Climate Prisms: The Arctic
Connecting Climate Research and Climate Modeling via the Language of Art

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Figure 1: Left to right: examples of content from *Climate Prisms: The Arctic* showing a visualization of ocean salinity; an Arctic map; and an aerial photograph of a research site; participants interacting with *Climate Prisms: The Arctic*.

Abstract

Climate science is conveyed via visualization of a climate model – an abstraction that removes the science from the research field activity that forms the basis for constructing the model. *Climate Prisms: The Arctic* is about bridging the distance between the physical world and the scientific visualization through multiple approachable modalities pulled from both the world of art and the world of science. By allowing participants to view science through different lenses, each person plots their own path, moving through the content at the pace and level that best enables them to engage with the material. The project itself is a museum-based exhibit featuring a large display screen driven by a touch interface designed for individual or small group viewing. Content paths are determined by an underlying system of tags, levels, content categories and related research areas. A screen shows a set of images. Each image can be accessed to provide image-specific information or can be a launching pad for a new set of related content and images that allows the user to continue on their exploration journey. Each person creates a unique path through hundreds of pieces of content. Embedded assessment will log basic demographics and each individual foray through the content. These assessments will be analyzed to explore trends of use and drive further content development.

Keywords: Art, scientific visualization, climate change, art science collaborations, Arctic research.

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1 Introduction

Climate change is a daunting topic, its complexity seeming to defy understanding for many. Yet its study has led virtually all scientists in the climate change community to foresee its dire consequences. However, their findings have not been accepted as uniformly by Americans [6, 13]. The diversity of cultural backgrounds, political leanings, and learning styles lead the population to be diverse in its engagement and conclusions about climate change. *Climate Prisms: The Arctic* is an interactive museum exhibit designed to engage participants in an exploration of the science of climate change through the many prisms of both art and science.

Much research has been done within the humanities on communicating the science of climate change (for example [8, 10]). This complementary project adds the visual arts to the process of communicating the science and the conclusion of climate change. *Climate Prisms: The Arctic* is an experiment seeking to identify the types of content and means of presentation that most effectively engage and maintain the participants attention.

Located within a free-choice learning environment, the goal of this project is to engage the section of the population that may be indifferent to climate change by enabling participants to create individual explorations through the content of the project that speak to each person at their own level. *Climate Prisms: The Arctic* allows each participant to write a unique visual story moving through the project content. Fields such as climate change generate vast amounts of data, both observational data and simulation data from climate models. To tease understanding from the data we turn to visualization. Visualization is a key link between the soil samples collected in the tundra and the climate models which provide insight into likely climate change impacts. This linkage is demonstrated in Figure 2. Visualization is an abstraction and can be easy to dismiss. *Climate Prisms: The Arctic* presents the pipeline from collecting soil samples in the Arctic to analyzing them in the labs to the statistical analysis of the findings and culminating in the input to climate models. By enabling learners to follow the scientists at their sites and in their labs, visually demystifying the statistics collected and tying them to the visualization and modeling, we hope to build understanding and acceptance of the results.

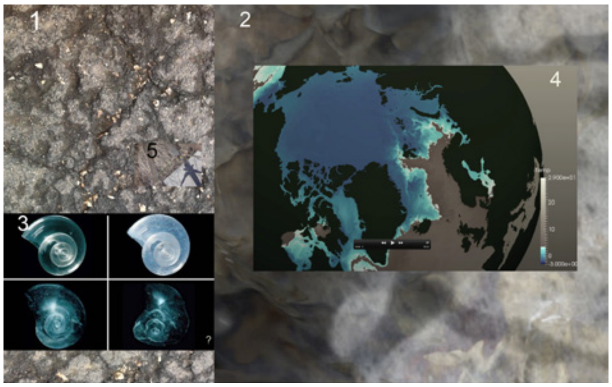

Figure 2: A typical screen display: on the left, artist's photographs (1, 2) are overlaid with shells showing the effect of ocean acidification (3). Also overlaid is a visualization of global ocean surface temperatures focused on the Arctic (4).

