibit on Star Trek, quoted the popular show, defining space as “the final frontier.” Few respondents actually listed objects found in space, saying instead that space is “anything out there, up there.”

“Solar flare” was a word most described as “flames on the sun,” or “flares that shoot up off the sun.” Some responded that solar flares were “storms on the sun.” One respondent confused solar flare with sun spots saying that, “solar flares occur every 11 years.”

Ten people out of 41 who said they knew or sort of knew both aurora and northern lights, felt that the terms were interchangeable. One respondent thought that auroral oval had to do something with northern lights, since it contained the word aurora. It appeared as though aurora was a familiar term, but only in its use as “aurora borealis” or “northern lights”

Two respondents defined aurora as “a glow around the planets.”

All of the respondents who said they knew or sort of knew the term ionosphere stated that it was a layer of the earth's atmosphere. Three people added that it contained ions. A few said that they had heard of the term but could not define it.

In response to electromagnetic spectrum, the majority of participants seemed to know what it meant, but had difficulty describing it. Some began listing various points of the spectrum, “Radio waves, visible light, ultra-violet, infrared, stuff like that.” Many participants associated the term with the colors of the visible light spectrum. “It's all the colors in the thing.” “A listing of wavelengths...blue, white, red higher to lower.” “It's those colors of lights that bond, right?”

Five of the responses to corona included the word “halo” or mentioned that it “is what you see during an eclipse.” Three participants actually named corona as a layer of the sun's atmosphere. A couple of people were confused as to whether the corona was associated with the sun or the moon.

One of the most prevalent misconceptions noted was in respondents' definitions of sun spots. The majority of respondents knew they were dark spots on the sun, but 9 out of 25 respondents said that sun spots were “areas of intense heat,” or were confused about whether they were hot or cold spots. A few respondents knew that sun spots came in cycles. The guesses included responses such as “isn't that what old people have on their hands?,” and “when you hit a warm pocket.”

Solar wind baffled the majority of participants. Many people who placed solar wind in the “know” or “sort of know” categories, merely responded “wind on the sun,” so it was difficult to tell if they were guessing or if they actually knew something about the term. Others stated they recognized the term but

could not define it. Still others said they had never heard of the term and had no idea what it meant. In defining magnetic field, again, most listed associations with or effects of the term, rather than defining it. Responses include, “it draws something to it,” “it shields the sun,” “where you have two poles, North and South,” “things are pulled toward it,” “an attraction area.” Many people said they had heard of the term but were unable to define it.

Most respondents stated that cosmic rays were simply rays or beams from the sun. Only one person mentioned that cosmic rays travel at the speed of light.

The term radiation had the largest discrepancy between what visitors thought they knew and what they could actually define. Many named its association with the field of medicine, “X-rays,” “it causes cancer,” “rays that kill cancer;” or with war, “like what a nuclear bomb gives off.” Overall, respondents felt that radiation was harmful to humans: “harmful rays from the sun,” “it's a bad thing,” “it's bad stuff in the air,” “things that give off toxic kinds of energy,” “stuff that comes through the ozone-it's getting us.”

Very few people said they knew radiation belts. Some responses include “rings of radiation,” “belts around the earth's atmosphere that have to be avoided when spaceships go up,” “belts around the earth.”

The term plasma also showed a wide discrepancy between what visitors thought they knew and what they could define. Eleven out of 25 responded that plasma was related to blood. Very few related plasma to space at all. One respondent said, “It is one of the four basic properties. The others are earth, wind, and fire. I think it's what makes up the sun and what the volcano liquid is made of.”

The fewest responses were given for the terms Magnetosphere, magnetic substorm, and auroral oval. For words like magnetic substorm, it was difficult to tell exactly how much visitors knew, since they often defined the term by using components of the word itself. For example, many people said that magnetic substorms were “storms in a magnetic field,” or “storms with a magnetic origin.” No one linked magnetic substorm or magnetosphere to the solar wind. All those interviewed were at a complete loss with auroral oval.

How do visitors interpret the statement, “Space is not empty?”

