Data Visualizations:
Year 1 Formative Evaluation

Redesign of *Sea Surface Temperature* and *Net Primary Productivity*

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Prepared for:

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Prepared by:
Susan Foutz, M.A.

Institute *for* Learning Innovation
3168 Braverton St. Suite 280, Edgewater, MD 21037 t: 410-956-5144 f: 410-956-5148 www.ilinet.org
Understanding, fostering, and promoting lifelong learning

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Established in 1986 as an independent non-governmental not-for-profit learning research and development organization, the Institute for Learning Innovation is dedicated to changing the world of education and learning by understanding, facilitating, advocating and communicating about free-choice learning across the life span. The Institute provides leadership in this area by collaborating with a variety of free-choice learning institutions such as museums, other cultural institutions, public television stations, libraries, community-based organizations such as scouts and the YWCA, scientific societies and humanities councils, as well as schools and universities. These collaborations strive to advance understanding, facilitate and improve the learning potential of these organizations by incorporating free-choice learning principles in their work.

Executive Summary

The American Museum of Natural History (AMNH) received a NOAA-ELG grant for a three-year project, entitled *Exploring Earth Systems: Expanding Data Visualizations Experiences for Museum Learners* (or Data Visualizations). The project focuses on the development, testing, and distribution of Visualizations for the Earth and Bio content strands of the AMNH's Science Bulletins program. The Visualizations are short media pieces that use satellite data to tell the story of Earth processes on land, in the oceans, and in the atmosphere, with the larger goals of helping viewers to understand the dynamic and changing nature of Earth's systems.

The Institute for Learning Innovation is serving as the independent, external evaluator for the three year life of Data Visualizations. This report documents the findings from the Year 1 formative study conducted in September 2011, which focused on the Visualizations entitled *Sea Surface Temperatures* and *Net Primary Productivity.* These Visualizations were the subject of an initial formative evaluation in January 2011 after which they were redesigned by the AMNH team. The results of the Year 1 formative studies have implications for the AMNH team as they develop other Visualizations over the course of the project since and future Visualizations will have many elements in common with the pieces developed in Year 1. The formative study gathered data from visitors to the AMNH using focus groups; visitors viewed the two Visualizations and provided feedback on the strategies used to display the data as well as the content. The results are organized around two primary evaluation questions:

How effective are the strategies used in the visualizations at conveying basic information to visitors?

Visitors were able to make sense of the Visualizations at the most basic level. Viewers appreciated the visuals for both pieces, including the data being visualized, the rotation of the globe, the cloud patterns, and techniques used to connect the captions with the data legends. Common themes throughout all groups were 1) the multiple areas of the Visualizations that compete for the viewers' attention, 2) a feeling that the paces was slightly fast, especially at the beginning of the Visualizations, and 3) the request for narration. When compared to the results of the January 2011 study, participants had many fewer areas of misunderstanding or suggestions for change when viewing the redesigned versions. This indicates that the team's redesign of both pieces were largely successful.

The following concrete recommendations are suggested as the team develops new Visualizations in Year 2 of the grant.

- Move the timestamp to the bottom of the Visualizations.
- Move the series name and Visualization title to the top of the screen.
- Consider using narration. Viewers consistently ask for and expect narration.
- Slow the pace at the beginning of the Visualizations, allowing for ample time between when each element (data, timestamp, legends, captions) appears and begins changing.

How effective is each visualizations in conveying its "big idea"?

Participants were able to make meaning from both Visualizations and largely understood the main messages; exceptions included not knowing that carbon is released by plants and that the data in the Visualizations was collected by satellites. The main message of NPP was well received in this study as

compared to the January 2011 study, indicating that the re-interpretation of the narrative was largely successful.

When considering the larger issues facing the team as they continue to design Visualizations in Year 2, the study found that:

- Participants consistently viewed museum-produced media as more trustworthy than what they might see in the mainstream media. This is consistent with other studies in the museum field that indicate visitors have a high level of trust in museums.
- About two thirds of the participants were able to make larger connections about global systems or were more curious about these connections. Those who did not make connections typically saw themselves as outside of the target audience for the Visualizations.

The following conceptual recommendations are suggested as areas for the team to continue brainstorming and experimenting as they seek to perfect the style of the Visualizations.

- Continue to choose topics that have compelling implications and push the limits of the "so what" messages of the Visualizations.
- Continue to find ways to explain the cause and the effect of natural processes.
- Continue to make strong connections to climate change and human connections to climate change.
- Continue to experiment with ways to enhance the readability of the data legends.
- Consider helping viewers to understand the differences between weather and climate.

Introduction

The American Museum of Natural History (AMNH) received funding through the NOAA Environmental Literacy Grants (ELG) program to "create and disseminate widely a suite of visually rich media productions that will engage, educate, and inspire public audiences about dynamic Earth systems."[1] The three-year project, entitled *Exploring Earth Systems: Expanding Data Visualizations Experiences for Museum Learners* (or Data Visualizations), is one of a suite of projects within the AMNH's Science Bulletins program. Science Bulletins are video content and interactive media for use in a variety of settings, including on the museum floor and online, and are distributed to a network of ISE institutions. There are four content strands within the Science Bulletins program (Astro, Earth, Bio, and Human) and a variety of presentation types (Features, Snapshots, Visualizations, and Events). The NOAA-ELG grant-supported project is designed to support the development, testing, and distribution of Visualizations for the Earth and Bio content strands.

Within Earth and Bio Bulletins, Visualizations are short media pieces (between 2.5 and 3 minutes in length) that use satellite data to tell the story of processes on the Earth's surface. Satellite data is displayed using a "birds-eye" view of the whole earth or particular regions. Earth Visualizations focus on atmosphere, climate, and weather; Bio Visualizations focus on ecosystems and human impacts (such as urban sprawl). Strategies used to display the data and support its interpretation include the color enhancement of the data, keys and legends, indications of the time period over which the data were collected, labels to indicate features of the data or geography, and captions which convey the narrative of each Visualization.

Although each Earth and Bio Visualization created for the project will focus on a separate topic and have its own sub-set of learning outcomes, overarching learning outcomes guide all Visualizations created for the project. As a result of viewing a Visualization created for the project, visitors will understand that:

- Earth systems are dynamic.
- There are natural seasonal variations, annual fluctuations, and long-term patterns within Earth systems.
- There are longer-term changes to Earth systems that can be tied to human activity.
- There are differences between variations in Earth systems that are natural versus those changes that are "forced" by human activity.
- Scientists use satellites to collect global data that provide evidence of changes in Earth systems.
- Data collected by scientists can be used to document what has happened and to project what will happen within the changing Earth systems.