The project has three key facets that blend together to achieve its goals. First, the broad and deep content ranges across both artistic expressions: visual art, literature, and videography; and scientific representations: field imagery, scientific text, information graphics, and data visualizations (see Section 2). The second aspect key to this project is the interactive platform used in the project presentation. As discussed in Section 3, the interactive platform allows hypermedia navigation through the individual pieces of content. The interface programming navigates through the content using a series of tags that brings up content based on participant selection. Finally, as discussed in Section 4, the free-choice learning environment available in the project's initial setting at the Bradbury Science Museum, Los Alamos National Laboratory, allows a long-term assessment of the project, both in how it engages and impacts people's views on climate change and as research into how a science museum can use art as a means of bringing science to people.

The project, as discussed in this paper, is currently a pilot version of the long-term project plans. Directions for future work will be discussed in Section 5.

2 The Content

The project content is organized along three axes. One axis is the range of subject matter. The subject matter is based on the lines of research of Los Alamos National Laboratory's Next Generation Ecological Experiments – The Arctic (NGEE) and LANL's Climate, Ocean Sea-Ice Modeling (COSIM) team. Specifically, in this early pilot part of the project, geomorphology, hydrology, biochemistry, paths of carbon transfer, permafrost composition and climate modeling are included.

The second axis is the prism continuum – a spectrum of communication prisms spanning artistic and scientific languages. The artistic end of the spectrum begins with visual abstractions, moving through poetry, artist-designed visualizations, and on-site photography and videography. The scientific continuum picks up and moves though scientist's blogs, data visualizations, journal entries, site documentation, and scientist interviews. The continuum ends with abstracts from peer-reviewed journal publications and related URL links.

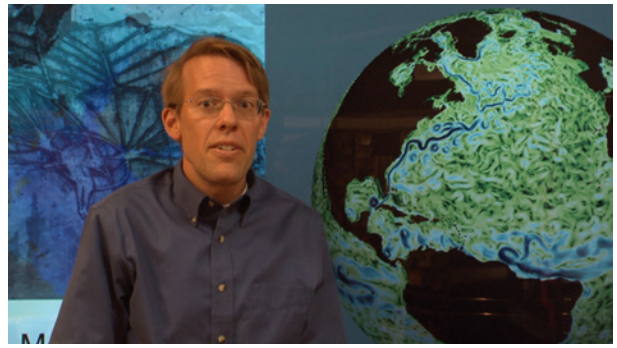

Figure 3: A still shot from a video interview with Dr. Mark Petersen, a climate modeling scientist with the COSIM Team at Los Alamos National Laboratory.

Figure 4: An aerial photograph of one of the research sites in Barrow, Alaska [9].

For example, on the artistic end of the spectrum are poems based on scientist interviews and blogs of their experience working in the Arctic. Moving along the spectrum, one might find video clips of a scientist explaining specific experiments, why they are important and how they tie to other areas of climate research. There are interviews with climate modeling scientists, Figure 3, explaining the role of visualization in verifying and validating their models as well as visualizations created in collaboration with artists. An aerial view of one of the Barrow, Alaska research sites can be seen in Figure 4. Metaphorical imagery of our relationship to the environment is shown in Figure 5. Typical scientific field notes, Figure 6, provide a contrast to the art and exposes the learner to the everyday activities of a scientist "in the wild" [4]. The participant can also move fully into the domain of validated scientific results such as this plot of the temperature anomalies spanning from 1880 to the present, Figure 7. An example of the benefits from artist-scientist collaboration can be seen in Figure 8 [2]. The Arctic tundra consists of polygonal shapes formed by natural forces over the eons. The ability of the scientist to see, explore, and understand these shapes has been enhanced by a palette of colors developed by a visual artist trained in the use of color.

The third axis is current levels of knowledge. We are creating threads appropriate for participants ranging from young users to seasoned scientists. We are engaging with teens to produce animated content. Teens speaking to teens in their own language will have a draw that dry science may not otherwise provide. On the other end are, for instance, links to the scientific papers on methods for improving climate models for participants who are interested and able to absorb the climate science at a peer-reviewed journal level. Overall, the content is designed to address learners at their current level of knowledge and entice them to wade in a bit deeper.

