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Designing and Prototyping an Interactive Exhibition at Te Papa Tongarewa

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Designing and Prototyping an Interactive Exhibition at the Museum of New Zealand Te Papa Tongarewa

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By

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Submitted to:
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Abstract

The goal of this project was to aid The Museum of New Zealand Te Papa Tongarewa in communicating the importance of ice core research as evidence for climate change by recommending designs for an interactive exhibition. To achieve this goal, our team developed, prototyped, and tested potential exhibition designs through an iterative process that allowed for improvements to be made based on visitor feedback. We used this feedback to gauge the visitor experience of our exhibition and to establish proof of our concept. Our team created a final design and recommendations for Te Papa to consider for their exhibition.

Executive Summary

Climate change is one of the most important and urgent modern global issues. As concern for environmental damage grows around the world, many countries are trying to further their understanding of climate change and reduce their greenhouse gas emissions. Scientists use ice core samples to study past climates and predict future effects of atmospheric changes. New Zealand undertakes world class ice core research and has drilled and studied Antarctic ice cores.

The Museum of New Zealand Te Papa Tongarewa wants to help create a net carbon-zero future for New Zealand by educating its visitors on climate change. With this intention, the museum launched the Natural History Renewal Project to update their exhibitions to contain more content related to climate change. This renewal project aims to inspire visitors to think critically about threats to New Zealand's natural environment and to provide them with a forum to discuss ways to mitigate effects of climate change. An exhibition within this renewal will highlight ice cores and their role in environmental research. Te Papa is determined to make this exhibition resonate with visitors by providing them with an opportunity for interactive learning. Developing this interactive museum exhibition requires an extensive and organized design process to allow for efficient progress towards a finished product.

Summary of Methodology

The purpose of this project was to aid the Museum of New Zealand Te Papa Tongarewa in communicating to its visitors the importance of ice core research as evidence for climate change by designing, prototyping, and testing an interactive component of an exhibition. To achieve this goal, our team completed the following three objectives: (I) assess Te Papa's progress on the renewal project and understand pertinent information to inform exhibition design, (II) develop designs for an interactive component of an ice core exhibition based on our research and Te Papa's specifications, (III) perform iterative prototyping to evaluate and improve the functionality and visitor experience of our most promising design.

Objective I: Site Assessment

Our team needed to understand the museum's parameters for the ice core interactive, the current stage of the renewal project, necessary information concerning ice core research, and visitor interactions with exhibitions at Te Papa. We collected this data through discussions with the museum's renewal team, reviewing documentation of the renewal project, meeting with an expert in ice core research, and observing visitors on the museum floor.

Initial meetings with the renewal team, along with document review, informed our team on the goals and specifications for the overall renewal project and the ice core exhibition. We analyzed this information to create an updated plan of action for our design process. In order to understand the level of interaction between visitors and current exhibitions, we observed visitors at the museum. The information we gathered through these observations helped our team understand what types of exhibitions were popular and which aspects of an interactive exhibition are important.

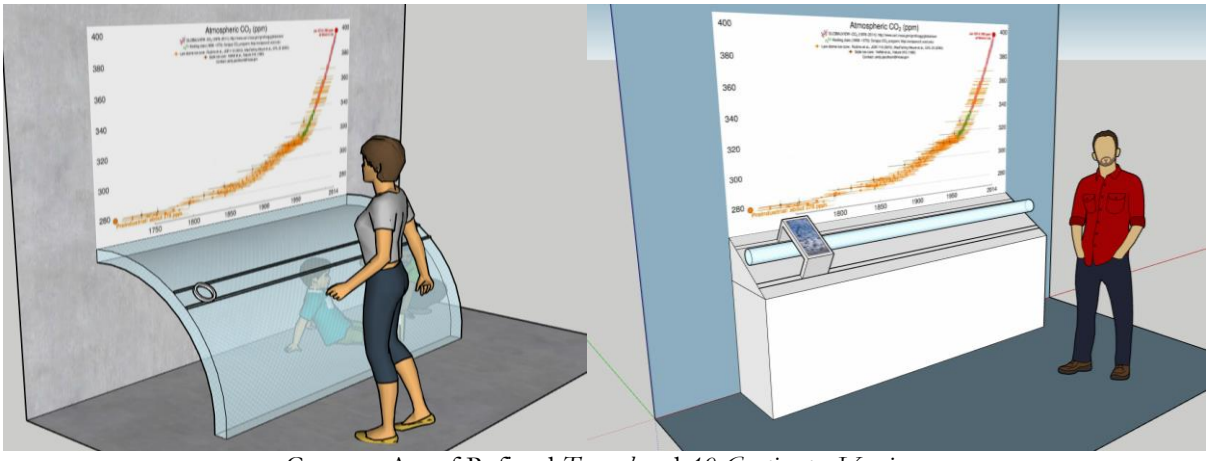
Our team, along with two members of the renewal team, visited the New Zealand Ice Core Research Facility to better understand ice cores and see one in person. We met with a leading ice core research scientist, Dr. Nancy Bertler, who presented information about her team's work in Antarctica, supplementing our background knowledge of ice core research. After reviewing themes of this gathered information, we found that a timeline displaying carbon dioxide levels over time would be an important part of the ice core exhibition.

Objective 2: Interactive Design Development

Based on the results of our site assessment, our team generated and refined design ideas for the ice core interactive. We conducted two rounds of brainstorming and evaluated the resulting designs, seeking feedback from the renewal team and an ice core expert for further refinement.

Our team held brainstorming sessions to generate preliminary designs. After individual brainstorming, our team convened to discuss our ideas. This method was consistent with Crawford's Slip Writing Approach and allowed each group member to discuss his or her individual ideas. After presenting these concepts, we conducted front-end evaluation, an established refinement method from the Worcester EcoTarium, to find common themes, strengths, and weaknesses in each design.

We organized discussions with members of the renewal team to present, assess, and review the results of our brainstorming. Throughout the rest of the design refinement stage, we sought and analyzed feedback to inform our future work. We cross referenced each of our designs with the goals of the exhibition components that were outlined by the renewal team. Consolidating this information allowed our team to decide on a design concept to prototype and test with museum visitors. This design consisted of an ice core model with a slider mechanism that was linked to a carbon dioxide timeline. The two versions of the refined design that our team produced include a 10 centimeter representation of an ice core and an enlarged representation with a tunnel for children to crawl through.

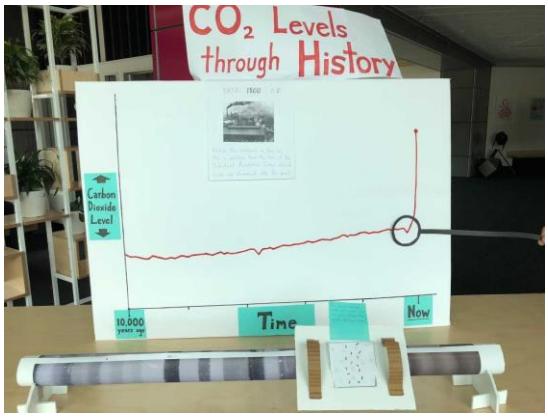


Concept Art of Refined *Tunnel* and *10 Centimeter Versions*

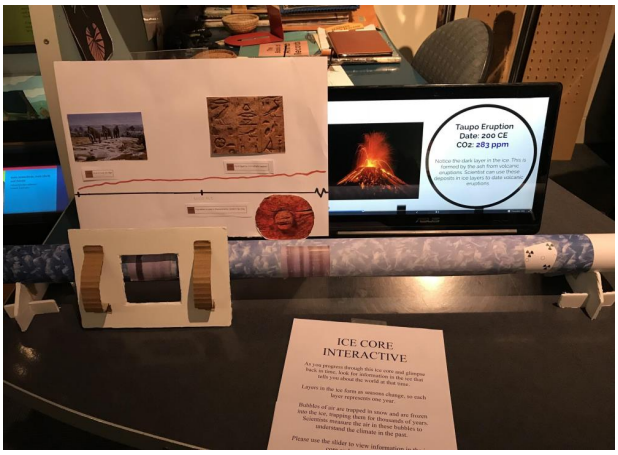
Objective 3: Iterative Prototyping

We created prototypes of our refined design and evaluated each versions' effectiveness in conveying our intended messages through testing with visitors. The main messages we wanted visitors to gain from our prototype were that the carbon dioxide concentration level was relatively steady for thousands of years but has increased at an alarming rate in the last 200 years and that ice cores play an important role in gathering data to understand climate change. We used feedback from visitor testing to iteratively improve our designs.

We sought to determine whether the designs successfully conveyed the intended messages. We focused on paper prototyping, a time and cost effective method to create and test multiple hand-sketched examples. In the first iteration, as seen in *Iteration 1 Prototype*, we used paper and cardboard to create a physical prototype to represent the timeline, ice core, and slider. We tested in *Nature Space*, a social learning space within the current *Mountains to Sea* exhibition. We set up our prototype with three team members assuming roles as a facilitator (asks the visitor questions), operator (operates the prototype), or observer (takes notes). We engaged with visitors as they passed by our prototype, inviting them to help us test the potential new exhibition. We asked visitors questions regarding their impressions, the appeal of design versions, the messages they took from our prototype, and whether they had any suggestions to improve our design. Based on the feedback we received from visitors, our team made updates and repeated testing with a refined prototype. In this second iteration, as seen in *Iteration 2 Prototype*, our team focused on updating the ice core model to be more closely representative of what visitors would experience in the final exhibition. We achieved this by shortening the time represented on the interactive timeline to reflect a more relatable time frame and by displaying the interactive portion of the timeline digitally. Feedback from our second iteration allowed our team to further refine our design and make well informed recommendations to Te Papa. The analysis of the results from testing Iteration 2 provided our team with opinions and suggestions from visitors as well as a proof of concept for the digital timeline interactive. This more refined version of our prototype allowed us to better gauge the visitor experience because it required less guidance from the facilitator and made visitor interaction more representative of a real exhibition.



Iteration 1 Prototype



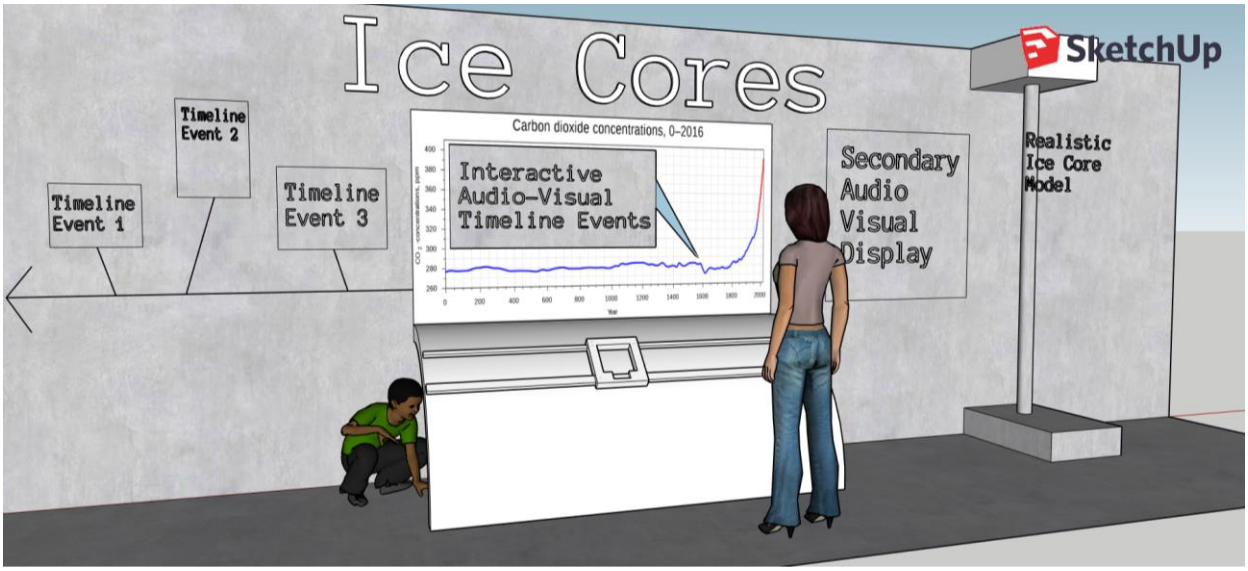
Iteration 2 Prototype

Recommendations and Conclusion:

This project aimed to aid Te Papa in communicating the importance of ice core data as evidence for climate change. Our team's goal was to develop an interactive exhibition that successfully conveyed this message. Based on the information we gained throughout this project and results of testing prototypes with museum visitors, our team created a set of recommendations for Te Papa to consider for their final exhibition. Along with our final design, these recommendations serve as a culmination of our work for the museum to use as a basis for the next stage of the renewal project.

- Incorporate tunnel into exhibition to target younger audiences
- Use a sliding mechanism and viewport linked to timeline

- Emphasize ice core visual aspects with a reveal factor
- Have a static and interactive portion of the timeline
- Link the timeline and layers linearly
- Present additional information regarding the ice core extraction process
- Maintain a positive tone that highlights ice cores and their purpose



Final Design SketchUp Model

Through assessment, design, and prototyping, our recommendations serve as the basis for a final design, shown in *Final Design SketchUp Model*, for an ice core interactive at Te Papa. In our final design, the interactive portion of the carbon dioxide timeline is linked to the position of the slider on the exaggerated ice core tunnel. The 'Interactive Audio-Visual Timeline Events' on the timeline would explain the event and encourage visitors to examine a corresponding visual within the ice core model. Younger audiences could examine the ice core model from inside the tunnel. External to this interactive would be a continuation of the carbon dioxide timeline with other timeline events. The 'Secondary Audio Visual Display' would convey other contextual information on ice core research and the 'Realistic Ice Core Model' would give visitors a sense of what an actual ice core looks like. Our project focused primarily on the development of the interactive timeline and ice core tunnel portion of the renewal project.