The Institute for Learning Innovation (ILI), a not-for-profit research and evaluation organization focused on learning in free-choice/informal contexts, is serving as the independent, external evaluator for the three year life of Data Visualizations. In Years 1 and 2, ILI researchers are conducting formative evaluation; Year 3 will focus on summative evaluation. This report documents the findings from the second formative study conducted in September 2011 of Year 1. This study focused on the newly redesigned *Sea Surface Temperatures* and *Net Primary Productivity.*

[1] From the grant proposal narrative.

Background on the Selected Visualizations

In the grant proposal, AMNH staff identified a set of topics to be developed into Visualizations over the course of the project. Included in the set of topics were ones for which the staff had previously created Visualizations. These existing Visualizations were candidates for new treatments due to the time that had passed since their creation and because of the storytelling opportunities they presented. The AMNH staff decided that their initial Year 1 efforts would focus on creating new Visualizations for two topics with existing versions: *Sea Surface Temperatures* (SST) and *Net Primary Productivity* (NPP). The existing versions of these Visualizations were the subject of a Year 1 formative study conducted in January 2011. After receiving the results from that study, the AMNH team redesigned both Visualizations and an additional round of evaluation was completed on these redesigned versions in September 2011. The study that emerged is, therefore, formative within the context of the current project, but remedial evaluation for these two Visualizations. The following descriptions of the content of each Visualization were posted on the Science Bulletins website (http://www.amnh.org/sciencebulletins/) and reflect the content of the original Visualizations before they were redesigned:

> *Sea Surface Temperatures* (Posted April 2006): Long-term observation of sea-surface temperatures reveals patterns and cycles of variation caused by seasonal winds, Earth's rotation, and other factors. This video shows sea-surface temperature measurements across the globe obtained by the Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS) satellite instruments. The historical data, gathered by AVHRR from 1985 to 2002, are shown in measurements of degrees Celsius. The current MODIS data (2002-2006), also in degrees Celsius, show deviations from long-term averages. Satellites provide scientists with a picture of what's happening daily over the entire Earth. The United States satellite measurement program for sea-surface temperature, run by the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), has gathered global measurements daily since 1979.
>
> *Net Primary Productivity* (Posted October 2006): Scientists use satellite observations to analyze plant growth rate on land and in the ocean. Outside the tropics, plants grow faster as Earth's tilt makes light available in spring and summer. In the tropics, some regions don't have enough water to support year-round plant growth, despite an abundance of light. Light changes with the seasons, and the biosphere responds.

Evaluation Questions

The results from this study have implications for the AMNH team as they continue to develop Visualizations over the course of the project. The following questions were developed to guide the Year 1 formative evaluation:

1. How effective are the strategies[2] used in the visualizations at conveying basic information to visitors?
    a. Are visitors able to make sense of their placement geographically, spatially, temporally?
    b. In what ways does the visualization help visitors make sense of their placement geographically, spatially, temporally?
    c. How do techniques like color variations and scales, time scales, and other "orienting" devices support or hinder visitor understanding of the visualization?
    d. What additional support do visitors need to understand the visualization at its most basic level?
2. How effective is each visualizations in conveying its "big idea"?
    a. Are visitors able to make meaningful interpretations of what they are seeing?
    b. What is the role of prior experience—with visualizations or with the topic—in visitors' ability to make sense of what they are seeing?
    c. What additional support do visitors need to understand the visualization at a level that achieves the project's learning objectives and the visualization's learning outcomes?

Because the Visualizations were redesigned between the January 2011 study and the September 2011 study, an additional focus of the September 2011 study included how the redesigned Visualizations impacted participants' responses to the topic and their overall understanding of the Visualizations. Participants' responses from January and September were compared to identify areas of enhanced understanding or greater clarity.

Methods

On September 17 and 24, 2011, ILI staff member Susan Foutz facilitated six focus group discussions with visitors to AMNH to gather feedback on the redesigned Visualizations *Sea Surface Temperatures* (SST) and *Net Primary Productivity* (NPP)[3]. Each focus group lasted between 45 and 60 minutes. Groups were recruited near the main entry of the museum by an ILI researcher. Visitors were invited to attend with their entire visiting group, with the majority of visiting groups consisting of two to four people. Due to the team's interest in the views of youth in middle and high school, attempts were made to recruit family groups with children in this age range was recruited for each focus group; youth were accompanied by their parents at all times. In exchange for their time, each visitor was given a SuperVoucher pass for free admission to the museum and all paid programs and $50 in cash per family/visiting group. Before the focus group began, adult members of the focus group read and signed a consent form disclosing the purpose of the study, the incentive, and the audio recording of the discussion.

The discussion began with an orientation to a focus group and discussion about top-of-mind ideas concerning earth and science climate (see Focus Group Protocol, Appendix 1). The majority of the

[2] The strategies used the Visualizations include the color enhancement of the data, keys and legends, indications of the time period over which the data were collected, labels to indicate features of the data or geography, and captions which convey the story of each Visualization. How these strategies are implemented vary from Visualization to Visualization.

[3] The redesign of SST was complete at the time of the study; NPP was nearing completion but was shown to participants in a rough-cut stage. Participants were told that NPP had more flexibility to change because of the design stage. AMNH staff continued to make improvements to NPP after the study; therefore, the findings reported do not reflect the final version of NPP.

discussion time was focused on viewing and providing feedback on the two Visualizations. Each Visualization was played through once in its entirety. Then participants were asked to complete a series of rating questions on their own (See Appendix 2) asking clarifying questions of the ILI staff member as needed. Five of the rating scales were developed through the AMNH's Human Bulletins project (funded by a NIH SEPA grant); these scales were validated with visitors to AMNH in Year 3 of the Human Bulletins project.

After completing all rating questions, participants took part in a brief group conversation about main messages of the video and initial feedback. Then the Visualization was shown a second time allowing for a guided deconstruction of the piece with participants giving feedback. The same procedure (two viewings, the second one guided) was used for the second Visualization.[4] Finally, participants were asked 1) how the Visualizations supported their thinking about global systems and interconnections between systems, and 2) whether and how the use of scientific data for such Visualizations impacted their opinion of the Visualization and its message. The researcher facilitated the conversation and took brief notes during the discussion. Each focus group was audio recorded. The audio recordings were transcribed by an independent contractor (Verbal Ink). The notes and transcriptions served as the basis of analysis. Analysis consisted of inductive and deductive coding techniques to identify trends and themes in the data.