Climate Prisms: The Arctic aims to make the research manage-

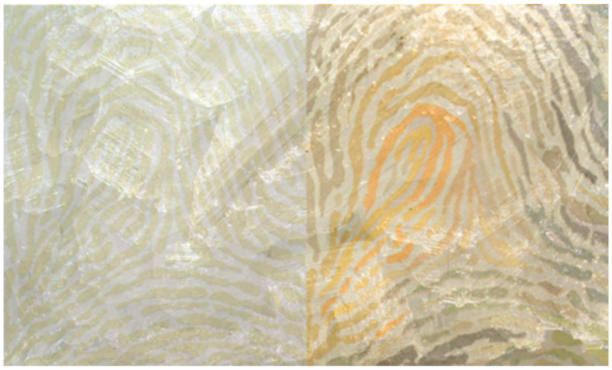

Figure 5: One of the metaphorical images: a combination of a fingerprint etching and a detailed photograph of Arctic ice.

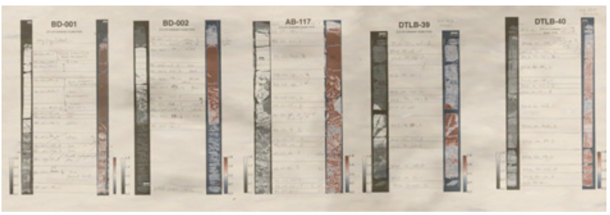

Figure 6: Scientific documentation: CT scans of tundra core samples (scanned at Lawrence Berkeley National Laboratory) [4].

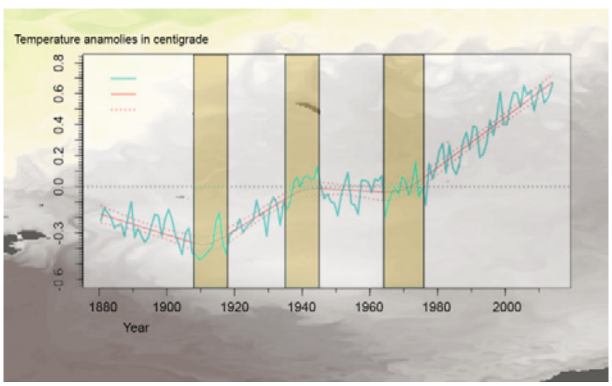

Figure 7: Graph showing temperature anomalies from 1880 to present day [5].

able and inviting, and it is specifically designed for users to chart their own path of discovery. It begins with Arctic research and proceeds to why the research impacts global climate models and the role of visualization in constructing models and understanding the predictions. The Arctic is one of the least understood drivers of climate change. Understanding the changes in this region is critical to building accurate climate models. *Climate Prisms: The Arctic* focuses on how and why the data are collected, how the data are explored through visualization and how the resulting models are verified and validated via visualization. By bringing the experiences of the scientists and research teams into view as they tease understanding from the pond samples, permafrost cores, satellite images, by showing the visual and numerical analyses, by highlighting the means by which the information is compiled and models built, we are shedding light on the means through which climate scientists arrive at their predictions. We draw in our audience through the beauty of science and the environment while we build trust by re-

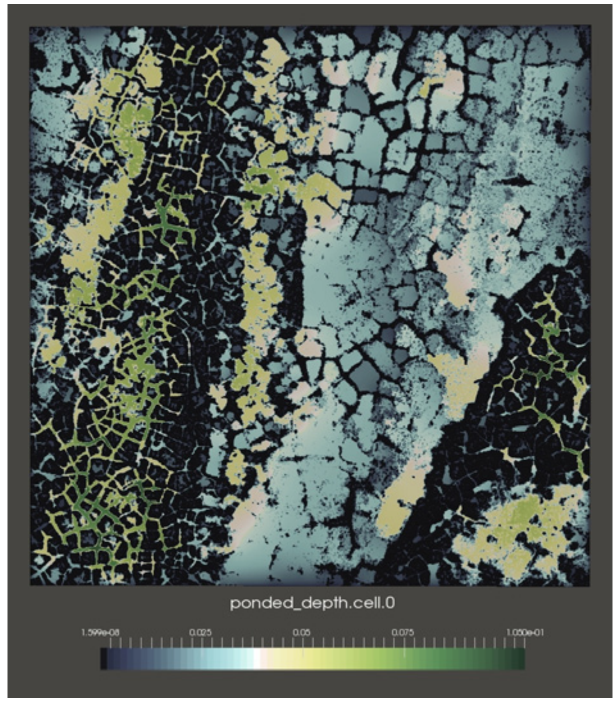

Figure 8: A graphic of a depth within a pond. The characteristic polygonal shapes are highlighted by an artist-developed *colormap*, or color palette, enabling the scientist to see more details within the data.

vealing the processes of science.