Acknowledgements

Our team would like to acknowledge the following for their contributions to our project:

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Authorship

Each member of the team contributed to writing this report. After many edits and changes to content and structure, no section consists of a single person's work. All sections are a culmination of work produced by the entire team.

Table of Contents

List of Figures

List of Tables

List of Terms

Carbon Dioxide (CO_2) - A gas that traps heat in the atmosphere, causing complex global changes.

Climate Change - Global, long-term changes to Earth's climate.

Conceptualization - The formation of an idea or concept.

Convenience Sampling - Non-probability technique of sampling used to select a subject based on their accessibility.

Crawford's Slip Writing Approach - Brainstorming technique that gives all ideas an equal weight, and uses pieces of paper to present main themes.

Facilitator-Observer Method - Term used to describe the method of having a facilitator walk through the interactive, while the observer takes notes.

Front-End Evaluation - Stage of developing an exhibition, selecting themes and content

Ice Core - Cylinder of ice drilled from Antarctica for use as a record for climate data.

Ice Core Interactive - An exhibition or device one interacts with pertaining to ice core information.

Individual Brainstorming - Process of generating ideas apart from a group.

Interactive - A feature that allows interaction, used as a noun or an adjective by Te Papa staff.

Iterative Prototyping - Design method that uses a cyclic process of testing, analyzing, and refining.

Natural History Renewal Project - Initiative to update the natural history content in Te Papa.

Naturalistic Observation - Research method of observing subjects in their natural environment.

Renewal Team - Group of Te Papa staff responsible for designing new exhibitions.

Paris Agreement - An accord to combat climate change.

Target Audience - Group for whom something is designed.

Prototype - Early model built to test a concept.

Paper Prototyping - A quick, cheap method for designing and testing.

Outline Method - Method of note taking that organizes main ideas.

Semi Structured Interview - Method that combines open response with determined questions, allowing the interviewer to further particular responses.

Round Table Discussion - Method of discussion in which a topic is talked about by pertinent people.

Storyboarding - Method of organizing images in a sequence to visualize a process or interaction.

Thematic Content Analysis - Method of qualitative analysis that examines and records patterns though coding for themes across data associated to a specific research objective

Chapter 1: Introduction

Climate change is one of the most important and urgent modern global issues. Ninety seven percent of climate change scientists agree that it is “very likely due to human activity” (NASA, Climate Change: How Do We Know, 2017). NASA reports that carbon dioxide levels in the air are the highest they have been in 650,000 years, 16 of Earth’s 17 warmest years on record have occurred since 2001, arctic ice has shrunk to the lowest amount on record, and sea level has risen nearly seven inches in the last 100 years (NASA, Global Climate Change, 2017). These vital signs of our planet serve as evidence for rapid climate change. Most countries address climate change by studying its effects and trying to reduce emissions. The Paris Agreement brings nations together towards a common goal, and out of the 197 parties involved, 170 have agreed to “undertake ambitious efforts to combat climate change and adapt to its effects. . . [and] assist developing countries to do so,” (UNFCCC, 2016).

Scientists use records of climate data to understand climate trends. Scientists study glacial ice because it preserves the necessary data such as atmospheric composition and temperature. They drill samples of ice called cores that act as time capsules looking at climate samples dating back 800,000 years (Davies, 2015). These ice cores provide long, accurate records of climate data which allows scientists to interpret modern climate change and to identify trends that predict future climate. This research is integral to raise climate change awareness and motivate effective actions to mitigate it (Bertler, Jan 18, 2018).

The Museum of New Zealand Te Papa Tongarewa wants to help create a net carbon-zero future for New Zealand by educating people about climate change. To do this, the museum has launched the Natural History Renewal Project to update their natural history section to contain more climate change components. One of the goals of this renewal project is to inspire visitors to think critically about threats to New Zealand’s natural environment. A section of the renewal project will highlight the threat of climate change, with an exhibition about ice core research and its relation to climate change. The renewal team is developing final concepts for interactive components within the Natural History Renewal Project.

The purpose of this project was to aid the Museum of New Zealand Te Papa Tongarewa in communicating to its visitors the importance of ice core research as evidence for climate change. We designed, prototyped, and tested an interactive component of an ice core exhibition to appeal to diverse audiences. Our team assessed the progress of the renewal team and observed visitors at the museum to gain an understanding of the renewal project and how visitors interact with current exhibitions at the museum. We brainstormed ideas for the ice core

interactive and refined our ideas into designs. Our team prototyped and then tested the designs with museum visitors to assess and improve them. We used the results and analysis from our testing to recommend an effective ice core interactive exhibition design for the renewal project.

Chapter 2: Background

The Museum of New Zealand Te Papa Tongarewa conceptualized an interactive ice core exhibition as part of their Natural History Renewal Project. The museum wanted to highlight the relationship between climate change, carbon emissions, and ice core research. In their goals for the exhibition, the museum described an interactive experience that would provoke thought and encourage visitors to become active participants in their own learning.

This chapter discusses climate change, the level of awareness of climate change in New Zealand, and its relation to education and future exhibitions at Te Papa. It discusses the relevant topics of conveying climate change information and fostering visitor engagement. It also references past and current exhibitions from multiple museums, particularly interactive exhibitions regarding the environment, to understand effective museum displays. The chapter explains the process of designing, creating, and testing prototypes to give insight into how museums develop interactive exhibitions. This combination of information helped our team develop an interactive exhibition that is informative and engaging.

I. Understanding Climate Change

Many countries are trying to increase their understanding of climate change and reduce their greenhouse gas emissions to slow environmental damage. Scientists understand modern climate change by studying past climates through ice core samples (Dusto, n.d.). Scientists examine the information ice cores contain to predict effects of climate change, to help design effective adaptation strategies to prepare communities for unavoidable effects, and to provide the knowledge base to reduce emissions globally (GNS, n.d.). New Zealand undertakes world class ice core research and has drilled and studied Antarctic ice cores (Bertler, Dec 14, 2017).

A. Understanding Climate Change Through Ice Cores

Studying past climates through ice core research helps scientists understand natural variability trends of past and future climate change. The age of an ice core can be approximated by the number of layers that have accumulated (Davies, 2015). These layers form as pressure compacts snow into ice (Figure 1). In Antarctica, high wind speeds in the winter cause the snow to form small crystals that form dense and dark layers (Bertler, Feb 22, 2018). Warmer summer temperatures, though still below freezing, allow more humidity and thus precipitation to travel inland making summer layers thicker and lighter (Bertler, Feb 22, 2018).

Figure 1: The Visible Layers of an Ice Core from Alaska (Dusto, 2015: Photo by Mike Waszkiewicz)

As the ice flows, layers spread out and thin, becoming difficult to tell apart (Davies, 2015). Fortunately, there are other ways of identifying the age of the ice including markers of dated volcanic eruptions and comparing data to other ice cores with known dating. These methods are integrated with the mathematical modelling of ice flow dynamics (Davies, 2015). For example, if scientists identify ash from a particular eruption within a layer, they can date that layer of ice to the year the eruption occurred. These methods provide a fairly accurate approximation of the age of the ice at that point in the core (Davies, 2015).

Ice core layers trap air bubbles that can be tested to gather data about past atmospheric composition, particularly ancient greenhouse gas concentrations (GNS, n.d.). As pressure compresses snow into ice, air trapped in the snow forms bubbles as shown in Figure 2 (Davies, 2015). These bubbles are samples of the atmosphere that scientists use to analyze gas concentration when the ice is crushed or melted during testing. Carbon dioxide, methane, and other gases are compared to create a continuous record of atmospheric composition over time (GNS, n.d.).

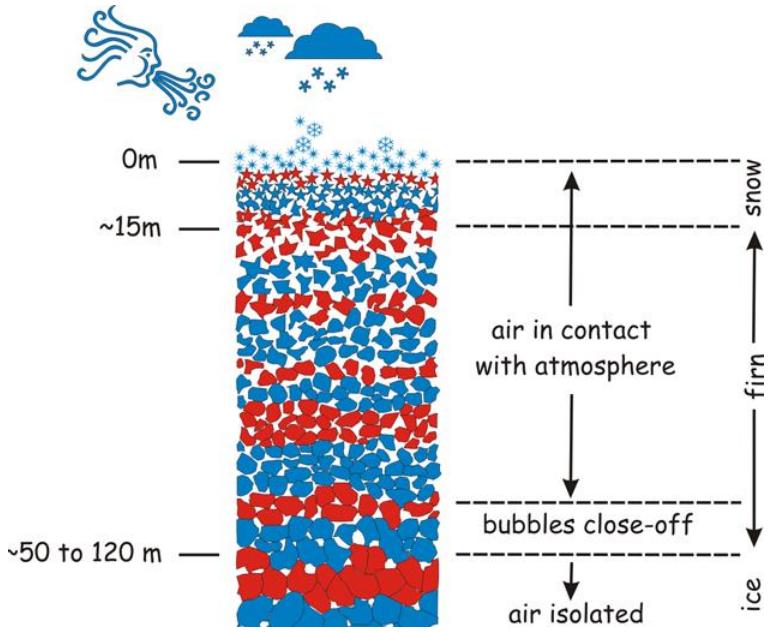


Figure 2: The Process of Snow Trapping Air Samples in Ice (Bertler, Jan 18, 2018)

Scientists approximate air temperature from the concentrations of oxygen isotopes in ice cores. Presence of the “heavy” oxygen-18 isotope in water causes the vapor to precipitate at a lower temperature, while the “light” oxygen-16 in water requires colder temperatures (Dusto, n.d.). Comparing the ratio of the two oxygen isotopes give scientists a highly precise record of past temperatures (Dusto, n.d.). Scientists compare temperature records with atmospheric composition, especially carbon dioxide, to understand their relationship. This is especially important for studying modern climate change because scientists use ice core data to verify the relationship between carbon dioxide and temperature (Bertler, Jan 18, 2018).

Antarctic ice cores can extend thousands of meters down to bedrock and are usually extracted in two to twenty meter long, ten centimeter diameter cylinders (Bertler, Jan 18, 2018). The drilling is done within trenches dug into the ice sheet and requires extreme care to extract pure samples. After they are extracted, the ice cores are cut to one meter long sections so they can be transported more easily. The ice cores are divided into sections and are tested or archived for future study as shown in Figure 3 (Bertler, Jan 18, 2018). Some tests are non-destructive, such as optical or conductivity tests, which are administered first. These tests include recognizing volcanic ash layers and other macroscopic features. Destructive tests, such as melting, crushing, or chemical tests, are performed after to maximize the information collected. These include testing the composition of trapped air bubbles to approximate air temperature and gas levels over time (Bertler, Jan 18, 2018).

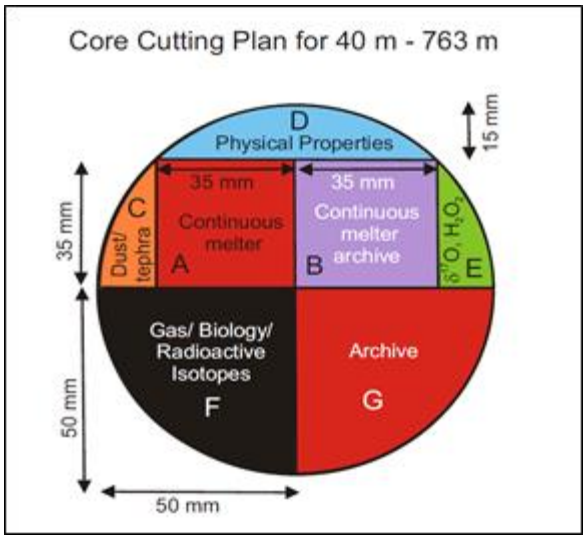


Figure 3: Cutting Plan for Antarctic Ice Core (Bertler, Jan 18, 2018)

Scientists from many countries share ice core data and there is usually cooperation between scientists in the ice core community (Bertler, Jan 18, 2018). Climate change is a global problem that requires international cooperation to reduce its impact and to unite communities to deal with unavoidable effects (Bertler, Jan 18, 2018). The analysis and interpretation of ice core records allow scientists to understand how the climate is changing, including predicting ice sheet retreat leading to sea level rise (Bertler, Jan 18, 2018).

New Zealand leads an international program for ice core research called the Roosevelt Island Climate Evolution (RICE) project. The project studies an ice core recovered from the northern edge of the Ross Ice Shelf to better understand the stability of the West Antarctic Ice Sheet as the climate is changing (RICE, 2015). Through the RICE project, scientists drilled 764 meters of ice and produced a continuous climate record of the past 83,000 years to date (Bertler, Jan 18, 2018).

B. The Effects of Carbon Emissions

Carbon emissions refer to the release of carbon based greenhouse gases, primarily carbon dioxide (CO_2) and methane (CH_4), into the atmosphere. Carbon dioxide is a byproduct of combustion reactions of hydrocarbons or fossil fuels. As a result, anything that is burned for electricity production, heating, or transportation creates large amounts of carbon dioxide. A single litre of common E10 fuel will produce 2.3 to 2.6 kilograms of carbon dioxide (US EIA, 2017). Since the industrial revolution, atmospheric levels of carbon dioxide have risen rapidly. Ice cores revealed that over the past 740,000 years, atmospheric carbon dioxide concentrations varied between 180 and 280 parts per million (ppm) (Bertler, Feb 22, 2018). In 2013, they

surpassed 400 ppm (NASA, Climate Change: How Do We Know, 2017). The last time atmospheric carbon dioxide concentrations were this high was three to five million years ago (Bertler, Feb 22, 2018). Records show that at this time the Greenland and West Antarctic ice sheets had collapsed and the East Antarctic ice sheet had partially melted causing global sea levels to be 10 to 20 meters higher than today (Bertler, Feb 22, 2018). The extreme rise in carbon dioxide is shown in Figure 4 and highlights the abnormality of the modern carbon dioxide concentration spike (NASA, Climate Change: How Do We Know, 2017).