Findings

An overview of the study participants and the findings are presented below, with findings organized by the major evaluation questions for the study.

Participants

The focus group participants were diverse consisting of adults and youth (n=19 and 6 respectively), groups living in the US (New Mexico, New York, and New Jersey) and international visitors from England, Australia, and Poland. English was not the first language for at least one member in four of the families/visiting groups. About half of the adults were continuing their education and the others were working in careers including pastry chef, small business owners, theater, salesperson, nanny, and artist. The following list details the make-up of each group:

- Group One: An extended family group of six from Australia, including two 6th graders (boy and girl), a 3rd grade boy, their parents, and a male relative in his forties or fifties.
- Group Two: A couple in their late twenties or early thirties.
- Group Three: Two friends (male and female), one in college and the other in his thirties; two friends (male and female) in their late twenties.
- Group Four: Two couples in their twenties, one from the US and the other from Poland.
- Group Five: A family group of four, including a 4th grade boy and a 3rd grade girl; a couple in their forties or fifties.

[4] On September 17, SST was shown to visitors first, followed by NPP; on September 24, the order was reversed. This approach was used to account for viewers' growing familiarity with the style of the Visualizations; researchers wanted to be able to control for the potential that participants' reaction to the second video were more favorable because they were now familiar with the presentation style. In actuality, the order of the videos did not seem to impact participants' responses.

- Group Six: Family group of three, including a high school-aged boy, from England.

Although the intent of the evaluation was purposely to recruit families with children in middle or high school, this proved difficult. Due to the timing of the study (late September), few families with school-aged children were at the museum on the days data were collected. As a result, only 6 children were included in the study, and 3 of those were in elementary school. It is important to note that the results of the January 2011 study indicated that there were very few differences in how adults and children understood the original Visualizations. It is hypothesized that these results would hold true for the redesigned Visualizations as well.

As in January 2011, participants in the focus groups seemed primed to learn the type of information that aligns with the goals of the Data Visualizations project. When asked what came to mind when they heard the words "earth and climate science," the most common response by adults was "global warming." Other responses included Al Gore and his work, "the ice caps melting," and "how the earth changes as a result of human activity." One adult said that while global warming is occurring "I doubt whether people are to blame for it." Other adults questioned the ability for individuals or humans in general to correct the course of climate change. Some adults however expressed real concern for the earth's future and the impacts of human activity. Children's responses upon hear the phrase "earth and climate science" included "the environment," "plants," and plastic bags and other trash in the oceans.

How effective are the strategies used in the visualizations at conveying basic information to visitors?

This evaluation question looked specifically at the design elements or strategies used in the Visualizations to display the data and how well these strategies conveyed information. The strategies used in these Visualizations include the color enhancement of the data, keys and legends, indications of the time period over which the data were collected, labels to indicate features of the data or geography, and caption placement and speed. In this section, general participant feedback is presented first, followed by feedback related to specific strategies.

As was found in the January study, participants were able to make sense of the Visualizations at the most basic level; they were able to interpret what was being displayed. A common theme throughout all groups was the multiple areas of the Visualizations that compete for the viewers' attention; this is consistent with the earlier study. Competing elements included the captions, the date, the data legends, and the eye-catching and dynamic nature of the data being displayed. Not knowing where to focus their attention was a prevalent theme among participants of all ages. "It's kind of hard to look at," said a middle school boy, "you wanted to look at the writing, and you wanted to look at the globe, and then you had to look up—and you really wanted to look at the temperature." An adult had a similar reaction: "So you're trying to focus your eyes on three things on the screen—the ticker [time stamp], the moving [images] and then you're also trying to read." Many suggested that adding narration would alleviate some of the pressure of having to visually process multiple pieces of information simultaneously.

When considering the pacing of both Visualizations, visitors were more positive in the September study than in January. They also found that both Visualizations had about the same pacing, whereas participants in the January study found SST to be fast and NPP a little slow. Therefore, it would appear that the changes made to both Visualizations were successful. However, some participants still felt that both Visualizations were slightly too fast, especially at the beginning. It is likely that viewers take a few moments to orient themselves to the data and the overall style of the Visualizations. As this orientation process takes place, they feel they are "missing something" when multiple aspects of the Visualization

are changing at the same time. Allowing for more time between the appearance of the legends and time scales at the beginning each Visualization may prevent this information overload.

Feedback on Specific Strategies

Geographical Location

In general, the vast majority of participants were able to orient themselves geographically when viewing the Visualizations. When asked if labeling the individual countries in SST was helpful, participants indicated that it was (See Image 1).

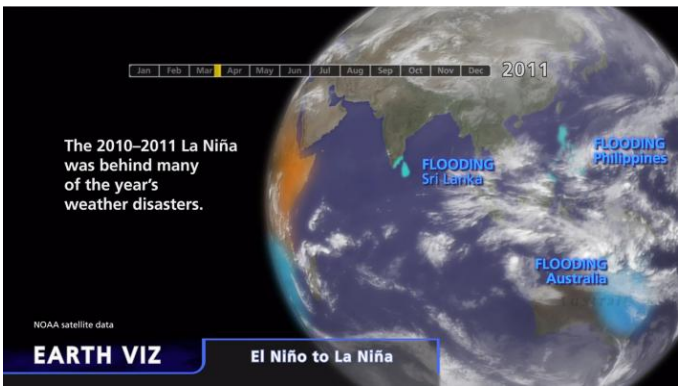

Image 1: Labeled Countries, SST

Temporal Location

As was found in the January 2011 study, participants had minimal difficultly in interpreting the timestamps used in the Visualizations. In the September study, the majority of comments relative to the timestamps were about placement on the screen. Some participants suggested that moving the timestamp to the bottom of the screen would make it easier to take in all the information; "Putting the moving band...down at the bottom with the text that keeps updating would keep you focused," suggested one adult. This is in keeping with results from both studies that participants find multiple areas of the Visualizations competing for their attention. Very few participants commented on the general appearance of the timestamp.

Color Choice and Legends

Participants had minimal feedback on the color choice and legend used in NPP; this is in contrast to the large amount of feedback on this issue in the earlier study. It seems as though the changes made by the team to the legend were pleasing to viewers, including increasing the font size and using a bar-type layout. Participants did not notice the addition of the plants to the legend (as seen in Image 2) unless the researcher drew their attention to it. This effect is subtle, fading in and out at a time when the captions and the visualized data are changing. Given that participants were already pre-disposed to interpret the dark green as plant growth, not seeing this effect did not hinder their understanding of the legend.