The work provides a glimpse into the laboratories, test sites and daily activities, pulling away the veil that surrounds the processes of science. By exposing the research paths, the reasoning and connections for the studies, findings – expected and unexpected -- provide a human connection to the abstraction of the science. Exposing the difficulties and uncertainties inherent in wresting knowledge from ice and soil turns the dialogue to a realm to which we can all relate. We aim to expose the range of experiments, research avenues, interconnectivity, as well as the wonder of discovery and acknowledgment of the known and unknowns that factor into studying climate change.

3 The Interface and Tagging System

Participants engage with *Climate Prisms: The Arctic* via a pedestal-mounted touch interface driving an 85 in screen. In addition to the main unit, there are two traveling systems which utilize 65 in screens. The large wall display presents sets of images in multiple selectable windows, known as a treemap format. Related in content and ranging in type, the images link the collection of climate science data to the scientific visualization of climate models. Participants, presented with a set of images, select an image that opens another set of images. The new images are chosen from related and/or tangential categories but varying in types, for example: visual, verbal or graphic. The content is computationally selected based on a system of tags, levels, content relationships and characteristics. Information on a particular image is provided by double-clicking on the image, illustrated in Figure 9. The size of the screen and the pedestal location is designed to facilitate small group viewing and interaction. Based on the team's experience with museum exhibit design, systems set up for small groups of participants provide a platform for interaction, encouraging discussion and exchange between other individuals and groups.

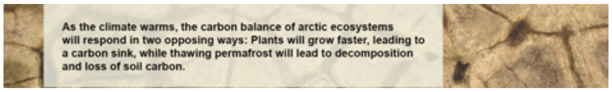

Figure 9: By double-clicking on an image, a learner accesses information about the image.

Each set of images is arranged in one of a number of possible fixed layout templates. Each template has from one to eight images. Videos and animations have a separate set of layouts which include options to view any related or sequential videos and a few related images. A "back" button allows the participant to return to the previous set of images.

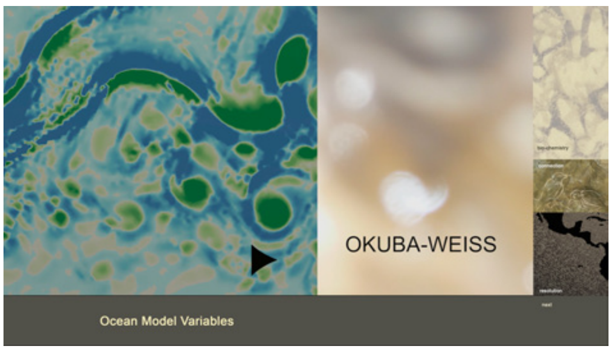

Figure 10: An example of a layout for a video clip. On the left, the video plays in the main part of the screen. On the right are several content items that the participant could explore. At the bottom right, a participant could choose to view the next video clip in a series. Visualization is of the Okuba-Weiss parameter depicting ocean eddies [14].

When a participant selects an image to explore further, a new layout of images appears. The next set of images are presented based on a series of tags. The top tag level, known as *Main* tags, defines the climate research area. For the current pilot version of the project, Main tags are Hydrology (H20), Geomorphology (GEO), and Biochemistry (BIO). The research in these areas connects to the Climate Modeling (CLM) tag which brings up images of related scientific visualizations. This high level linkage between specific research topics and the climate modeling visualizations ensures that participants are able to experience the interconnections between specific research topics and the models that go into climate change predictions.