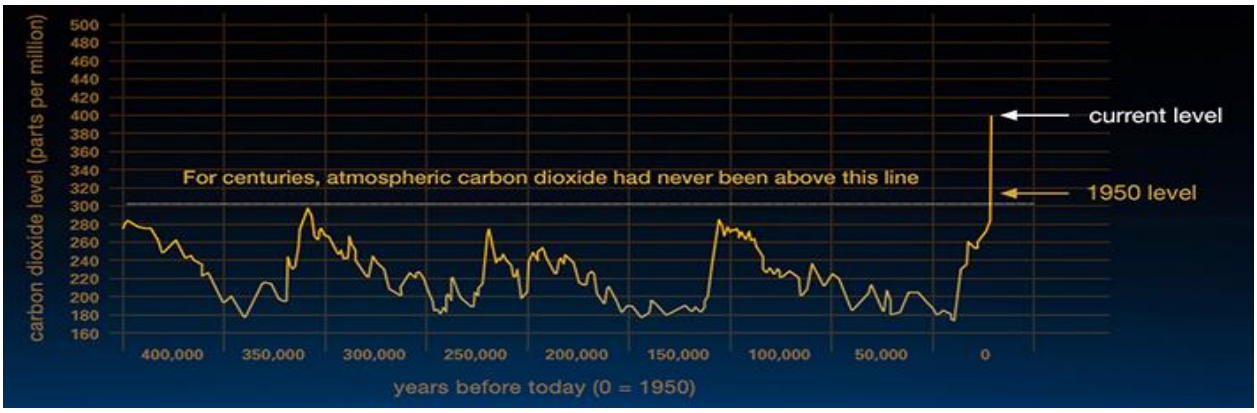


Figure 4: Atmospheric Carbon Dioxide Levels Over Time, Pre-Record Data Approximated from Ice Cores (NASA, Climate Change: How Do We Know, 2017)

These conditions trigger changes to the climate and environment and scientists predict that droughts, extreme weather, ocean rise, and glacier melt will become larger problems (NASA, The Consequences of Climate Change, 2017).

Atmospheric conditions are a global issue. However, New Zealand's net carbon dioxide production is relatively small. Forests cover 24% of New Zealand and act as a carbon dioxide sink, removing carbon dioxide from the atmosphere through photosynthesis (ERS, Carbon Stocks in Forests, 2015). The electricity generation, transportation, and industrial sectors are relatively small, and New Zealand's carbon sinks offset about 66% of the country's carbon dioxide production (CAIT, 2014) & (ERS, Carbon Stocks in Forests, 2015). New Zealand has conserved many of its forests to help offset greenhouse gas emissions, and has observed increasing stores of carbon in the forests as a result (ERS, Carbon Stocks in Forests, 2015).

II. Climate Change in New Zealand

New Zealand has undertaken several initiatives to be environmentally friendly through efforts such as the Paris Agreement and the Zero Carbon Act, but still faces challenges. New Zealand signed the Paris Agreement, an international agreement to take action against climate change, in 2016. Since this date, the government has organized an official committee of experts to advise New Zealand's adaptation to climate change (Ministry for the Environment, New Zealand's climate change programme, 2017). In mid-December of 2017, the Minister of Climate Change announced the government's first steps toward creating a Zero Carbon Act that will become "a cornerstone of New Zealand's transition to a low emissions" (Ministry for the Environment, Zero Carbon Act, 2017). Agriculture is New Zealand's largest emission sector, but road transport emissions have had one of the largest increases: 78% since 1990 (Ministry for the Environment & Stats NZ, 2017). Five of New Zealand's warmest years on record took place in the past 20 years. Although New Zealand's contribution to global emissions is relatively small, it has the fifth-highest per capita emissions out of 35 countries in the Organization for Economic Cooperation and Development. Atmospheric carbon dioxide concentrations near Wellington have increased 23% from 1972 to 2016, matching the global trend (Ministry for the Environment & Stats NZ, 2017). Many organizations in New Zealand are already part of an initiative working towards a carbon-zero future.

New Zealand has been recording human effects on the environment and climate for over a century. The country's government started examining the weather in the 1860's by establishing a centralized weather-forecasting service. European settlers were often interested in keeping personal weather data because the weather played a role in determining much of their economic success. Farmers and business owners would track daily weather and use the data to make predictions about future weather. European settlers and Māori alike noticed increased flooding throughout the late 1800's and were quick to blame local deforestation as a potential cause of this change (Newell et al., 2016). At the time, the director of the Colonial Museum, which would later become the Museum of New Zealand Te Papa Tongarewa, claimed that deforestation would cause the country's climate to dry up because forests prevented flooding and held water. This popular but scientifically unsupported belief influenced the country to pass legislation against deforestation by the 1870's to limit the supposed anthropocentric effect on climate change (Newell et al., 2016).

A. New Zealand Initiatives to Mitigate Climate Change

New Zealand is working to reduce its carbon footprint by educating people and enacting programs to reduce carbon emissions. The Ministry for the Environment highlights the abundant evidence for climate change on their webpage and attributes these effects to human behavior. The Ministry highlights data, such as reduced glacier size and increased levels of heat stored in the ocean over the last 150 years, and directly states that the dramatic increase of greenhouse gases and climate warming "can only be explained by the influence of humans" (Ministry for the Environment, Evidence for climate change, 2017). To support this, the Ministry also highlights the importance of ice core research on this matter:

> "We know this from a number of ice core studies. Snow traps tiny bubbles of air as it falls and is compressed into ice. Over the years, more and more ice layers stack up on top of each other. Drilling into ice sheets in Antarctica and Greenland provides a record of what the atmosphere was like back in time. Direct measurements of atmospheric concentrations of greenhouse gases show how our global greenhouse gas emissions have grown in past decades" (Ministry for the Environment, Evidence for climate change, 2017).

New Zealand has a multi-faceted plan to combat climate change including emission goals set by the Paris Agreement, a global effort to limit humans' greenhouse gas emissions. By this agreement, the country's goal by 2030 is to reduce greenhouse gas emissions by 11% below their emission levels in 1990 (Ministry for the Environment, New Zealand's climate change programme, 2017). In addition to the Paris Agreement, the government has announced plans to enact a Zero Carbon Act. This bill will outline future goals for curbing greenhouse gas emissions toward a zero carbon future and establish an independent Climate Change Commission. The New Zealand government wants to ensure "a just and effective transition to net zero carbon emissions" by consulting a diverse range of industries (Ministry for the Environment, New Zealand's climate change programme, 2017).

Since introduction of the Zero Carbon Act, the government has agreed to establish an Interim Climate Change Committee to advise climate change policy, including legislation around the agriculture industry and renewable electricity (Ministry for the Environment, New Zealand's climate change programme, 2017). The government has also established separate organizations to advise the government on related economical and agricultural matters. These groups include the Climate Change Forestry Reference Group and the Biological Emissions Reference Group (Ministry for the Environment, New Zealand's climate change programme, 2017).

Trees That Count is a non-governmental organization that is working towards slowing the effects of climate change. This organization focuses on preserving the environment and

promoting biodiversity by planting native trees all over New Zealand. In 2017, Trees That Count set a goal to plant one tree for every New Zealander, approximately 4.7 million trees, and in a year they have more than doubled that goal. Community members are involved in this program through planting projects, which encourage citizens to plant trees in their own communities. The Kirehe Restoration Project and Paper4Trees are examples of two very successful projects through Trees that Count. The Kirehe Restoration Project was implemented on the Coromandel peninsula because Kirehe Point was destroyed by a wildfire. Trees That Count organized volunteers to plant native trees in this area and approximately 70 acres of trees were planted and restored. Paper4Trees was implemented to reward schools in New Zealand for recycling of paper each year by donating native trees. The Trees That Count program accommodates all ages because planting trees is easy and accessible (Trees That Count, 2016).

B. Māori Views on Climate Change

Māori are the indigenous people of New Zealand that lived in Aotearoa, the Māori name for New Zealand, for hundreds of years before Western colonization. Māori still have a strong cultural presence in New Zealand today and share a equal voice with the non-Māori in the New Zealand government. Caring for nature is a Māori tradition, and they have an advanced understanding of changing climates. When the first Māori ancestors discovered Aotearoa, they settled in a land that was very different from their previous homes, so they had to adapt to the new environment quickly. Scientists project changes to New Zealand's climate to continue over the coming century, and adaptive resilience of the Māori may be regarded as a valuable experiential resource (King et al., 2008).

Cultural explanation of the climate is connected with Māori mythology. There are many Māori traditions related to weather that give meaning to the atmospheric elements (Newell et al., 2017). Māori use indicators from the environment to predict future changes in weather. Table 1 shows how Māori used clues such as forms of the clouds and sounds of the sea to predict weather (King et al., 2008).

Name	Indicator	Expected outcome
Tihirau (Cape Runaway)	The clouds in the sky above Tihirau	Approaching rainfall or storm
Nga ngaru (Waves)	The booming sound of waves across the land	A storm is coming
	The sound of waves hitting local rocks	Rough or calm weather conditions are expected
Poanganga (Clematis)	Periodic blooming	A warm season lies ahead with gentle breezes
Whakaari (White Island)	The plume lies to left	Rainfall is expected
	The plume stretched inact across the horizon	Fair weather is expected
	The plume flattens and the end breaks off	Watch out extreme weather is expected
Marama (Moon)	In the first five nights of the lunar month	
	The moon is lying on its back	A month of spilling water is ahead
	The moon is at an angle or straight up and down	A dry month lies ahead
Parearau (Jupiter)	The shimmer of Parearau is light and misty	Wet conditions for the next month
Ra (Sun)	A ring around the sun	Bad weather is expected

Table 1: Weather and Climate Indicators from Te Whānau-ā-Apanu (King et al., 2008)

Some details may have been lost to history, but environmental indicators are still used by Māori across New Zealand. Some of these indicators can effectively predict weather. For example, the booming sound of waves might be a sign that a storm at sea is making the waves rougher than normal. The ancient use of environmental indicators to predict the weather is an example of how nature is an important part of Māori culture (King et al., 2008).

Kaitiakitanga, which translates to guardianship and protection, is another important part of Māori culture. Based on the idea that man and nature are closely linked, kaitiakitanga means that people have a responsibility to care for and protect the earth (Te Ahukaramū, 2007). Modern climate change due to human activity is a clear violation of kaitiakitanga, which makes climate change an important issue to Māori (Ngati Porou, 2014). To maintain kaitiakitanga, Māori have started a collection of projects called the Vision Mātauranga science programme to investigate climate change impacts and ways to combat and reduce these impacts (Morrison, n.d.).

C. Emotional Connections to Climate Change

Climate change often brings up negative emotions such as anger at past generations or other nations, guilt of one's own contribution, and fear of the consequences that may come. Researcher Susanne Moser assembled a focus group to study emotional responses to climate change where a participant said, "There's no way that we can deal with this [global warming] as individuals. It's a problem that's almost too big for anybody to deal with," (Moser, 2013, p. 6). Others avoid talking or thinking about the subject because, "the topic [is] so emotionally distressing," (Moser, 2013, p. 6). Climate change is such an urgent topic that it often becomes an emotional one.

Educators can bore informed people by only presenting obvious and depressing facts about climate change. Although these facts are important and can motivate some audiences to act, research has shown that positive emotions tend to motivate and energize people better negative ones (Swim & Fraser, 2013). As a result, teaching by appealing to positive emotions such as awe of nature's grandeur, pride in one's home, and hope that nature can be preserved is more successful in communicating the urgency of combating climate change.

Presenting the complexity of the system is another way to help visitors emotionally connect with climate change. Although appropriate information varies among different ages and oversimplification bores people, highlighting some of the complexities of climate change can provoke thoughtful consideration (Cameron & Neilson, 2015, p. 252-253). This method allows people come to their own conclusions, giving them ownership of the problem. It helps bring climate change into their lives as a real problem, not just a scientist's or a politician's, thus encouraging people to remember the information and do something about it.

III. Interactive Exhibitions

The Te Papa museum has the opportunity to become a platform for informing visitors about climate change and ways that individuals can make a difference. However, Te Papa is faced with the question of how to make climate change resonate with visitors. This provides an opportunity to teach through an interactive exhibition. To better understand the context of interactive exhibition creation, it is important to understand successful interactive features, visitor engagement, and examples of other interactive climate change exhibitions.

A. Successful Interactive Features

Exhibition designers incorporate interactive features to encourage hands-on learning. According to Michael Horvath, the Director of Exhibit Design and Production at the Boston Museum of Science, visitors want exhibitions that are unique, exciting, and provide a learning experience that they cannot get at home. This means minimizing writing, videos, and even touchscreen interactives in exchange for tactile interactives (Horvath, 2017). Tactile interactives include physical objects or mechanisms and provide a novel experience, while video and touchscreen interactives could be easily replicated on a device at home. The unique participation of tactile interactives set museums apart from other learning methods.
Visitors tend to be attracted to exhibitions that move, include animals, and are physically large (Barron and Leask, 2017, p. 476). When children are busy playing with an exhibition, their

parents are usually close by, extending learning time for all audiences. *Assessing Visitor Experience for the Te Papa Natural Environment Zone Renewal* recommended using these hands-on, interactive exhibitions for all ages noting that they, "engaged visitors for relatively long periods of time," and "were noted as the most popular during interviews," (Harrington et al., 2017, p. 60).