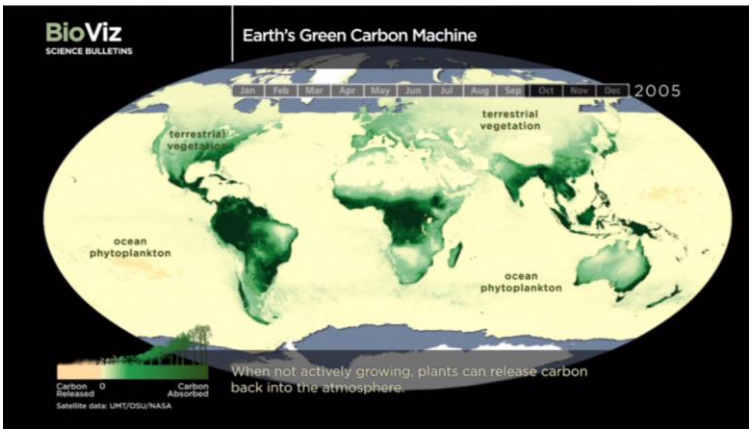

Image 2: Screen Shot from NPP

There were some issues with how the scale in NPP was being interpreted. Drawing on comments made by participants, it appears as though they were interpreting the scale as absorption on one end and no absorption on the other, rather than a spectrum of absorption and release. This issue is likely complicated by participants' lack of knowledge relative to plants both absorbing and releasing carbon. Even after viewing the Visualization, many participants were not aware of this cycle (see the "Main Message" section for NPP below for more on this topic).

Participants in general made very few spontaneous comments about the color choices and legend in SST. When asked by the researcher, participants indicated that the colors were intuitive or "obvious". A few participants were critical of the placement of the relative temperature legend saying that it was difficult to read because of its placement directly on top of the globe (Image 3). One man indicated that he did not believe the relative temperature legend was correct. He questioned how the water off the coast of Ecuador could be -5 degrees Celsius. "I'm familiar with Celsius. I've been living with Celsius all my life, so that's not true." It became apparent through conversation that he was interpreting the relative temperature scale as the actual temperature. Upon re-watching SST, he indicated that he did not understand the distinction the first time he viewed it.

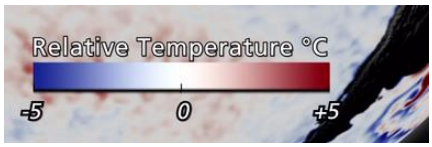

Image 3: Data Legend, Relative Temperature, SST

In an effort to increase the readability of the color scales in SST, the team employed techniques that were not used in the original version. This included color coding the text to the scales (i.e. the words "warmer" and "El Nino" are shown in red font) and using this colored text to highlight the relative temperature scale (as seen in Image 4 where the text moves across the screen to rest upon the scale). These techniques were viewed positively by participants in the focus groups. The movement of the colored text to the relative temperature scale was described by participants as "cool," helpful," and making the data "more understandable if you're unfamiliar with it." Overall, these techniques appear to have greatly improved viewers' ability to understand the relative temperature scale. In fact, the comment of the man above who questioned the scale's use of Celsius was the only time in the focus groups where it was clear that the scale was being misinterpreted. The remaining participants did not highlight the transition to the relative temperature scale as a confusing or needing more explanation.

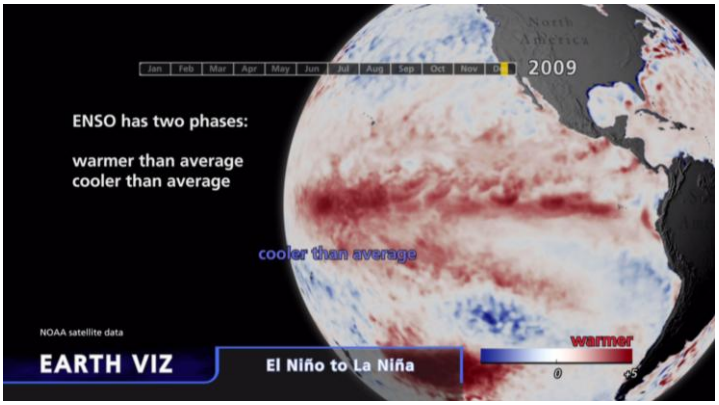

Image 4: Screen Shot from SST

<u>Visualizations and Effects</u>

As a whole, participants indicated that they were most drawn to the data visualizations and that these were the focus of both videos. As discussed above, the eye-catching nature of the visualizations competed with other elements for viewers' attention. Participants also gave feedback on various visualization techniques including:

- *The rotation of the globe*: Participants in half of the groups called attention to the scene in SST where the globe rotates and highlights the effects of the ENSO on various countries. They

appreciated the scene as a whole and a few named this as their favorite part of SST. However, in NPP a few participants indicated that at times the globe was spinning too fast; this was especially the case near the end of the video.

- *The cloud patterns used in SST*: In five out of the six focus groups, participants indicated that they liked seeing the cloud patterns on the globe. This was a pleasing effect for both adults and children.
- *The model of the Earth's rotation around the Sun*: This element which was also used in the original version of the NPP remained a favorite of participants.
- *The satellite used in SST:* As was found in the January study, many viewers found the satellite image used at the beginning of SST distracting. This image may not be easily recognizable as a satellite, and in conjunction with data suggesting that many participants did not know the Visualizations used satellite data, the image may not support this larger concept (See the section on "Authentic Scientific Data" below for more information).

<u>Captions, Labeling, and Narration</u>

Many of the findings relative to captions, labeling and narration mirror those from the earlier study. In general, participants did not feel strongly about the captions or labeling in the Visualizations. Groups typically did not comment on these aspects unless the topics were raised by the researcher. A few specific issues were raised including:

- *Placement of the captions in SST*: A few participants did not like having captions appear on the globe (Image 5). They felt this text was hard to read, and one person thought the text looked like it was "vibrating." They also pointed out that having the text on the globe as well as captions at the bottom increased the reading load at this point in the video.