Within each Main tag, there are possible sub-category tags. For example, under the H2O tag are: Lakes and Ponds (LAP), Sea Level Rises (SLR) and Surface Albedo (SLA). There are several other types of tags that the system uses to connect and distribute content. These tags enable the presentation of scientifically related content from other main categories and balance the presentation of images. For example, a tag defines the *Prism* through which a participant views the science. This tag can include Animation (ANI), Art (ART), Articles (ATC), Maps (MAP), Information Graphics (ING), Scientist Interviews (SIV), etc. Each Prism tag can have sub-categories such as Poem (POM) under the ART tag. Another set of tags defines the *VisualChar* or visual characteristics of each image. These can include People (PPL), Color (COL), Scale (SCL) and other options. The purpose of the VisualChar tag is to allow the programming to create dynamic and visually harmonious sets of images. A dynamic layout involving a range of content provides the participant with a wider range of direction choices.

Augmenting the tagging and level system is a system of weights which also factor into the content selection. The balance of those weights is still under consideration. For the pilot version of the project, 40% of the content is chosen such that it has the same Main tag. Another 40% is chosen such that it has one of the same subtags, e.g., the Prism tag or one of the Prism sub-categories. Finally, 20% of the content is chosen from distantly related content to enable participants to move between themes and types of content. The weighting scheme facilitates a participant's ability to delve deeper into one particular subject or to broadly experience a wide range of content across the many aspects of climate science.

The tags help to define and answer two important questions for each piece of content in the project: *Who am I?* and *To whom do I connect?*. Every piece of content needs to link to the science. We want *Climate Prisms: The Arctic* participants to understand the connections between the research areas and, through the visual story that they create, to understand how the various research topics work together to make a complete and holistic picture of the climate science and climate change.

Examples of layouts that a participant may encounter can be seen in: Figure 11 which focuses on content related to hydrology of ponds in the Arctic; Figure 12 which comes from the carbon transfer theme; and Figure 13 which stems from geomorphology. One of the images may be a link to a video or animation. An example of a video layout is in Figure 10.

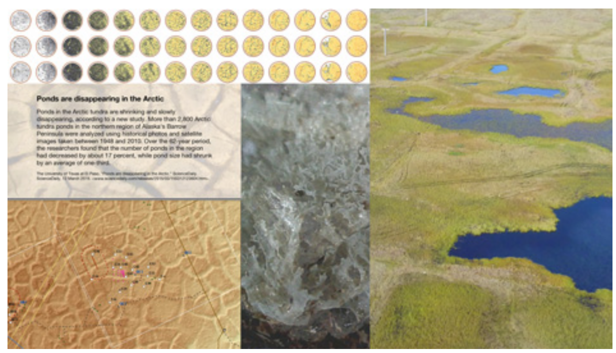

Figure 11: One of the layout examples. On the right is an aerial view of an Arctic pond. In the upper part of the aerial view, one can see the polygonal structure common in the Arctic [12]. The polygons can be seen again in the LIDAR map detailing the research sites (lower left) [7]. An info-graphic (center left) explains recent research into the shrinking of Arctic ponds. In the upper left, CT scan slices of tundra core samples are processed at LBNL, providing a possible launching pad into related research. In the center is a layered image of ice and plants – something that might be seen in soil core samples.

As can be seen, participants can sample many aspects of the content continuum: photographs of the researchers, their field sites, their equipment and materials; scientific visualizations; graphic representations of the data; documentation of the science; poetry based on the scientists' blogs; abstraction and metaphor relating to the relationships within the eco-systems; site maps created by artist / scientist collaboration; visualizations from national laboratory ocean modeling; scientist interviews; journalists' reports; and importantly, the contemplative spaces created by abstract imagery. It is these pauses that provide the mental quiet for participants to internalize the connection between the science and humanity.

4 Free Choice Learning and Assessment

With this project, we ask whether art can facilitate access into intertwined complexities of science. Our challenge is to build a platform that will allow participants to access the voice, the mode of communication that speaks to them, and motivates them toward a