Exhibitions that engage groups of people encourage social learning and reduce the number of people who avoid the exhibition because of wait time. Although the most engaging exhibitions allow multiple visitors to operate them simultaneously, ones that are interesting enough for people to want to watch others operate or that are humorous can be very successful as well (Horvath, 2017). Challenging games encourage people to stay interested, and competition will keep visitors engaged in multiple repetitions of a game. It may not be feasible for some exhibitions to include all of these features, but attempting to incorporate a few may help an exhibition succeed.

Museums can discuss solutions rather than problems to bring an optimistic view to a serious topic. For example, presenting opportunities to reduce carbon emissions to visitors could make it seem like an obstacle that is manageable and will encourage action (Moser, 2013, p. 6). Relating such problems to a visitor's life can motivate them to take action (Swim & Fraser, 2013). Whether it be an elementary class who all decide to try to shut off lights at home or an adult who decides to invest in solar heating for their house, this method is a positive way to encourage action against climate change.

Hands-on learning is another education method that brings a positive experience to any topic, and is especially popular with younger audiences (Horvath, 2017). Children can become bored at museums because their attention span may be less than an adult's. An interactive exhibition can make learning feel like playing. Research photographs from the Boston Museum of Science and Worcester EcoTarium are in Appendix A.

B. Visitor Engagement

Strong visitor engagement enhances the quality of learning that takes place at a museum and increases the local and tourist presence at the museum. Museums must catch visitors' attention to entice them to learn hands-on. According to a WPI project completed in Costa Rica in 2000, "The main objective of these museums is to create a nonthreatening, interactive environment that supplements and positively reinforces the learning that occurs in schools and homes," (Archer et al., n.d., p. 8). Technology provides new ways to learn, and the

modern abundance of technology impacts learning expectations. Current expectations are of user-friendly entertainment with attainable goals.

For New Zealand, a country that cherishes both the past and present, it is important to keep the following in mind: “Traditionally seen as places to view the past, museums also have a role in providing communities with the opportunity to understand the present and inform the future,” (Barron and Leask, 2017, p. 475). This is relevant when discussing climate change, a modern crisis that will impact the environment for generations. An effective climate change exhibition would demonstrate that events from the past have impacted the environment while suggesting which actions today could reverse those negative impacts. The exhibition would inform visitors to act with the future in mind. Interactive exhibitions invite visitors to engage and learn, emphasizing that they have a role to play in making positive change.

C. Examples of Interactive Environmental Exhibitions

Interactive environmental exhibitions are widely used by museums. Selected examples of interactive exhibitions highlight technology and mechanisms, including moving projections and tactile pieces. They convey content related to the environment, with a focus on human impact. These exhibitions draw people in to learn about their own environmental influences through active experience. One such exhibition is the *Handprint Globe* at MOXI, The Wolf Museum of Exploration + Innovation in California. This exhibition (Figure 5) asks visitors to photograph their hands and gives the option to alter the resulting image with photographic editing. The completed photos are then digitally displayed on a large, live-updating globe. Many of these visitor-generated images can be displayed on the globe at the same time, covering the globe’s surface. This is meant to show that everyone contributes to the environment, and has power over what kind of contribution they make. Advantages of this design include that is it accessible for all ages, easy to use, and visually striking, which engages many visitors to interact and learn simultaneously (Handprint Globe, n.d.).

Figure 5: Visitors Engaging with the *Handprint Globe* (creativemachines.com, n.d.)

The American Museum of Natural History in New York offers an interactive environmental exhibition called the *Enchanted Book*. This exhibition (Figure 6) looks like a large book with environmental illustrations inspired by Leonardo da Vinci's notebooks (AMNH, 2015). These illustrations, along with accompanying information, are not written in the book, but projected onto its blank pages. As visitors turn the pages, new displays are projected. There are touch sensors embedded in the book, so visitors can call up additional information by touching a topic. This design allows visitors to intuitively direct their own learning, using a familiar object in a unique way. It combines the everyday motion of turning a page with the unexpected addition of interactive projections, creating a user-friendly learning experience.

Figure 6: Children Use the *Enchanted Book* to Learn About the Environment (AMNH, 2015)

Another example is *Conserve @ Home* at the Boston Museum of Science in Massachusetts. This exhibition (Figure 7) frames energy use in terms of an average home. It

provides tips for staying within a home's energy budget to conserve money and natural resources. One part of this exhibition is "Turn Your Energy into Light," that lets visitors generate electricity by spinning a wheel. The electricity powers light bulbs of various efficiencies, physically demonstrating how much energy they require. Another part is "What's a Watt," that relates something invisible, electricity, to something tangible, water. This exhibition is designed to look like a backyard with an adjoining section of a home, creating a playful and relatable environment for learning important facts and skills for energy conservation. Visitors can interact with the various parts of this exhibition by using example environmentally friendly fixtures and practicing energy saving tips (MOS, n.d.).

Figure 7: *Conserve @ Home*, Left "Turn Your Energy into Light," Right "What is a Watt" (mos.org, n.d.)

The Burrator Discovery Centre features an interactive exhibition about the surrounding natural environment in southwestern England. The centerpiece of this exhibition consists of two large, natural tree trunks that are decorated with seasonal, interchangeable tags for visitors to investigate. Each tag displays a photo of a local species on the front and information about that species on the back. The exhibition includes interactive tree stump tables with handles that can be pulled to hear the sounds of local animals, as well as a rotary phone that visitors can use to select and listen to others' perspectives on the natural environment. In some areas, touch screens are used to convey additional information. According to Smith and Jones Design Consultants, who were responsible for the design of the exhibit:

> "It was essential the displays captured the quirky, mysterious personality of the surrounding areas...We created chunky, rustic hands on interactives, informative and impressive wall graphics, digital multi touch screens with various content about the heritage and environment," (Burrator Discovery Centre, n.d.).

Bringing the natural environment into the exhibition connects visitors with the topic by giving them a personalized view and allowing then to gain firsthand experience through action and

sound. The designers created an exhibition that would reflect the unique environment and compel visitors to learn.

A 2012 project at the Miami Science Museum in Florida closely studied an interactive climate change exhibition (Figure 8) that prominently features a large globe. Visitors operate nearby touch screens to control the display. They are able to choose the environmental topic that the globe shows, including options such as “Population Growth” and “Energy from the Sun,” (Yalowitz et al.). The designers created this exhibition with the intent of increasing visitor awareness about climate change while being accessible for English and Spanish language speakers.

Figure 8: The Exhibition at the Miami Museum of Science (Yalowitz et al., 2012)

IV. Design Process and Prototyping

Developing an interactive museum exhibition requires an extensive design process. This process is organized in a way that allows efficient progress and improvement towards a finished product through iterations of a design. An article produced by the Smithsonian Office of Policy and Analysis titled “Developing Interactive Exhibitions at the Smithsonian” lists the key points of interactive exhibition development (Pekarik, 2002). This information has three sections: designing, building, and testing and is supported by various other designers and institutions, described in further detail throughout this section.

A. Designing an Exhibition

Conceptualization of an exhibition is the first step of design. Exhibition designers must discuss the target audience and purpose of the exhibition to begin research. The museum then decides what content to highlight and the means of interaction. Exhibitions with multiple functions and interaction points enhance visitor engagement, but can increase costs (McElroy, 2016). Once the design of an exhibition has commenced, it is important to make sure there is interesting and informative content, which may involve synthesizing requirements laid out in museum documents and exhibition team meetings. One way of synthesizing content is the outlining method: organizing information in headings and bullet points. This versatile method involves noting topics, subtopics, and facts to demonstrate relationships between details (Oxford Learning, 2017). The design of the interactive must engage the users and be accessible for all audiences. The process involved in creating an exhibition is dynamic and evolves continuously to maximize the engagement level of visitors and the extent to which they interact.

The EcoTarium, a science and nature museum located in Worcester, Massachusetts, illustrates an iterative exhibition development process in Figure 9 (Loring, Nov 29, 2017). The methods displayed in this figure build upon the process laid out by the Smithsonian in further detail. In the initial stage, designers research the content that the exhibition focuses on and brainstorm interactives that portray the information intended to be gained from the exhibition (Loring, Dec 8, 2017). A practice from the EcoTarium is to reach out to scientists and researchers in the field to serve as content advisors for the exhibition design.

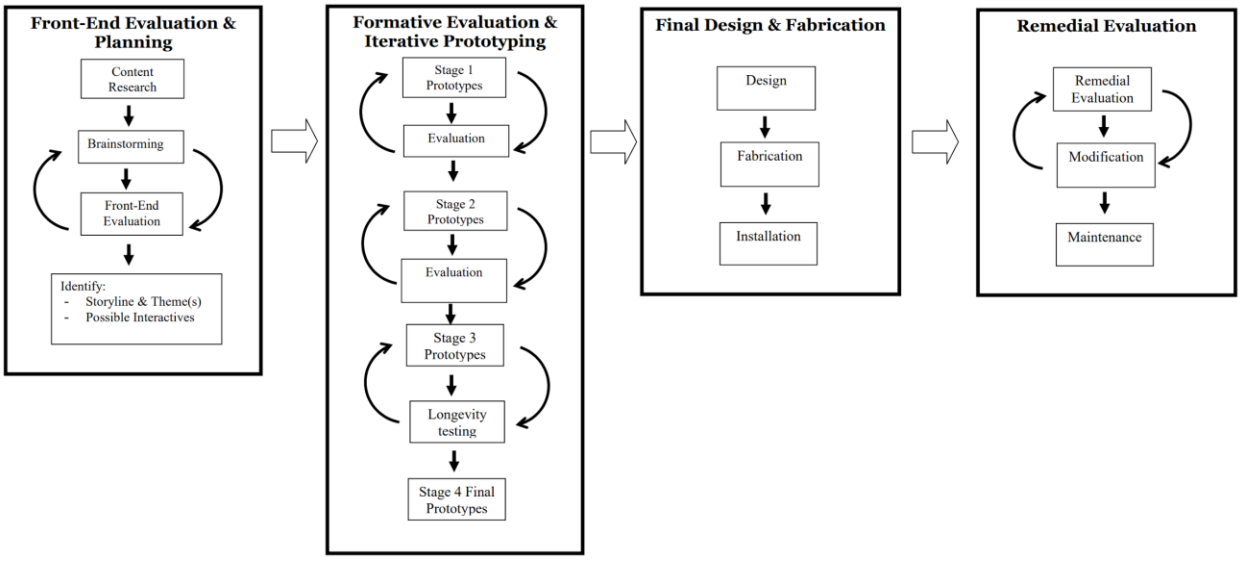


Figure 9: The Exhibition Development Process Created by the EcoTarium in Worcester, Massachusetts (Loring, Prototype Schematic, 2017)

The broad term brainstorming includes several techniques for concept generation. The early stages of forming an idea are very rough and answer many questions about what to focus on in designs. Some aspects that are meant to be identified in this process are themes of the exhibition and possible interactives (Loring, Nov 29, 2017). This part of the process is about learning and not meant to produce a final idea (Prototyping Dashboard, 2017). One brainstorming technique is the Crawford's Slip Writing Approach, in which design team members write ideas that they generate on slips of paper and then come together to share these concepts (MindTools, n.d.). This technique gives all team members a voice and highlights which concepts are more or less popular than others. It encourages team members to come up with unique ideas, showing a wide view of potential design solutions.

The early evaluation of concept development, which the EcoTarium refers to as front-end evaluation, consists of multiple meetings with staff, visitors, and other groups to gather feedback on possible themes and interactives. When this process is executed successfully, additional themes and interactives can emerge from these meetings (Loring, Nov 29, 2017).

B. Building a Prototype

Before creating a prototype, design teams use storyboards to outline the flow of the exhibition. Storyboarding is a quick method to help visualize a concept (DesignKit, n.d.). Storyboards are usually broad in scope and not intended for direct use with visitor, but meant for the design team to walk through the experience they are creating. This is meant to capture preliminary ideas, questions to ask when testing, and issues that may be addressed (Snyder, 2003). Storyboarding is an effective step prior to building and testing prototypes to aid the design team in gauging visitor experience.

Established designers agree that an effective method to assess the performance of a proposed design is to build and test a prototype (McElroy, 2016). A prototype's purpose is tangibly represent a concept. This can be most any representation of a design, from a drawing to a physical proof of concept. Iterative, feedback-based updates are integral to the design process (McElroy, 2016) & (Horvath, 2017). Rapid prototyping is an effective method for designers to make ideas tangible and to quickly get key feedback from potential design users (DesignKit, n.d.). This quick method of prototyping, receiving feedback, and integrating it into future designs is integral to exhibition development. Betsy Loring, the Director of Exhibits at the Worcester EcoTarium, advises to "fail early, fail often, fail cheap" (Loring, Nov 29, 2017). Screening many ideas for content and receiving feedback early is an efficient design process.

Paper prototyping is a widely used method for creating and testing a design using iterations of hand-sketched models. According to Snyder, paper prototyping is defined as:

> "A variation of usability testing where representative users perform realistic tasks by interacting with a paper version of the interface that is manipulated by a person 'playing computer,' who doesn't explain how the interface is intended to work" (Snyder, 2003).