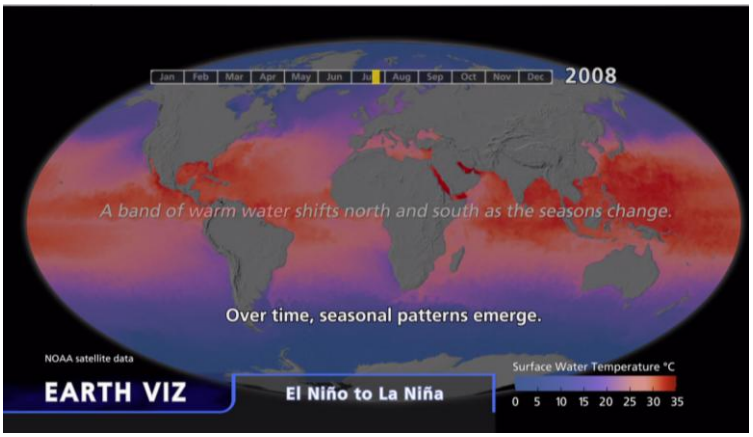

Image 5: Screen Shot from SST

- *Color of the captions in NPP*: Some participants felt that the captions in NPP were hard to read in general (See Image 2). They suggested making the captions brighter or whiter, not using a grey background, or using a dark outline around the letters to make them stand out.
- *Size of the series name and Visualization title for SST*: A few participants in one focus group felt the series name and title of the Visualization took up too much space (See Images 1 and 5). They suggested making it small for the whole piece or having it appear larger at the beginning and then shrink down. This group did not have a similar issue with NPP where the series name and title are at the top of the screen (as seen in Image 2).
- *Narration*: As in the earlier study, participants consistently requested narration for both NPP and SST. This request was made by adults and children, those speaking English as their first language, and those for whom English was not their first language. "In my opinion, since I'm kind of a slow reader, I would like a video with someone explaining to me what's happening," remarked an adult whose first language was English. Many participants felt they would be able

to pay more attention to the data, timestamp, and legend if they were able to listen to a narrator. “It’d be easier to focus on what we’re seeing as we’re learning about it rather than just reading it and watching it, reading it and watching it” said one adult participant. The consensus was that the Visualizations should be closed-caption-style, so that the text would still be visible. One group felt that narration would help to alleviate what they felt as the “impersonal” style of the Visualization.

How effective is each visualizations in conveying its “big idea”?

Participants overall were able to make meaning from the Visualizations and understood the main topics of both Visualizations. There was evidence that the changes made to NPP, in particular, were helpful in creating a more interesting and nuanced message than in the original version. Participants’ understanding of the main messages, areas of new learning, and unanswered questions for both Visualizations are detailed below. This is followed by a summary of the responses to the rating questions and the results of the focus group questions related to viewing authentic scientific data and the fostering of connections on a global scale.

Sea Surface Temperatures

Main Message

Participants’ overall ability to understand SST was unchanged from the January 2011 study to the September 2011 study. This is not surprising as the message remained largely the same in both versions. Participants, in general, understood the main message of SST. Most were able to describe the video accurately with varying levels of detail, ranging from one-word answers to detailed explanations. When asked what they thought the video was about, responses included “how the temperature of everything changes” to “it’s like more of an explanation of the major differences between both [La Niña and El Niño] and its effect on the rest of the world.”

New Learning

The majority of participants reported learning something new as a result of watching SST. The most common area of new learning was with regards to La Niña; for many participants, watching the video was the first time they had heard of La Niña. This is in contrast to El Niño which most participants indicated they had heard of previously. This trend was also seen in the prior study conducted in January 2011. An area of new learning that was not expressed in the earlier study was a deeper understanding of the nature of El Niño and La Niña. Some participants indicated that the video helped them to realize that these are larger reoccurring patterns rather than “the name for like a crazy tropical storm.” For adults from Australia, no new learning was reported which they indicated was a result of the extensive media coverage of these patterns.

Unanswered Questions

Some participants in the focus group identified larger questions they had after watching the redesigned SST. One question was “why [the] temperature of water impacts droughts or floods or heat waves.” The participants who had this question were unclear of how water temperature on one side of the world could have such far-reaching and varied effects. “It’s just I don’t understand why it’s…affecting each area differently” remarked one man when he saw how some areas had droughts and others floods during an El Niño pattern. “Do they know why this phenomenon exists, like why this happens?” asked another person. Another question asked in more than half of the focus groups was related to why the

water temperature changes in this particular pattern. As one adult said, "It didn't seem to relate how the temperature in the sea rose…It told you…not really the cause, just the effect." Both of these questions were raised by some participants in the January 2011 study.

In the January 2011 study, some participants expressed concern was relative to the statement "Every 3 to 7 years, surface temperatures along the equatorial pacific become warmer than average." This statement was seen to be so vague as to be not scientifically accurate. The new version of SST did not include this statement, rather saying that the ENSO was on a five year cycle. Participants did not question this statement, and instead remained focused on the overall message of the Visualization.

Net Primary Productivity

Main Message

Participants, as a whole, understood the main message of NPP. Most were able to describe the video accurately with varying levels of detail. When compared with responses to the original version, participants who watched the redesigned version were much more likely to talk about carbon absorption and release, global warming in terms of human impact, and mitigation possibilities. These types of responses were largely absent from the first study.

Participants who viewed the rough-cut of the redesigned NPP may not have understood the finer points of the cycle of carbon absorption and release. They seem to have generally understood that carbon can be absorbed and released, but the idea that plants are doing the releasing (as well as humans) was missed by some people. Many focused only on humans releasing carbon. Others thought that only oxygen was released by plants as shown in the following excerpt from Group 4:

Moderator:	Was that clear enough in the video that plants both like absorb carbon and then release carbon back? I mean, did you get that as a point or could they have emphasized it better?
Adult 1:	Well, I think it's common knowledge that plants absorb carbon and release oxygen.
Moderator:	Okay.
Adult 1:	To the earth, for us to breathe. They breathe the carbon dioxide to help us breathe, so that's pretty self-explanatory. I mean, that's pretty much general knowledge, but if they just explained maybe other ways other than the planting to remove carbon, like I know that they're building like tubes to like suck carbon out of the atmosphere to contain it, you know, then maybe explain something like that about what we can do to help with the elimination of carbon in the atmosphere.
Moderator:	And how about you guys?…do they do a good job explaining the idea that plants both take in carbon but also actually can release carbon?
Adult 2:	I didn't know they released carbon.
Moderator:	Okay.
Adult 2:	I thought they release oxygen only.
Adult 3:	You didn't know?
Adult 2:	I didn't know that.
Adult 4:	I didn't know they release carbon either.

Moderator: Did you know that they release carbon?
Adult 3: Yeah.