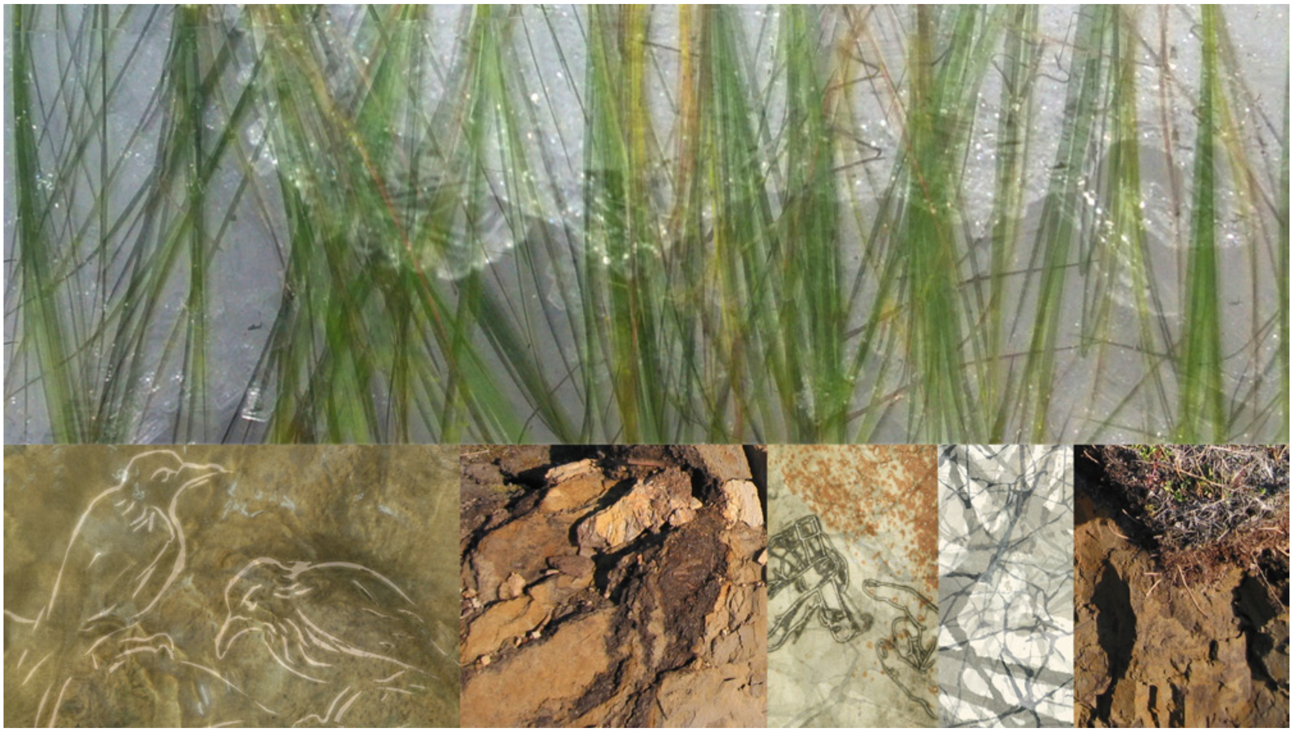

Figure 12: Another layout example, the top is a documentation of Arctic grass overlaid with ice, evoking a metaphorical reference to the freeze/thaw cycle of the tundra and its contribution to the density of carbon storage. Along the bottom are prints and paintings of the wildlife and biochemistry of the Arctic, interspersed with carbon-rich tundra photographs.

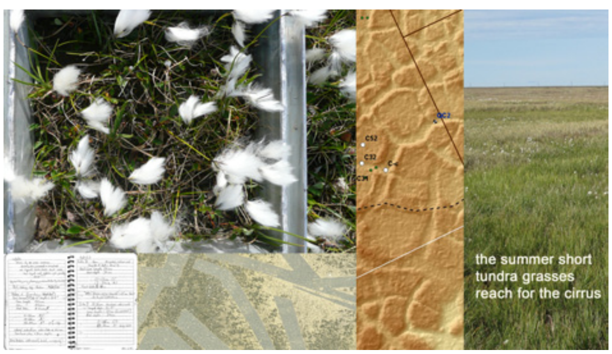

Figure 13: In this layout, the center includes a zoomed image of the Arctic research site location map. The haiku provides context for the photo of Arctic grasses on the right. On the top left is a close-up of a standard research plot used to track yearly changes. On the bottom extreme left is a page of field notes and bottom middle left is a detail from an abstract print drawn from Arctic research equipment.

deeper understanding. An ever-growing body of research in Informal Science Education is showing that the arts contribute greatly to engaging the "free-choice learner". This kind of learning goes on outside of the classroom, notably in science centers and museums, where novel, experiential approaches can be piloted. As pointed out by CAISE (Center for Advancement of Informal Science Education), the arts provide ways for both scientists and laypeople to approach understanding scientific content and concepts in new ways, leading to new understandings, making new memories, and establishing new connections and motivations for action [3].