This method is used to gain feedback from visitors and to update prototypes quickly, easily, and cheaply. According to Snyder, paper prototyping provides "maximum feedback for minimum effort" (Snyder, 2003). It requires few resources and allows for fast updates with each iteration. There are a few disadvantages of paper prototyping as well. The simple prototypes can cause confusion and may require explanation to use, and sizing may not be portrayed accurately (Snyder, 2003).

Once prototypes are fabricated, they are brought to the audience and evaluated. It is important to involve the audience early in order to receive feedback and make iterative improvements to a design (DesignKit, n.d.). One method of testing involves a design team member acting as a facilitator, working directly with the visitor to explain a prototype, and another member of the design team acting as an observer, taking notes on the interaction (Snyder, 2003). If the audience cannot understand a concept with the help of the facilitator, it is unlikely they will understand it on their own. The price of these prototypes is negligible and designs can be adjusted in seconds based on feedback, allowing them to be tested quickly. This makes paper an effective medium for preliminary prototyping (Horvath, 2017).

Computer modeling is a form of prototyping that is an appropriate second step for designs that show promise in paper prototyping. Computer generated designs take more time to create and modify than paper illustrations, but offer more advanced features. Once both of these prototyping methods have been completed, tangible prototypes become a sensible investment. Figure 10 shows three stages of development of the *Engineering in a River System* exhibition at the Boston Museum of Science in Massachusetts.

Figure 10: Paper Prototype → Computer Rendering → Final Exhibition on Display (MOS, 2017)

C. Testing Functionality

Testing prototypes is an essential element of the design process because it can identify whether a concept will be feasible and successful. Designers may regard testing as two distinct and important methods (McElroy, 2016). The first involves testing for function, which is more applicable to physical aspects of a machine. The other assesses concepts' appeal and ease of use for a target audience. During user interaction with the prototype, designers observe the user, looking for frustration, excitement, or bewilderment and ask them about the cause of this reaction. For interactive exhibitions, the minimum requirement for success is usability (Hall, 2014).

The Nielsen Norman Group, which specializes in evidence based user experience research, defines usability as five components: learnability, efficiency, memorability, errors, and satisfaction. Learnability is the user's ease of accomplishing a basic task the first time they encounter the design. Efficiency is the speed that the user can perform a task once they learn the design. Memorability is how easily the user can re-establish proficiency when returning to the design after a period of time without using it. Errors describe the obstacles the user faces, the severity of each obstacle, and how easily they can recover from such errors. Satisfaction is the level of pleasure gained from using the design (Nielsen, 2012). These five qualities refer to the general level of usability, gauged from a user's interaction with a design. Usability is important to ensure that a user has a positive experience with a design and that the design serves its purpose. At these early stages of testing a prototype, cheap tests should be performed first and expensive tests done later once the design has been refined (Hall, 2014). Cheap tests, such as proof of concept and paper prototyping, can reveal issues that lead to meaningful design updates, saving time and resources by reducing in depth testing administered at initial stages. Other aspects of the exhibition design include durability, updatability, low needs for maintenance, and ease of repair.

Design refinement depends on testing prototypes and subsequent feedback from users. Testing has three stages: identifying a focus group, observing, and receiving feedback (McElroy, 2016).

> "Testing with users is the process of getting someone as close to your ideal user...to interact with your prototype to test a specific assumption or to find any pain points, problems, or confusion within your proposed idea," (McElroy, 2016, Ch. 7).

Observing user interaction with prototypes will provide an idea of design functionality and testing with users will provide insights from the audience's perspective. Soliciting feedback on ideas

and prototypes is a core element of the design process. It is very helpful to keep the target audience at the center of the project, and allows for feedback to directly impact design development (DesignKit, n.d.). After testing the prototype with users, designers craft questions to supplement observations of users' reactions to aspects of a prototype. Testing with users provides both qualitative and quantitative data.

Establishing questions and feedback questions help designers understand user responses (McElroy, 2016). Establishing questions refer to those proposed to the user to determine their personality or views about certain subjects prior to testing. This includes asking visitors questions about their views on climate change or what they know about ice core research. Feedback questions elicit the user's thoughts, concerns, and expectations of the prototype. These questions will be asked after the interaction and will be along the lines of what the user liked and disliked about the prototype. This combination of information gives insight to the user's background and reveals any bias that could affect results. Additionally, it is helpful to know if the user has a meaningful experience.

It is necessary to seek feedback regarding updated designs. Users' views lead to iterative changes and improved functionality. The preliminary tests determine functionality of the design and whether users interact with the prototype as expected. It is important to gain honest feedback from a wide range of potential users to identify opportunities to improve a design (DesignKit, n.d.). Once the design team conducts testing, their expectations may change to reflect results. Designing is a dynamic and iterative process, therefore the purpose of testing may vary throughout the process based on changes made to the design. The results of the questions should reveal whether the user's interactions match designers' assumptions, and whether the prototype performs its purpose. Open-ended questions ask the visitor's impression rather than "yes" or "no" questions (McElroy, 2016). This format encourages the user to share more of their experience, ultimately providing more detail on the effectiveness of the design. It is important to avoid leading questions as they can influence the user's feedback. Erika Hall discusses the techniques of crafting and framing questions for testing designs in her book *Just Enough Research* (Hall, 2014). The responses from well-crafted questions can be used for improvement of designs and changes can be applied to subsequent prototypes as part of the development process.

D. Testing At Te Papa

One of Te Papa's methods of acquiring feedback is testing at local schools to gain perspectives from children. For example, designers traveled to Island Bay School to observe

children's interactions with two potential designs for *The Nest* exhibition. Testing continues as concepts are developed to optimize them. Te Papa also outsources professional peer reviews of exhibit concepts. Dave Bucy Associates (United States), The Natural History Museum of London (England), and Morris Hargreaves McIntyre (New Zealand, Australia, and England), have provided peer reviews for Te Papa's Natural History Renewal Project. These groups developed recommendations for the exhibition's concept and content, as well as specific feedback for aspects where the exhibit succeeds and aspects that could be improved (Natural Environment Exhibition Renewal, 2017).

Morris Hargreaves McIntyre is a research consultant that Te Papa works with regarding consumer focus and to understand audiences more deeply. "Culture Segments" is a standardized system used to classify different audiences and provide deep insight into understanding people's deep-seated values and beliefs (MHM, 2016). This system is separated into eight unique segments, enrichment, entertainment, expression, perspective stimulation, affirmation, release, and essence. As seen below in Figure 11, each distinct segment includes traits that are used to classify a visitor.

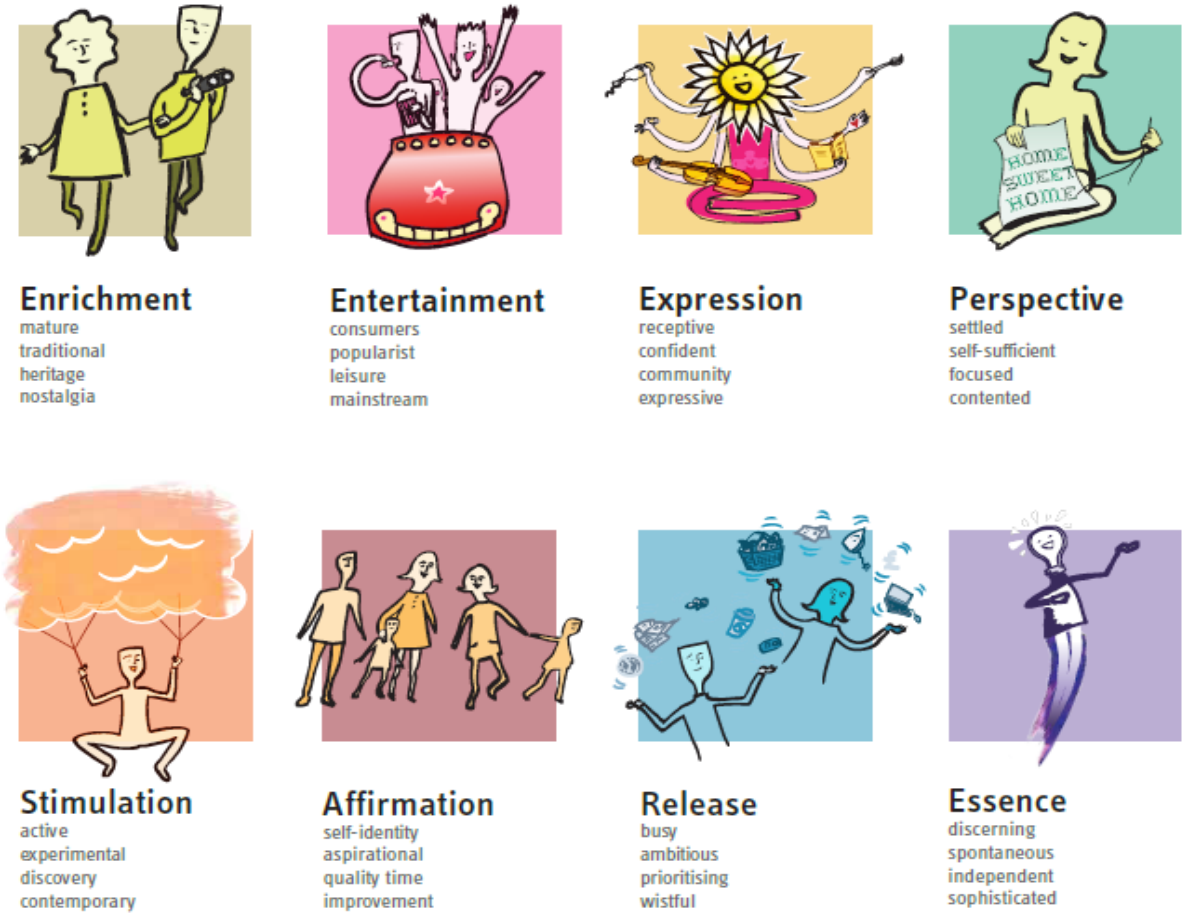


Figure 11: 8 Segments Within the Market for Arts, Culture, and Heritage (MHM, 2016)

Te Papa measures success in multiple ways. One of these includes summative evaluations, through observations and surveys, which provides qualitative data. The museum conducts follow up interviews with a sample of users a month after visiting their exhibitions. The museum uses visitor exit surveys to collect psychographic and demographic information and assesses satisfaction and learning. These design techniques have resulted in years of successful exhibitions at Te Papa.

V. The Te Papa Museum

The Museum of New Zealand Te Papa Tongarewa, New Zealand's flagship national museum, recognizes the urgency of climate change. Te Papa was founded as the Colonial Museum and was centered on geological information. This started the museum's historical reputation of connecting weather and climate (Newell et al., 2016). In 1992, the government passed legislation encouraging the museum to include Māori culture and history in their exhibitions. This change reflected efforts to give Māori people equal representation throughout the country, and let the museum appeal to a more diverse population (Museum of New Zealand Te Papa Tongarewa, 2017).

Despite the progressive nature of Te Papa and New Zealand, there is currently little information displayed on climate change and its effects. In 2016, 71 words on the issue of climate change were exhibited in the museum (Newell et al., 2016). Weather-related exhibitions, such as the *Wahine Disaster* at the Wellington Museum of City and Sea, have proven effective and emotional for visitors (Newell et al., 2016). This exhibition describes the devastating effects of a tropical cyclone that sank an inter-island ferry in Wellington Harbor. Although the focus of this exhibition is tragic, contour maps show signs of wear—an indication that visitors are moved to physically connect with the exhibit. In response to this and the age of the natural history section, the museum is reworking many of its exhibitions to include more information on climate change.

A. The Natural History Renewal Project

In the next sixteen months, as part of their Natural History Renewal project, Te Papa hopes to combine existing exhibitions to create a new interactive space that highlights New Zealand's unique environment and sheds light on the associated environmental crisis. The new exhibition will be separated into nine zones: four that describe the natural landscape and five that explore environmental issues. Central to this renewal is zone eight (Figure 12), the climate

change exhibition, which will incorporate multiple interactive machines. One of these interactives features ice cores and the records of past climates they preserve. The other interactive features carbon emissions and their role in climate change. In April 2018, the old natural history exhibition will close for construction of the new exhibitions. Both interactive concepts should be complete by this time (Peterson, 2017).