As seen in this exchange, three of the four adult participants did not realize plants release carbon even after they viewed NPP.

A few participants clearly understood that plants both absorb and release carbon. For example, one adult summarized the redesigned NPP as follows: "It was meant to tell us why there's too much carbon, that the plants give it off and the other plankton absorb it, and why there is too much to be absorbed." This explanation is more sophisticated than those given by most participants.

New Learning

Many participants reported learning something new by watching the redesigned NPP. Areas of new learning included the existence of phytoplankton in the oceans (especially in the southern hemisphere) and its role in absorbing carbon. A few children indicated that they had not heard the word "phytoplankton" previously. Some aspects of the video were familiar to most participants, including the idea that the Earth's rotation and tilt causes the seasons, that the seasons are reversed in the northern and southern hemispheres, and that plant growth is a seasonal process. Participants for whom NPP provided no new information tended to be non-Americans; the Australian and Polish respondents in particular indicated that this information is often covered in school and the media in their countries.

Unanswered Questions

With the original version of NPP, a major issue for respondents was the lack of vital information that hindered their understanding of the piece; this included wondering if low plant growth was due to the lack of water and the implication of the areas labeled "no data." No such issues were identified with the newly redesigned NPP, an indication that the approaches the team took to address these issues were successful.

Implications of the Visualization

When compared with the results of the January 2011 study, the results of the September 2011 study indicate that the redesigned version was much more successful at conveying larger implications. In the prior study participants in about half of the groups wondered what the larger implications were for the video or wanted a stronger explanation of "how it is connected to us." These concerns were not raised in the September 2011 study, indicating that the stronger approach to messaging was successful. Likewise, respondents in the second study did not call into question the reason for studying plant growth, which was an issue raised in the first study.

A few respondents expressed their desire for NPP to go a bit further in explaining why it is necessary to reduce carbon in the atmosphere. One adult said, "The thing that really stood out to me was that it didn't talk about the impact of the fact that the plants won't be able to absorb the carbon…what's the impact of that?" A few others in another focus group echoed this concern: "I think they could have expressed the importance of eliminating the carbon in the atmosphere more." These adults knew what the ultimate impact of the increase in carbon would be; however, they wanted this made even more explicit for those who might not already know these details.

Responses to the Rating Questionnaire

Before participants discussed each Visualizations as a group, they were asked complete a short questionnaire consisting of rating items on range of aspects (See Appendix 2 for the questionnaire). The purposes of collecting these ratings were 1) to get a sense of how participants respond to each Visualization, and 2) to compare across Visualizations and age groups.

When considering familiarity of the information presented, content, pacing, length, and vocabulary used in SST and NPP, participants responded similarly to both Visualizations (Table 1). Both Visualizations were rated as containing information that was relatively unfamiliar to participants, with the information in SST rated as slightly less familiar (a median of 3.0 compared to 4.0 for NPP). The content, length, and vocabulary of both were rated as "just right," or a median of 4 on the 7-point scale. The pacing of both SST and NPP was rated a 5 on the 7-point scale, indicating that they were thought to be a little fast.

Table 1: All Participants' Ratings of the Visualizations

Rating Categories	**SST (n=25)**		**NPP (n=24)**	
	Mean	**Median**	**Mean**	**Median**
Information *(1=Not at all familiar, 7=Extremely familiar)*	3.4	3.0	4.1	4.0
Content *(1=Too Basic,4=Just Right, 7=Too Advanced)*	4.1	4.0	4.5	4.0
Pacing *(1=Too Slow,4=Just Right, 7=Too Fast)*	4.4	5.0	4.7	5.0
Length *(1=Too Short,4=Just Right, 7=Too Long)*	4.0	4.0	4.1	4.0
Vocabulary *(1=Too Simple,4=Just Right, 7=Too Difficult)*	4.5	4.0	4.6	4.0

Participants were also asked to rate each Visualizations' content for trustworthiness, interest, cutting edge, and relevancy (Table 2).

- Both SST and NPP were received a median rating of 5.0 on trustworthiness, a fairly high score. Conversation on the origin of the data which occurred at the end of the focus groups suggest that had participants known the data was authentic and collected by satellites, they may have rated the trustworthiness even higher.
- SST was rated as more interesting than NPP, 6.0 compared to 4.0. This could be a result of the information in SST being less familiar to participants (as rated above) and qualitative responses that indicate SST provided contained more opportunities to learn new information.
- Both SST and NPP received relative low ratings on the degree to which the information was "cutting edge".
- SST and NPP were rated relatively low in terms of relevancy to participants' lives.

Table 2: All Participants' Ratings of Aspects of the Visualizations' Content *(Scale: 1= Not at All, 7=Extremely)*

Rating Questions	SST (n=25)		NPP (n=24)	
	Mean	Median	Mean	Median
"Trustworthiness of the information in the video"	5.2	5.0	4.8	5.0
"How **interesting** was the information in the video?"	4.8	6.0	4.3	4.0
"How **'cutting edge'** was the information in the video?"	4.3	4.0	3.8	3.5
"How **relevant to your life** was the information in the video?"	4.1	4.0	4.0	4.0

Ratings of adults and children (those under 18 years old) were compared within each Visualization. There were some differences in how adults and children rated the following items.

Sea Surface Temperature:

- Children viewing SST rated the vocabulary significantly higher than adults. While the median vocabulary rating for adults was 4.0 ("just right"), it was 6.0 for children indicating it was difficult for them (p=.02).

Net Primary Production:

- Children viewing NPP rated the length significantly higher than adults. While the median vocabulary rating for adults was 4.0 ("just right"), it was 5.0 for children indicating it was slightly too long (p=.01).
- Children viewing NPP rated the vocabulary significantly higher than adults. While the median vocabulary rating for adults was 4.0 ("just right"), it was 6.0 for children indicating it was difficult for them (p=.03).
- Children viewing NPP rated the trustworthiness significantly lower than adults. While the median vocabulary rating for adults was 5.5, it was 3.5 for children (p=.02).

Note that of the six children who rated the Visualizations, 3 were in elementary school (i.e. outside of the intended audience of the Visualizations), 2 were in middle school, and one was in high school. Because of the low number of children in the study that were in the target audience, there is inconclusive evidence as to how children in the target audience may perceive these issues.