All but three participants responded by listing things in space. Examples of typical responses are: “Well there's other planets, meteors, moons, the sun,” “Atmosphere, particles, dust...solid waste maybe from the astronauts,” “Space has the planets, stars, and sun. It can't be empty with all those things up there,” “It means there is always some matter occupying space.” Almost all responses only listed physical bodies that can be seen. Some included atmosphere, atoms, molecules and gases in their lists. Two responded that “even though you can't see something it doesn't mean that nothing's there.” Only one responded that they didn't know what was up there. “Rocks? I don't know.”

How familiar are visitors with an illustration of the magnetosphere?

Only two respondents stated that the illustration showed the magnetosphere. However, eight mentioned that it looked like the earth's magnetic field. It should be noted, however, that over half of these correct responses were from the second group of interviewees who had been given the words magnetosphere and magnetic field in an earlier section of the interview. Therefore, they may have been influenced by that fact. Likewise, two respondents who identified the illustration as the solar wind, had seen that term during an earlier portion of their interview.

Most immediately identified the sun, but had great difficulty with identifying the earth and the surrounding magnetosphere. Responses ranged from, "It looks like an atom splitting," to "This looks like a human eye." Some were confused and were unsure that the two elements of the illustration really belonged together. Many simply stated, "That's the sun. I have no idea what that (the earth) is." A number of respondents said gravity or that it looked like something was coming toward the sun or that the sun was drawing something into it.

When given a clearer, labeled drawing, visitors responded that the new drawing helped somewhat because it was labeled, but that without knowing the terms, they were still unsure about the concepts behind the drawing. A couple of people said that although the second picture gave more information they were drawn more to the first, more artistic illustration of the magnetosphere. One person stated, "I would remember the first one." Another person suggested that a poster of the first illustration would be desirable.

When asked if anything was wrong with the picture, only eighteen thought there was something wrong. However, of those eighteen, only six noticed that the drawing was not to scale. Three did note that other planets between the earth and the sun were not included. Most of the other responses were guesses, "Well, maybe the Milky Way is out of place," "Maybe there should be more sun."

How familiar are visitors with the structure of the Sun?

The majority of respondents (44 out of 50) correctly identified the illustration of the cross-section of the Sun. Five people identified the illustration as a star, noting that it could be our sun. Only one respondent thought the illustration was of the earth.

Most respondents (31 out of 50) stated that color was the major visual clue they used to identify the illustration. The next most frequently mentioned visual clue named was used the outer surface flames/flares (23 out of 50), and 22 participant cited labels as an important visual clue. Other clues mentioned were the shape, and sun spots.

SUMMARY AND CONCLUSIONS

Respondents clearly had an aversion to having their knowledge tested. They disliked feeling pressured to perform higher level cognitive activities when they were not experts. They were pleased, however, to discover answers to their own questions about the terms and concepts discussed in the interview, and a number said that their curiosity and interest had been peaked by the interview. Some seemed genuinely grateful to have been asked to participate in the evaluation survey.

Plasma is something that definitely needs to be clarified and explained in this exhibit. The majority of people, although obviously being interviewed about space and space science, responded that plasma was something in the blood. Visitors seem to know that there is something different about objects that would be classified as plasma (florescent bulb and neon tube) but had no idea what makes them different from other, more familiar states of matter.

Another concept that needs explanation is solar wind. People are unfamiliar with the term and with its interactions with and effects on other concepts discussed in the exhibit such as magnetic substorms and the magnetosphere.

What is more important than knowing strict definitions, however, is understanding the ideas behind this exhibit. In order to achieve this, it is necessary to find as many ways as possible to describe or show the important concepts, rather than to focus on visitors knowing all the “correct terms.”

Misconceptions should be attacked head-on. For example, since many visitors thought that sunspots were areas of intense heat, start with a label stating that sunspots are NOT areas of intense heat, but cooler places on the sun's surface.

Concerning the illustrations, although artistic renditions are appealing to the eye and may grab visitors attention, the graphics must not confuse or garble the intended message for the viewers. In the magnetosphere illustration in particular, visitors should be able to easily identify Earth. Although the sun was immediately recognizable, many participants failed to identify the earth. Many were unaware that it was even a planet.

Overall, respondents wanted to know the answers to the questions after they completed the interview, and looked at the fact sheet with great interest. Quite often, the participants' companions listened to the interview and became curious as well. This suggests that visitors may enjoy a group experience of shared learning in the exhibit. Their own interest in what may be a subject they have “never thought about much” may be piqued by the interest of others with them.