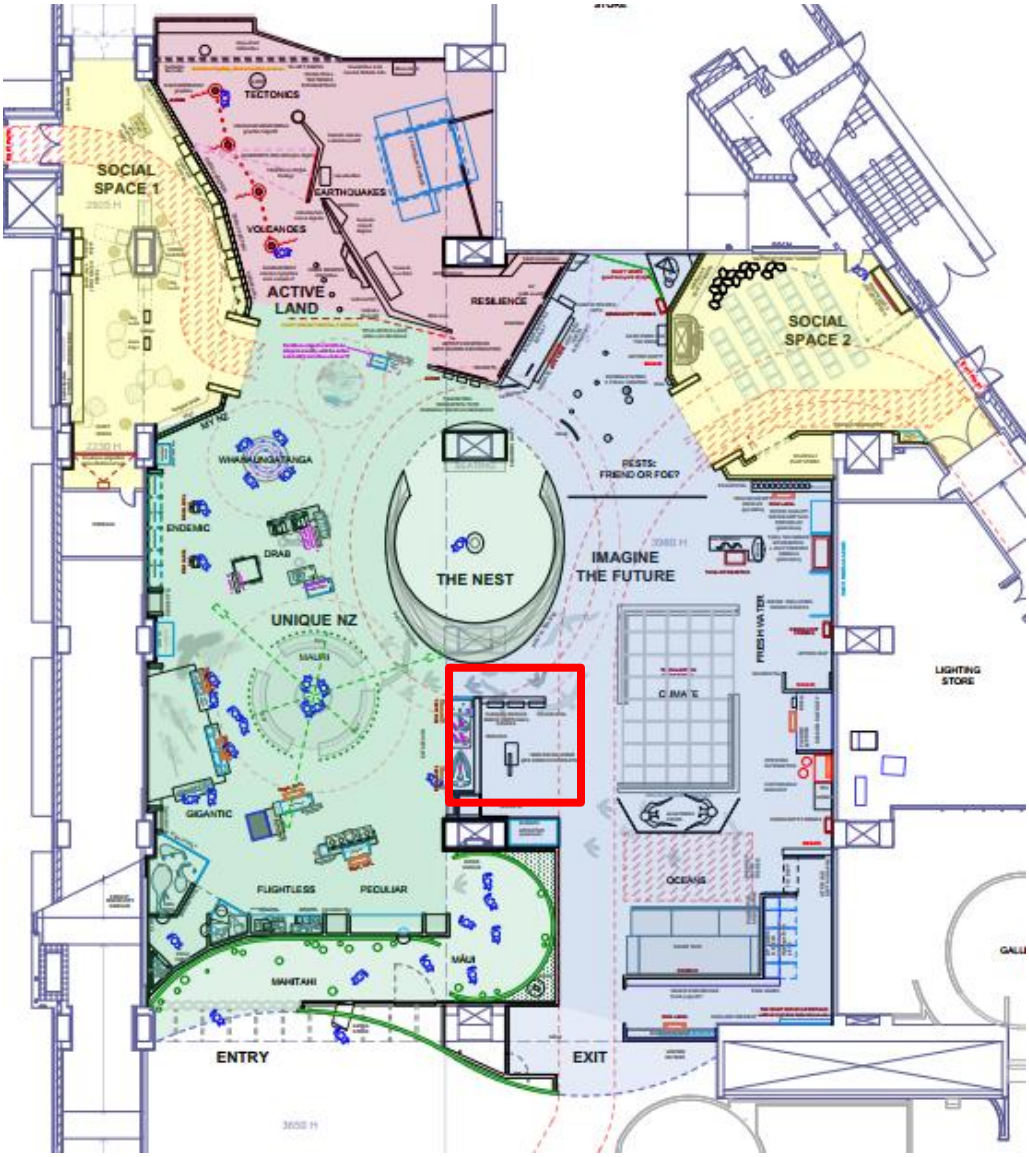


Figure 12: Exhibition Layout for the Natural History Renewal Project at the Museum of New Zealand Te Papa Tongarewa. The Ice core and CO_2 Interactives are Marked with a Red Box in the Figure (Natural Environment Exhibition Renewal, 2017).

Chapter 3: Overview of Methodology

The purpose of this project was to aid the Museum of New Zealand Te Papa Tongarewa in communicating to its visitors the importance of ice core research as evidence for climate change by designing, prototyping, and testing an interactive component to appeal to diverse audiences.

To achieve this goal, our team identified the following objectives, illustrated in (Figure 13):

I. Assess Te Papa's progress on the renewal project and understand pertinent information to inform our exhibition design.
II. Develop designs for an interactive component of an ice core exhibition based on our background research and Te Papa's specifications.
III. Perform iterative prototyping to evaluate and improve the functionality and visitor experience of each proposed design.

Our team developed an ice core interactive through three sequential objectives. We completed site assessment first to understand the context and parameters necessary to design the exhibition. We developed ideas based on site assessment results and produced an exhibition design to prototype and test. We prototyped and tested the design in two iterations that provided final results and yielded our principal recommendations to Te Papa. Figure 13 shows our process and emphasizes that each task completed during each objective phase produced specific results that led to the next step of the process. Chapters 4, 5, and 6 present the methodology, results, analysis, and discussion of each objective independently to reflect our process.

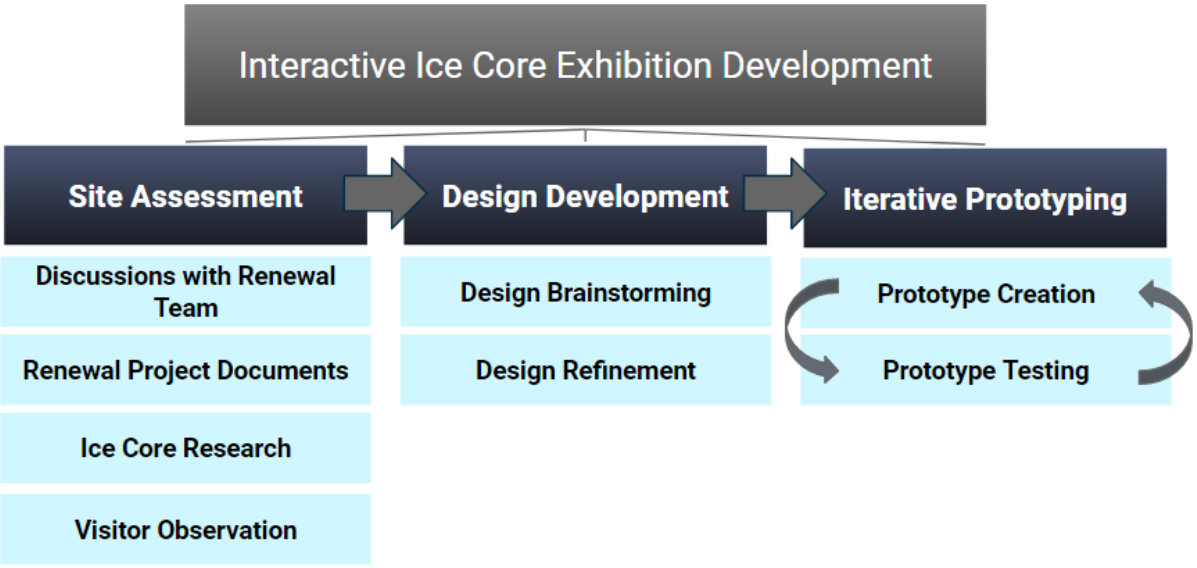
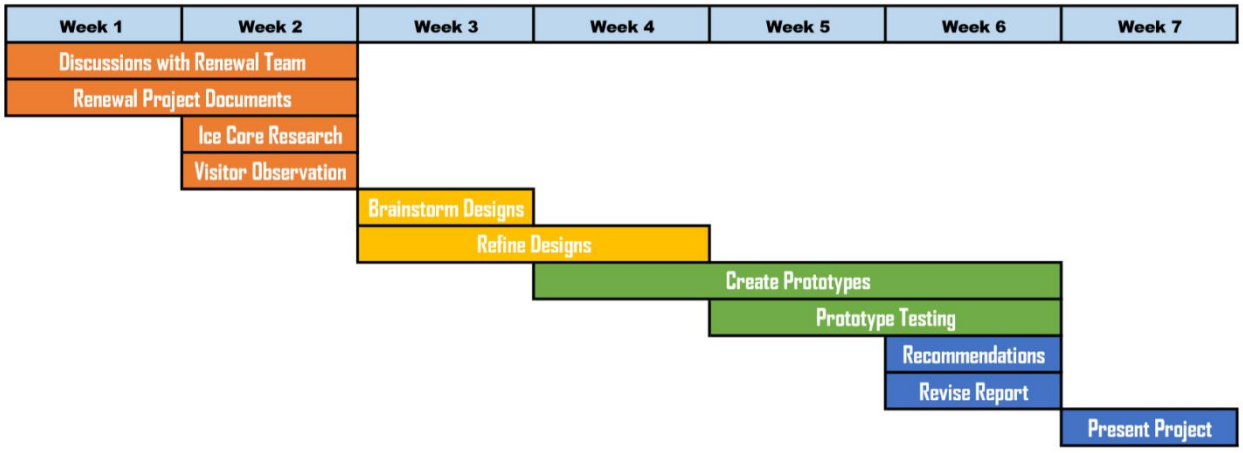


Figure 13: A Flowchart of the Methods We Executed on Site

We proposed a timeline to accomplish these tasks, which is outlined in Table 2. The tasks are color coded to group them by objective and show the steps in the development process.

Table 2: Gantt Chart of Project Timeline



Chapter 4: Objective I - Site Assessment

The purpose of this objective was to understand the museum's parameters for the ice core interactive, the current stage of the renewal project, necessary information concerning ice core research, and visitor interactions with exhibitions at Te Papa.

Methodology for Objective I

Site assessment methods included discussing design criteria with the renewal team, reviewing documents concerning the renewal project, touring an ice core facility, and observing museum visitors. We used the outlining method to record and organize notes from meetings and documents using headings and bullet points to identify themes and details. We analyzed our qualitative data using thematic content analysis. This involved coding data, searching for broad patterns and trends, and categorizing or naming the themes that emerged.

A. Discussions with Renewal Team

Our group organized round-table discussions with renewal team members to understand their vision for the new exhibition and parameters for the ice core interactive. Through these meetings, we sought to clarify our team's role in relation to the renewal team as well as the goals and intended messages to be communicated to visitors in the new exhibition.

B. Renewal Project Documents

We reviewed documents on Te Papa's internal database to further our understanding of the exhibition goals and recommendations. We focused on documents pertinent to our project such as the interpretive framework, visitor demographic target distributions, graphic models, logistic requirements, hosts' observations of visitor interactions, and recommendations for successful exhibition features.

C. Ice Core Research

Our team organized a meeting with Dr. Nancy Bertler, Leader of the National Ice Core Research program at the Joint Antarctic Research Institute, at the New Zealand Ice Core Research Facility to better understand ice core research. Dr. Bertler presented the process of Antarctic ice core site selection, collection, and analysis. We toured a freezer where the ice samples are preserved and studied to experience the conditions of the laboratory and to

examine an ice core. We sought insight into ice core research and to inform the development of our interactive designs with this knowledge.

D. Visitor Observation

We observed the engagement levels of visitors with the current exhibitions at Te Papa in preparation for the design phase of our project. Our team used naturalistic observation, a research method to observe visitors without communication to understand the way visitors interacted with the exhibitions. From the thematic content analysis of our observations, we drafted a list of general observational notes and a list of general guidelines for the design phase of our interactive.

Results for Objective I

We assessed the renewal team's progress towards the new exhibition, with a focus on the ice core interactive, which informed our design development. Primary results included outlined notes from meetings with renewal team members, museum documents, the ice core research facility, and visitor observations.

A. Discussions with Renewal Team

The round table discussions that we organized with members of the renewal team were integral to our site assessment because we made connections that were necessary to involve the renewal team in our project. The names and titles of the team members with whom we worked are shown in Table 3.

Table 3: Members of Renewal Team

Nick Clarkson	Graphic Designer
Jen Craddock	Lead Exhibition Experience Developer
Raewyn Cummings	Programme Manager Exhibitions
Chloe Johnston	Experience Designer
Clayton McGregor	Contract Exhibition Designer
Leon Perrie	Curator Botany
Dean Peterson	Associate Director Collections, Research and Learning
Ralph Upton	Exhibition Content Writer

Our initial meeting with the renewal team on January 17th included Leon Perrie, Ralph Upton, Clayton McGregor, and Jen Craddock. In this round table discussion we learned about the exhibition design progress and renewal team members' perspectives on the project. They explained that the narrative of the Natural History Renewal Project covered three main ideas:

1. New Zealand is unique and wonderful
2. The environment is under threat
3. Actions can be taken to mitigate these threats

We discovered that the ice core exhibition would accompany an adjacent carbon emissions exhibition to comprise a larger climate change section of the whole renewal project. The ice core exhibition fell primarily under the second main idea, 'the environment is under threat', while the carbon emissions exhibition would reinforce this idea and introduce concepts in the third main idea, 'actions can be taken to mitigate these threats'. We learned the ice core exhibition should demonstrate that scientists have learned about changes in the environment by studying ice cores and that the exhibition should include a timeline to show changes in atmospheric concentration of carbon dioxide over time.

The renewal team recommended that our team focus on designing the interactive within the ice core exhibition because it would be the most beneficial contribution to the renewal project based on our project length and the resources available. We found that this interactive should appeal to a cross-generational audience and inspire "positivity through physicality." It should include updatable facts and aim to remain relevant for 15 years. Designers had formed some preliminary concepts described in the museum documents, but were open to completely new ideas. They encouraged us to be creative and ask questions as needed throughout the design process. A sample of the outlined notes from this initial meeting are shown here:

- Our design must last long term
    - 10 years is the planned duration but it will probably be 15 years
    - Must remain relevant as well as functional
    - [Information] must be updatable
- 3 ideas [to the renewal project]
    1. New Zealand is unique and wonderful
    2. It is under threat
    3. You can do things to help
- The Nest exhibition is the turning point between points 1 and 2
- Should promote positive action and expression
- [Should evoke] emotion → feeling of positivity through physicality
- Inspiring storytelling will help visitors connect [to the information]
- [Main idea] an ice core is a timeline
- [Ice cores are used to] project [climate change information] to future
- [Target] audience → cross-generational

    - Have fun while learning
- Exhibition should not be isolated
    - Must integrate into rest of the renewal project

Our team met with Raewyn Cummings and Chloe Johnston on January 19th to discuss additional details and project logistics. Raewyn Cummings advised that the final design for our interactive should cost less than $10,000 NZD and should fit into the allotted space outlined in the renewal project floor plan. Chloe Johnston was knowledgeable about the design process and encouraged our team to think creatively and not focus on the budget while brainstorming. Some of the outlined notes from this meeting are shown here:

- Hosts are a good resource [for visitor interactions]
  [Hosts are museum staff who give tours and have extensive knowledge of exhibition content and visitor behavior]
- Do not focus on budget parameter until designs are being refined
    - Should keep [ice core interactive] around $10,000
    - There is some room for changing that number depending on design
- [In exhibition design] more can be less
- Keep footprint of exhibition keep in mind
- Can set up visitor testing in Nature Space [in *Mountains to Sea* exhibition]
    - Arrange with Chloe Johnston
- Message to keep in mind: people are sick of hearing about climate change
    - Ice cores provide a unique insight into climate change
- Our facilitator/observer method [for visitor testing] is good
    - Practice with each other first [before testing with visitors]

B. Renewal Project Documents

The renewal team sent our team documents about all aspects of the renewal project. One of these documents, the 'Natural Environment Exhibition Renewal 90% Concept Design Document,' contained an overview of Te Papa's progress on the renewal project. This document included details of the exhibition's target audience, shown in Figure 14.