The free-choice learning environment that will be home to the pilot is the Bradbury Science Museum of Los Alamos National Laboratory. Additionally, the two traveling systems will expand the reach of the project nationally. The Bradbury currently uses a wide range of current technical approaches to helping free-choice learners find their way through science concepts. Many computer and hands-on interactives, iPad apps, videos, and all the traditional fare of photos, graphics, artifacts and text are used.

Climate Prisms: The Arctic is a strikingly different experiment into alternate means of engagement. Rather then a specific educational tool with scripted content, *Climate Prisms: The Arctic* is designed as an exploratory platform. It provides content and context enabling exploration that mimics scientific and artistic processes. It is designed to open the conversation, allowing learners to formulate their own understanding and conclusions.

Ensuring that this installation succeeds in deepening a participant's understanding and engagement will be assessed through ongoing evaluation. A survey protocol will begin with collecting minimal yet descriptive demographics for each participant to assess their current level of interest and views on climate change. Front-end assessment is already underway to assess the user interface and content. With content spanning a continuum from the fine arts to technical scientific jargon, many different languages are part of the participant experience. Initial surveys are planned to assess the content images and language to ensure comprehension by a wide range of demographics. The software code tracking user paths is in place and the embedded assessment is currently being tested. These components will record each participant's path through the content. Once data are collected, they will be analyzed to show what trends of use correlate with the descriptive demographics. This will enable a statistical evaluation of the core question: did the project reach a range of participants and engage them long enough to expose deeper levels of content and thus understanding? We will also be accessing which modes of information were most important in engaging participants, providing valuable feedback for development of new content or the distribution of content displayed at each step to a participant.

Initial assessment has already indicated the need to customize the content presented depending on the venue demographics and goals.

5 Future Work and Conclusions

As presented, the project is in a pilot state, researching effective means of conveying the connection between the data collected by the scientists and the abstraction of data visualization. We are tracking user paths and audience demographics. The aim is to identify the content that elicits extended exploration as well as areas of interest to those unfamiliar and/or disengaged from the discussion. Results from this embedded assessment will be one of the drivers of future content.

Through the system of tags and weights, the project is expandable to other areas of climate research. This weighted tag system provides an organizational structure which allows the presentation of related content, both directly and tangentially associated, allowing each participant to discover their own story. We are exploring other potential methods to choose and present content. One such collaboration underway is with the Data Science at Scale team at Los Alamos National Laboratory. James Ahrens and David Rogers are working on image-based query systems that might assist in the goals of this project [1].

We plan on expanding by adding content prisms from other artistic practitioners who might be interested in lending their voices to building context between the collection of data and the abstractions of visualization. *Climate Prisms: The Arctic* is a broad collaborative effort between scientists and artists. It is not the work of one individual or even one team. It draws on decades of the diversity of scientific research, computer science, visual and verbal communication methodologies, artistic exploration and cognitive science. It stands on the shoulders of so many while designed to welcome content from those as yet unknown. Cathy Wilson, Los Alamos National Laboratory's Next Generation Environmental Experiments, Senior Scientist, provides the scientific compass. Mark Petersen and the COSIM team at Los Alamos National Laboratory provide the climate modeling knowledge and visualization. Bruce Campbell at the Rhode Island School of Design translates the artistic vision into a computationally-generated experience. Artistic direction is led by Francesca Samsel, Artist-in-Residence at Los Alamos National Laboratory. Linda Deck, Director of the Bradbury Science Museum maintains our focus on the learner and their experience.

Climate Prisms: The Arctic is an exhibit on climate change but more importantly it is a thinking tool. As participants select and follow paths through the content, the imagery provides a framework for their own internal dialogue. It is the scaffolding upon which learners create their own story line and arrive at their own understanding. *Climate Prisms: The Arctic* is a means for engaging with difficult topics, easing our reticence to contemplate the complex contradictory relationship between our environment and ourselves.

Supporting video can be found at: https://www.youtube.com/watch?v=IjxEu-dUCEg. High resolution photographs and supporting documentation is available at: https://datascience.lanl.gov/samsel.html.

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