Authentic Scientific Data

After viewing both Visualizations, participants were told that the Visualizations were created with authentic scientific data that can be used by scientists and researchers in their work or to create media pieces like the ones they watched. About half of all focus group participants indicated that they knew the Visualizations used authentic data, some thought it might be real data but did not know for sure, and a few thought the Visualizations were an approximation of natural processes but not drawing on actual data. For those participants in these last two groups, knowing that the Visualizations used authentic scientific data from satellites increased the trustworthiness of the information. A few participants indicated that knowing that it was authentic data made the data an even greater focal point of the Visualizations than it already was; they indicated they would have paid greater attention if this was stated up front. For example, one man replied, "Now that I know it's actually satellite [data] I thought it was quite impressive." This is despite the fact that SST uses an image of a satellite at the beginning.

Participants overwhelming thought that using scientific data in the Visualizations made them more authentic and trustworthy. One man said authentic data "just gives it credibility." Another man indicated that knowing it is scientific data "you're going to take it seriously." A couple in another focus group felt that authentic data made the issues covered in the Visualization more "real" by showing that "it's actually happening." For other participants the visuals themselves, not the fact that it was satellite data, helped to make the Visualizations trustworthy; actually seeing the processes rather than just reading about them helped to make it "real."

Participants also indicated that they typically put more trust in something created by the museum than from other sources. The mass media was seen as particularly unreliable for the participants in the focus groups. "Nothing's really trustworthy, what anyone says on the news," said one participant. Another member of that same group agreed: "Yeah. I'd probably think this [Visualization] would be more credible than something that a reporter reported on the news." Another participant felt like the museum was more likely to use "hard facts." Given this preference for museum-produced media, participants said the Visualizations were unbiased and credible. For participants this creditability when combined with the general skepticism of the media was seen as a valuable reason for the museum to create the Visualizations.

The vast majority of participants did not notice the line of text that credited the data. Even when their attention was drawn to this line of text, the majority indicated that they would not necessarily have known this meant the data was authentic or collected by scientific methods. Some indicated that they were not familiar with the acronyms/organizations credited, especially NOAA.

Global Connections

Participants were told that the design team hoped the Visualizations would help people to "think differently or in more depth about" connections on a global scale. Participants were then asked if this happened for them. There were differing points of view on the degree to whether this happened.

- About a third of those in the focus groups said the Visualizations did not help them make larger connections. One of these participants indicated that this did not happen for him because the videos were aimed at a younger target audience. The other participants who felt the Visualizations did not change their thinking about global systems and connections were from Australia. This group felt they already knew most of what was presented in the videos, that they hear global warming messages on a regular basis, and that many of the changes that a family can make they have already made (like installing dual flush toilets and solar panels on their homes). The implication is that viewers who do not see themselves as part of the target audience may not be disposed to making larger connections.
- About a third of participants felt the videos had enhanced their ability to see the connections on a global scale. This was a result of being able 1) to see through the Visualizations that these connections actually do exist, and 2) solidifying their prior understanding through the information in the Visualizations. One man indicated that he "thought about the different interplay" of the issues in a way he had not before. A woman had a similar reaction saying "it makes you think about a lot of things that I personally don't normally think about on a regular basis." A few visitors felt that SST supported their ability to make connections more than NPP did.

- Another third of visitors felt they had no change in understanding per se, but that they were now more curious about these global connections. This curiosity extended to wanting more information on the topics. One woman from England said "It makes me more interested to know a bit more about global warming and what it actually means." For this visitor and a few others the map-like aspect and the visualized data itself helped spark their interest, as opposed to the narrative of the Visualizations.

Visitors made a few suggestions that they thought would enhance viewers' ability to make global connections. These included:

- Making the implications of global warming, ENSO, and carbon release more obvious in the Visualizations. They suggested that stronger "so what" messages might help to make these connections.
- Including specific, concrete information about what would happen in a few locations if the course of global warming is not reversed. For example, one man suggested a message like "average temperatures in say Florida is supposed to be so and so…and in five years, it'll be 105 [degrees]." He thought a more specific example would help viewers understand the issues in a concrete way.

Conclusions and Recommendations

Both of the redesigned Visualizations tested in this study were found to be effective at conveying basic information and the larger ideas of the narratives. When compared with the results of the prior study, the findings indicate that many of the approaches used by the team enhanced viewers' ability to understand and make sense of the Visualizations. Significant areas of improvement included both the strategies used to convey basic information and the "big idea" of the Visualizations; areas of improvement are highlighted below:

- Labeling countries.
- Improving the overall readability and understandability of the data legends.
- Using color coded text to increase viewers' ability to make connections with the data legends.
- Clarification of "vague" statements or sections of the Visualization (i.e. the length of the ENSO cycle and the "no data" labels in NPP) that caused viewers to question the validity of the Visualizations.
- Enhancing the "so what" message in NPP by adding a more complex and nuanced interpretation of the data.

The study found that some issues that were prevalent in the January study were still apparent in the September study. This included:

- The multiple areas of the Visualizations that compete for the viewers' attention.
- A pace that is slightly too fast, especially at the beginning of each Visualization. Although pacing showed great improvement from the earlier study, it remained an issue.
- Participants' strong preference for narration in videos of this type.
- Participants' curiosity in the causes or the "how and why" of these cycles, not just the effects.

The study also focus on some of the larger issues facing the AMNH Science Bulletin team as they seek to create Visualizations that meet the project objectives.

- Findings from the study demonstrate that not all viewers understood the Visualizations to be based on authentic satellite data. The focus group conversations indicated that knowing it is authentic data may increase the trustworthiness and credibility of the Visualizations.
- Participants consistently viewed museum-produced media as more trustworthy than what they might see in the mainstream media. This is consistent with other studies in the museum field that indicate visitors have a high level of trust in museums.
- About two thirds of the participants were able to make larger connections about global systems or were more curious about these connections. Those who did not make connections typically saw themselves as outside of the target audience for the Visualizations.
- Participants consistently have difficulty with nuanced scales, such as the relative temperature scale in the original SST and the carbon scale in the redesigned NPP.

Recommendations

The following concrete recommendations are suggested as the team develops new Visualizations in Year 2 of the grant.

- Move the timestamp to the bottom of the Visualizations.
- Move the series name and Visualization title to the top of the screen.
- Consider using narration. Viewers consistently ask for and expect narration.
- Slow the pace at the beginning of the Visualizations, allowing for ample time between when each element (data, timestamp, legends, captions) appears and begins changing. What seems like a snail's pace to the team may be "just right" to the viewer.

The following conceptual recommendations are suggested as areas for the team to continue brainstorming and experimenting as they seek to perfect the style of the Visualizations.