Priority culture segments:

- **Expression (Creative Communicators)** – seek fun, social, hands-on, immersive experiences, 32% of Te Papa's culture market
- **Stimulation (Experience Seekers)** – seek cutting-edge, fun, social, challenging/risky experience, 17% of Te Papa's culture market
- **Affirmation (Quality Timers)** – seek fun self-development and learning ('edutainment'), 12% of Te Papa's culture market (often young families)

Other priority social groups:

- **Children and families** – seek collaborative, hands-on discovery and learning, easy planning and access, and reasons to return

- **Young Māori** – seek experiences showcasing Māori people, perspectives, taonga, stories, reo
- **Educators and learners** – seek authentic objects and immersive, social, hands-on, inquiry-based opportunities, links to the NZ curriculum, easy planning and access, places to gather
- **Nature lovers**

Figure 14: Target Audiences Excerpt from 'Natural Environment Exhibition Renewal 90% Concept Design Document' (Frith Williams, pg. 10, 2017).

The targeted culture segments were based on Morris Hargreaves McIntyre's model of culture segments displayed in Figure 11 of Chapter 2, Section V. In the same document, our team found the three major content ideas for the renewal project. This information is shown in Figure 15.

Level 1 – Big Ideas

1. **TAONGA/UNIQUENESS** – Aotearoa New Zealand's natural environment is a taonga – unique, diverse, and central to our culture and survival.
2. **TOKOTOKO RANGI/THREAT** – Our environment faces serious threats (and, through natural hazards, poses threats to us).
3. **KAITIAKITANGA/ACTION** – Our future depends on the action we all take now to protect the environment.

Figure 15: Big Ideas Excerpt from 'Natural Environment Exhibition Renewal 90% Concept Design Document' (Frith Williams, pg. 11, 2017).

The '90% Concept Design Document' defined common types of exhibition features. The ice core exhibition most prominently features a hands-on interactive and incorporates an audio-visual space, sharing space, and interactive graph. These aspects are described below in Figure 16.

HANDS-ON INTERACTIVES AND GAMES
PHYSICAL, SOCIAL, SCIENTIFIC METHOD
Physical or digital activities/games that invite play and support embodied learning around key concepts, often involving collaboration.

AV STORIES: FIRST-HAND ACCOUNTS & EVERYDAY ENVIRONMENTAL HEROES
REAL, DIVERSE, UPDATEABLE, NETWORKED, SCIENTIFIC METHOD, BICULTURAL
Short, moving videos of New Zealanders telling their stories of connection – and loss – in relation to the environment. Also videos showcasing innovative conservation success stories from communities around the country, among them initiatives based on mātauranga, with some featuring young people (including girls) – real people making a difference. To be updated yearly.

SHARING AND DEBATE SPACES
REAL, SOCIAL, DIVERSE, UPDATEABLE

Regularly changing spaces where visitors are invited to share and compare their views/stories related to the environment, and debate solutions connected to the latest issues around pests, fresh water, oceans, and climate change. To be updated every 6 months.

STATUS/ACTION MAPS
REAL, UPDATEABLE, NETWORKED, SCIENTIFIC METHOD
Interactive maps that allow visitors to discover the status of the environment where they live in New Zealand (eg, hazard risk, pest problems, water quality, climate change risk), and – in some cases – browse related conservation or citizen-science projects nearby. To be updated as necessary.

Figure 16: Exhibition Features Excerpt from 'Natural Environment Exhibition Renewal 90% Concept Design Document' (Frith Williams, pg. 30-31, 2017).

The '90% Concept Design Document' outlined elements that the renewal team wanted to highlight in the climate change section of the new exhibition. Because the ice core interactive was located in the climate change section of the renewal project, these elements, shown in Figure 17, applied to the ice core interactive.

SCIENTIFIC METHOD: Reflect the scientific method in presenting content, particularly the process of observation and hypothesis (eg, via question-based text prompts and playful activities that require interaction and prediction, rather than didactic information delivery).

SOCIAL: Support cross-generational exploration, collaboration, and discussion among families and friends.

PHYSICAL & PLAYFUL: Convey concepts in hands-on, sensory, interactive ways – because physicality supports memorability (embodied learning). As much as possible, embed digital media within the physical environment to avoid an overly screen-based experience.

Figure 17: Highlighted Elements Excerpt from 'Natural Environment Exhibition Renewal 90% Concept Design Document' (Frith Williams, pg. 27, 2017).

Each exhibition section is designed with three aspects in mind, referred to by the renewal team as "Do, Think, Feel" goals. The "Do" explains how visitors will engage with the exhibition, such as watching a video or viewing an artifact. The "Think" aspect describes the thoughts the visitor may have while experiencing the exhibition. The "Feel" aspect is the effect of the exhibition on the visitor's emotions and how they react to the presented information. Some exhibitions, such as the carbon emissions exhibition, have a "Do Next" aspect that describes what the visitor could be inspired to do with the new information upon leaving the museum.

Our team reviewed the document 'Ice Core Experience Outline'. This document included the "Do, Think, Feel, and Do Next" goals that were specific to the ice core interactive, as well as goals for the interactive experience. These are shown below in Figure 18.

Ice Core Experience

Do:

'Extract' and examine a model ice core

Watch video of climate scientists in action in Antarctica

Think:

1. Climate change predictions are based on scientific observation. These observations are how we know that what's happening in our atmosphere is not normal.
2. Ice cores are time capsules. Their trapped C02 bubbles tell us what the climate was like in the past.
3. New Zealanders are at the forefront of climate change research.

Feel:

Sense of discovery and adventure. Intrigued at how we can look at the past. Proud of the work our scientists do.

Do next:

Be inspired to be part of scientific research in future – particularly students.

Figure 18: Experience Excerpt from 'Ice Core Experience Outline' Document (Ralph Upton, pg. 1, 2018).

The 'Ice Core Experience Outline' laid out a preliminary direction for the ice core interactive experience. This description included a key question and three examples of exhibition elements, detailed in Figure 19.

Key question for experts: Which 50-60 centimeter of ice core from Antarctica would give us the greatest insight into:

a) what we can find out from ice cores and
b) the length of time it has been since we had the current level of greenhouse gases in the atmosphere?

Direction for experience:

Three elements:

1. Ice core model that you can lift from the table to align with the graphic and interpretation. Accompanied by headset where you can listen in to a scientist talking you through it.
2. Graphic showing what kind of information you get from dust, ash, and gas in ice cores, illustrating the depths the cores can drill to (up to 3km) and the timeframe they illuminate (up to 800,000 years). Additionally, we could show the temperature fluctuations over that time, and where the physical core model fits into this story (it will be a tiny point in a long history)
3. Video of scientists at work on ice cores, showing the 'real thing'. Visitors can listen in, perhaps via a handset.

Figure 19: Key Question Excerpt from 'Ice Core Experience Outline' Document (Ralph Upton, pg. 1, 2018).

We used the document 'Climate Change, Timeline and Causes, Goals and Notes' which focused on a timeline in the ice core exhibition. The timeline would help communicate the link between ice core research and climate change. The "Do, Think, Feel" goals for this timeline are shown in Figure 20.

Climate Change and Causes

Do:

Discover the 'human induced' aspect of CC - in two surprising, engaging ways.

1. Follow a humorous timeline showing that human-induced cc is real.
2. Explore the different possible causes of CC and find out what's really warming the world

Think:

Climate change is happening, and humans are causing it.

Feel:

Confident in understanding the big picture.

Timeline:

The purpose of this is to show that the earth's climate has remained relatively stable over the past 22,000 years (the peak of the last glacial period), and the current warming period is very much out of the ordinary. It also illustrates that humans have thrived in period of stable climate….To do this, we'll need to ask our experts for relevant details about how what was happening in (mostly pre-human) Aotearoa during that period.

Figure 20: Climate and Timeline Excerpt from 'Climate Change, Timeline and Causes Goals and Notes' Document (Ralph Upton, pg. 1, 2017).

The document 'National Visitor Study Results' summarized the results of a visitor study on the initial concepts of the renewal project. From this document, our team gained information on visitor reactions to the original concepts of the climate change section of the new exhibition. This study consisted of a series of workshops in which facilitators from the renewal team asked participants questions about particular topics and concepts relevant to the new exhibition design. The facilitators performed the study throughout New Zealand with several demographic groups including new immigrants, 55+ year olds, Maori (age 17-30), millennials, and parents. The results of this study were summarized and compiled into a list of recommendations based on the topic of discussion. The recommendations for the climate change portion of the new exhibition are outlined in Figure 21.

3.12 Recommendation: Climate Change – One of the strongest messages for Te Papa from these workshops is the tone and angle of discussing climate change. In the words of the millennials: Make people feel "you can be the change' not constant 'you are destroying it!' The majority of workshops stated that climate change should be 'within the Te Papa exhibition.' However, the notion of what constitutes an exhibition was extended by some participants to include debates and forums. The majority of workshops accepted that human induced climate change was a reality. Common effects of; rising temperatures, rising sea levels, more extreme weather, and changing/damaged ecosystems were widely discussed.

Figure 21: Climate Change Recommendations Excerpt from 'Te Papa Tongarewa Museum of New Zealand Natural History Renewal Project, National Visitor Study Results, 24 November 2016' Document (NEILANDERSON.COM, pg. 8-9, Nov. 2016).

Our team reviewed a document summarizing a series of interviews with museum hosts, staff who give tours and have extensive knowledge of exhibition content and visitor behavior. The museum conducted these interviews to understand visitor behavior and engagement with current exhibitions. An excerpt from the 'Host Interviews Summary' is shown in Figure 22.

Drivers for engagement
This section summarizes what hosts told us visitors find most engaging within the Natural History exhibitions, in terms of experiences, content and tone. It also highlights museum-wide visitor needs.

Type of experience

- Social experiences shared with family members ('Anything social') - Shared family experiences that enable parents to be teachers too are popular. Interactives that prompt conversation and enable group participation are enjoyed by families. A 'most memorable moment' for Hosts included intergenerational conversations (provoked by an object or interactive) where families engaged in excited dialogue.
- Hands-on, tactile, interactives with high pay off ('People like touching things, touching is cool and should be encouraged.') - In AF, the magnitude jumping game, lifting the rocks and earthquake house are popular and have the most engagement – 'families want to do things'. Payoff for interacting is key. In AF, 'crack the earth has a disappointing result, lots of work for lame outcome'. Kids will run to the top of the ramp in MTS but there's nothing to do when they get to the end.

Content

- One clear message with a direct hook ('The moving blocks and map [in Awesome Forces] showing how plates move looks old and it's confusing because it's two stories combined.') - The water section in AF is unclear because there are too many layers of information. People often complain that labels are hard to read because the font size is generally too small. Hosts comment that there are great stories in the current exhibition but we could be telling them better. 'It's not about the number of objects, but what we do with them'. Interpretation for different levels of knowledge was important too. Transition spaces that signal you are entering a different story or space are effective to guide visitors through exhibition zones, e.g. the video presentation of the creation story works because it's isolated.

Figure 22: Drivers for Engagement Excerpt from 'Host Interviews Summary' Document (Natural History Renewal Team, pg. 2, May-July 2016).

C. Ice Core Research

We met Dr. Bertler at the New Zealand Ice Core Research Facility where she conducts research on ice core samples from Antarctica. Our team, along with two members of the renewal team, visited the facility to better understand the study of ice cores. Dr. Bertler presented a slideshow with background information about her team's work in Antarctica and explained the processes of selecting a drilling site, drilling, analyzing, and archiving the ice cores. This presentation supplemented our background knowledge and revealed some important themes. A sample of our outlined notes are shown here.