- Continue to choose topics that have compelling implications and push the limits of the "so what" messages of the Visualizations.
- Continue to find ways to explain the cause and the effect of natural processes.
- Continue to make strong connections to climate change and human connections to climate change.
- Continue to experiment with ways to enhance the readability of the data legends.
- Consider helping viewers to understand the differences between weather and climate. In conversations, participants consistently conflate the concepts which may prevent them from fully appreciating some of the larger messages the team hopes to impart to viewers. The following websites have straightforward explanations of the differences.
  http://blogs.smithsonianmag.com/science/2009/08/weather-vs-climate/
  http://www.diffen.com/difference/Climate_vs_Weather

Appendix 1: Focus Group Protocol

Thank you all for joining us today. I'm Susan and I'll be leading this focus group for the next sixty minutes. As you heard when we first approached you, AMNH is developing new programs about earth and climate science. The organization I work for, the Institute for Learning Innovation, has been hired by the Museum to help them to learn what their visitors think of this work. You've been asked to be part of this group because you were visiting the museum today. Have any of you participated in a focus group before? [Adapt to responses] I always like to share some ground rules before I start.

Focus groups bring together people with different backgrounds because they each have something valuable to say. We want to make sure that everyone has a chance to share their thoughts, and that we respect each other's opinions. We are interested in the positive and the negative, so please don't be shy about sharing something you feel might be negative. We want to hear about that, too.
We have about 50 minutes for our discussion and want to use that time as efficiently as possible. You're welcome to any refreshments that you see and feel free to stand up or move around if you need to, we'll keep talking as a group. I'm sure you already figured out by the machines around here that we're recording this session. While I'll do most of the talking, my colleague will also be taking notes and may have some questions for you as well.

1. Okay, I know you've all met me but we haven't had a chance to really learn who's who. Let's get started by quickly going around the room with each of you saying your first name and what you do OR what grade you are in.
2. As I mentioned a minute ago, we are going to watch a few videos about earth and climate science. So, what comes to mind when you hear those words, "earth and climate science"?
3. I'd like to show you a short video now, and after you've seen it, we'll talk about what you saw.

<Show visualization: Sea Surface Temperature>

4. Now I'm going to ask you to complete a short paper survey, and then we'll talk as a group about the video. (Have everyone complete their own survey). Ok, is everyone done? Great.
5. What did you think about that video?
    a. What do you think it was about?
    b. Was any of this information new to you?
    c. Did you need prior knowledge of the topic to understand the video?
        i. What prior knowledge did you draw from?
6. What interested you the most in the video?
7. What was least interesting?

Transition: One of the reasons we're doing this is to learn how to improve these videos for people like you. That means that it's sometimes difficult to respond to a film when you've only seen it zip by once. What I'd like to do is spend a few minutes slowly reviewing the scenes to see if that reminds you of what you were learning, or what appeared to be unrelated or vague.

8. I'm going to play it for a bit, and then stop the video and you can tell me what you discovered new, what you didn't see the first time that you wish you had, or what you thought was not that interesting for you, and which parts you'd really like to hear more about. If I don't stop it fast enough or you want to say something, pipe up and yell STOP so we can talk about what interests you [play in chunks]. [after general feedback and probing, make sure to cover specific points below]
    a. Are you able to tell **where** you are? How about **when**?
        i. What are the clues that help you? Do they need to be clearer?

b. What do you think the color variations mean?
    i. How helpful are they? What clues did you use to interpret it? (ask specifically about the labels with arrows)
    ii. Is contrast an issue? How about color blindness?
c. How about the transitions, when it is going from one type of information or scene to another? Was that clear enough?
d. What about the placement of the captions? Did that work for you?
e. What other elements were helpful in making sense of the video? Tell me more about that?

9. Now that you have seen it again, is there anything else the producers could do to improve the video? [after general feedback and probing, move to specific points below]
    a. Was there anything that you felt you really needed more information on to make it clearer? What type of information could be provided?

<Repeat questions 4-9 with second visualization: Net Primary Production>

Transition: We are nearing the end of our time. But before you go, I just wanted us to think more generally now about these two videos.

10. You might have noticed that both videos were about **global systems** that effect climate. The producers who designed these videos were hoping that people who watched them might start to think differently or in more depth about how there are all these connections on a global scale.
    a. Did that happen for you?
    b. How would you describe the way you are thinking about these global connections now?
    c. What parts of the video supported that?
    d. Was there anything the producers could have done to make that message come across more strongly?
11. Now also probably noticed that both videos used authentic scientific data—this data is collected by satellites and used by scientists and researchers studying the Earth. The same data can also be used to create media pieces like the ones we saw.
    a. Does knowing that it is scientific data make you think differently about the videos? How?
    b. What do you see as the advantages to using scientific data in a media piece like this—something that museum visitors will see? (i.e. is it more authentic, intimidating, help them understand the issues better)
    c. Now compare these videos to something like a newspaper article or news story on TV. Does a presentation that allows you to see the real data help? What does it add to the experience? How does it impact your understanding?

We've reached the end of our time together and you've given us some wonderful ideas to think about.

Thank you so much everyone for being so open and sharing so much. I know this will help the Museum revise this work to suit people like you.

On your way out, <ILI NAME> has something to thank you for your help.

Appendix 2: Self-report Ratings Questionnaire

1. Rate how familiar you were with the **information** that was presented in the video. *Please circle a number.*

Not at all familiar						Extremely familiar
1	2	3	4	5	6	7

2. Thinking about the video overall, rate the **pacing** of the video. *Please circle a number.*

Too Slow			Just right			Too Fast
1	2	3	4	5	6	7

3. Thinking about the video overall, rate the **length** of the video. *Please circle a number.*

Too Short			Just right			Too Long
1	2	3	4	5	6	7

4. Thinking about the video overall, rate the **vocabulary** used in the video. *Please circle a number.*

Too Simple			Just right			Too Difficult
1	2	3	4	5	6	7

5. Thinking about the video overall, rate the **content** of the video. *Please circle a number.*

Too Basic			Just right			Too Advanced
1	2	3	4	5	6	7

6. Thinking about the content of the video, please circle a number for each statement.

	Not at all						Extremely
Please rate the **trustworthiness** of the information in the video?	1	2	3	4	5	6	7
How **interesting** was the information in the video?	1	2	3	4	5	6	7
How **"cutting edge"** was the information in the video?	1	2	3	4	5	6	7
Now, how **relevant to your life** was the information in the video?	1	2	3	4	5	6	7