- “There is no such thing as a perfect ice core”
    - Usually several are cross referenced to get quality data
    - Sometimes sections are affected by ice sheet movements
- Ice core research is needed because meteorological, terrestrial, and satellite observations do not go back [in time] far enough
    - Terrestrial weather records only go back 30-200 years
    - Satellites only go back to about 1970
- Details of the RICE, (Roosevelt Island Climate Evolution) project:
    - 9-nation collaboration led by New Zealand
    - The ice core was recovered from Roosevelt Island
    - Ice core is usually 10 centimeters (4 inches) in diameter
    - This core was drilled to [the depth of the] bedrock which was at 764 m
    - Drilled in 2m sections and was cut into 1 m cores for transportation
- Ice cores in Antarctica and Greenland are used to compare climate in both hemispheres and improved our understanding of how the hemispheres “communicate” with each other via the atmosphere and ocean
- Scientists use tents to shelter [ice core] drill site
- Future drill sites may be cut into the ice to create a shelter that does not need to be taken down when [scientists] leave
- Have to cool the ice [core samples] to -26 C during storage and transportation
- Ice between 500-1000 m depth comes out brittle and needs to rest [to adjust to atmospheric conditions]
- Continuous flow [tests on ice core samples] - take continuous measurements as the ice melts [can reveal information about:]
    - Water isotopes
    - Methane
    - Black carbon
    - Dust particles
    - pH
    - Calcium
    - Conductivity
- Discrete samples - pieces of the drilled core are tested directly
    - 100,000 vials needed to be cleaned!!
    - Geochemical
    - Discrete gas
    - 7 visible volcanic ashes
    - Dust prevalence
    - Physical properties
    - Biological samples
    - Geophysical (radar/GPS)
    - Borehole measurements
- Core is split into multiple parts and the different parts are analyzed for different properties
- 98 mm diameter
- Use every drop [of ice core samples], there is never enough ice to go around [between countries and scientists]
    - This requires negotiation between countries about who gets ice
- Part of the [ice] core is archived for future [testing], [these cores are] very precious
- Some tests are destructive [to the ice cores] and some aren’t
    - Conductivity and optical are not destructive
    - Use lasers to evaporate ice and measure evaporat[ing vapor]

    - Vapor tests use a very small amount of [the ice core] sample
    - Discrete tests destroy the sample and are done all at once
- Layers [in the ice samples] that are older are thinner as [the ice's] density changes and layers get compressed
- Choosing the drill site is ⅓ of the whole project
- Ice flows and moves, not always where it started
    - Best drill sites are on ice divides – i.e. the ice accumulated there and flows away into all directions from this location
- In general, there is less snow during winter and ice ages
    - Less water vapor in the air because colder temperatures

After Dr. Bertler's presentation, she led us on a tour of the freezer where the facility stores the ice cores at 26-30ºC below zero. She showed us the laboratory and an ice core that was approximately 2,000 years old. The core looked plain at first and ice layers were not visible to the naked eye. Dr. Bertler explained that illuminating the ice core with light reveals the layers and bubbles. She explained that scientists use both discrete sampling and continuous flow tests to retrieve information from the ancient ice. Discrete sampling involves using regular samples of ice cores to measure ice layers, volcanic ash samples, and physical properties. Continuous flow tests destroy the sample to produce data including the atmospheric composition of the air bubbles and isotopic ratios in the water. Two photos from the tour are shown in Figure 23 and Figure 24.

Figure 23: Dr. Bertler Presenting a 2,000 Year Old Ice Core from Antarctica

Figure 24: The New Zealand Ice Core Research Facility Refrigerated Laboratory

D. Visitor Observation

Our team gathered preliminary data by exploring the museum individually to evaluate how visitors interacted with current exhibitions. We observed visitor engagement with interactives and took notes on our findings. A sample of our observations for specific interactive exhibitions from the museum floor are shown here:

- Quake ratings (Stomp on a pressure plate to see how large of an earthquake it registers)
    - Most visitors that walked into the exhibit and tried it - kids, teens, adults, elders
    - Jumping could be a group experience
    - [The interactive] sometimes [became] a competition to see who could make it read the highest
        - Not competitive if it was too easy [for visitors]
        - People were disappointed and would not retry if [their interaction] was anticlimactic
    - Some of them tapped [the interactive] lightly to see what the effects were of a light stomp
- Quake safe (Touchscreen game to stop house from getting destroyed in earthquake)
    - A lot of people spent a lot of time here
    - [Interactive] seemed to interest [visitors] - maybe because it relates to everyday living?
    - People watched and gave advice [to each other,] making it a group activity
    - Two people could play at the same time

    - ['Winning' the game] was difficult so people retried to improve their score
    - Words "game" and "play" attracted people's attention [to the display]
- Gallipoli (Large World War I exhibition with many varied components)
    - Table [display of war progression] drew in a lot of people at once
    - Path on the ground gave visitors direction
    - Touch screens seemed popular, more interesting than just reading a plaque
    - Kids shared observations with their parents
    - Family members shared personal connections [to information in the exhibition]
    - People seemed to find creative places to put the poppy reflection cards, placing them on parts of the exhibit where they don't belong
    - Morse Code Interactive was a cool concept that added another level [of interaction] to the experience
- Time Traveler (Spin wheel to go back in time)
    - Handle [located] at child height
    - Middle aged/young adults drawn by content on clock
        - Did not always spin crank
    - Children liked spinning crank
    - Some kids turned the crank to get the needle on a specific animal
        - Focused on the animals rather than the time period and the relationship between periods
- Surveying Scope (for measuring land movement)
    - Children ran upstairs to look through scope without reading directions [on plaque]
    - Adults usually read the instructions first
    - Parents sometimes explained the process of land surveying and its purpose to their children
- Grinding on (NZ changes over million years)
    - Kids were just pushing the lever back and forth as fast as they could
    - Lever caused movement which grabbed attention and was the main focus
    - Worked 'both ways'
        - Visitors could read first and then push lever or push lever first and then read the info
    - Time scale on the left side was sometimes overlooked
    - It was hard to push the lever to the right and some people struggled/gave up
    - Several teens and young adults were interested in the content and pushing the lever
- It's got to give (pumping the lever to see the earth split)
    - Kids were interested and pumped [the lever] quickly
    - Some kids could not get [the earth to split] and some did
        - became a competition because all of them wanted to when they saw it could be done
    - Young adults, teens, and elderly tended to give up after a few strokes because there was a lot of cranking involved
    - People give up and leave if nothing happens [after a short period of time]
- Passport
    - Linear timelines were easy to follow
    - People told each other about things they learned
    - Mixing room has more serious theme and people seem respectful and quiet
    - Interactives in mixing room were not intuitive
        - No one used [the interactive] as intended and this made it less user friendly
    - Language barrel is cool

        - [Display] looks unassuming but seems to draw people. Gives some info and lets people figure out their own conclusions
    - Lots of younger people and fewer families in pop culture section
- Lifting Rocks
    - Many people liked the physical exertion
    - Challenging - people showed off [to each other]
    - Spotlight in dark area draws people to rocks quickly
        - White writing reflects spotlight and makes the writing very obvious
    - One hand interaction could be good
        - People carrying things would skip lifting and also reading the content
- Touch screen by rocks
    - Needs constant interaction to keep people entertained
        - Pressing one button to get a 30 second animation bored people
    - Older visitors were not as interested in screens as much as younger visitors

Analysis for Objective I

Our site assessment produced qualitative data and we used thematic content analysis on this information. We coded the data from each section of results and identified important themes. We categorized themes that were similar and named them. We reviewed our results to verify that they accurately reflected the data that we collected.

A. Discussions with Renewal Team

We coded our outlined notes from round table discussions with the renewal team to determine the relevant themes for our exhibition design. The themes that recurred most in coding were:

- Exhibition as a narrative - New Zealand is unique and wonderful, the environment is under threat, and actions can be taken to mitigate these threats.
- Recommendation to focus on ice core interactive - The needs of the renewal team and our available resources indicate that we should focus on the development of the ice core interactive.
- Appropriate amount of content - Trying to fit too much information in an exhibition makes it overwhelming and counterproductive.
- Project logistics - Our design is limited by budget, floor space, and the time of this project.
- Exhibition lifetime - Exhibition should remain functional and relevant for 15 years.

We reviewed the data to search for themes that were not highlighted by coding and found that creativity would be important for our team. This would allow our team to design an

exhibition that is unique, exciting, and effective. We also found that the surrounding exhibitions and features would support the ice core interactive so their functions became important context for our design process.

B. Renewal Project Documents

We coded our outlined notes from reviewing renewal project documents to determine the relevant themes for our exhibition design. The themes that recurred most in coding were:

- Target audience - Documents referenced the targeted demographics, culture segments, and priority social groups of the renewal project.
- “Do, think, feel” - Use visitor experience and content goals specific to the ice core interactive to design based on content.
- Exhibition as a narrative of three main ideas - New Zealand is unique and wonderful, the environment is under threat, and actions can be taken to mitigate these threats.
- Ice core specifications - Numerous details, such as budget, size, and content, will influence our designs.
- Context of interactive - The ice core interactive fits with a larger exhibition and must be consistent with the overarching goals of the entire renewal project.

We reviewed the data to search for patterns that were not highlighted by coding and found several additional themes. This interactive would focus on the “threat” of climate change and would let surrounding exhibitions in the renewal project communicate the “uniqueness” and “action” themes. We also found that a timeline displaying carbon dioxide levels over time would be an important part of the ice core exhibition.

C. Ice Core Research

We coded our outlined notes from Dr. Bertler’s tour of the ice core facility to determine the relevant themes for our exhibition design. The themes that recurred most in coding are shown below:

- International cooperation - Drilling for ice cores is expensive, the conditions are extreme, and the data is important, so international collaboration is common.
- There is no such thing as a perfect ice core - Ice cores do not have all the data scientists would like and contain so ice cores from several locations are cross referenced for accuracy.

- Drilling ice cores is difficult - Extreme weather and isolated locations make this process very expensive and demanding, but the data extracted from ice cores is very important.
- Ice cores are priceless - Ice is regulated and shared to maximize the amount of data extracted from the ice core.
- Ice is saved for future experimentation - Scientists acknowledge the limitations of modern science and save a significant portion of the core for future testing.

We reviewed the data to search for patterns that were not highlighted by coding and found that comparing ice cores between different locations in both hemispheres give scientists a global understanding of climate. Ice moves so much that drilling in the right location is essential to provide useful data. Site selection is so important that Dr. Bertler said it accounts for about one-third of the process of ice core research.

D. Visitor Observation

We categorized the exhibitions that we observed based on levels of engagement: non-interactive, button press, touchscreen, and simulations and mechanisms. We coded observations for exhibitions at each level to determine observational themes that recurred most frequently and display them in Table 4.

Table 4: Observations from Visitor Assessment

Type of Exhibition	**Examples**	**Observations**
Non-interactive	Words on wall/ground Photos Squid Display Gallipoli Pathway Maori Displays Passport Timeline	• People often look first and then read • Clear paths seem to give visitor a clear way to navigate exhibition • Clear, linear displays seem to attract people
Button press	Mountains to Sea Exhibition Passport Exhibition	• Kids tend to press button but often walk away soon after • Adults sometimes explain interactive to kids • Kids tend to wander through open exhibition • People sometimes share learned information with each other (especially between parents & kids) • Some interactives are not used in the intended way
Touchscreen	Quake Safe Squid Designer	• People often exchange learned information with each other

	Gallipoli Screens Rock Exhibit Screens	● Screens can involve multiple people ● Some interactives not used in the intended way ● Most people, except elders, seem to be attracted to screen type displays ● Games let people retry activity to improve their “score” ● People drawn to personal activities that allow the visitor to take “ownership” of something
Simulations and mechanisms	Quake House Quake Ratings Time Traveler Surveying Scope Grinding On Tectonic Globe Rock Lifting	● Adults tend to read content first, sometimes will do interactive after ● Adults sometimes provide explanations for kids ● Kids do tactile, movement activities/interactives and often don’t read ● Kids sometimes make interactives a group competition amongst themselves ● People of all ages often give up on strenuous or non-intuitive interactives ● Words and smaller information is sometimes overlooked at interactive

We reviewed the data to search for patterns and formulated the following brief list of notes from our observations:

General Observational Notes

- Kids like to touch, move, and do things with their hands instead of reading.
- Kids like competitive activities or will make an activity competitive.
- Game-like activities allow people to ‘win’ and retry the activity to improve their ‘score.’
- Adults tend to read more than kids. Adults sometimes explain exhibitions to kids.
- Sensors that trigger activation (ex: lights & sound) attract people to the exhibition.
- Large displays with lots of details are intriguing and hold people’s attention.
- Clear, linear displays are effective for guiding visitors and communicating clear messages.

From these observational notes, we drafted a list of principles to guide our brainstorming process:

General Principles from Observations

- Make exhibitions accessible for group audiences as well as individuals.
- Make displays and exhibitions clear, large and linear so that visitors are intrigued and can follow them intuitively.
- Allow visitors to learn from the exhibition by reading or interacting. Appeal to audiences of all ages and abilities.
- Incorporate game-like and competition based activities.

Discussion of Results for Objective I

Thematic content analysis revealed important information from our results. The targeted visitor demographics from the '90% Concept Design Document' gave our team a sense of the audience for whom we should design our interactive. The '90% Concept Design Document' provided context for the ice core interactive in relation to the rest of the new exhibition. The content structure of big ideas from this document confirmed the information from discussions with the renewal team and further established our understanding of the ice core interactive's place within the 'Threat' portion of the renewal project.

Our team read about different types of exhibition features that the renewal team wanted to include in the climate change section of the project from the '90% Concept Design Document.' While we concluded that the ice core interactive primarily fell under the 'Hands-on Interactives and Games' category because it would stimulate physical interaction and embodied learning, features such as 'AV [Audio-Visual] Stories," 'Sharing and Debate Spaces,' and 'Status/Action Maps' gave us insight into other ways of communicating information around the ice core interactive. For example, supporting information that might not be communicated through the ice core interactive could be conveyed through an audio-visual first-hand account from an ice core scientist. This prompted our team to decide what information to communicate in the interactive and what information to convey in other exhibition features in the beginning of our prototyping and testing phase.

The elements of 'Scientific Method,' 'Social,' and 'Physical & Playful' from the '90% Concept Design Document' informed our design phase. These details confirmed that our interactive designs should be based on scientific content, be accessible for multiple people at once, and be supportive of hands-on learning. Information, such as the 'Do, Think, Feel' goals for the ice core interactive and climate change timeline, laid the foundation for our designs. For example, the two documents on the ice core experience and the timeline stated that the interactive should be comprised of an ice core model component and a timeline component, which was congruent with the exhibition goals laid out by meetings with renewal team members.

Although we wanted our interactive to be accessible for all, we referred to Morris Hargreaves McIntyre's model of culture segments, used by Te Papa to prioritize target audiences. We concluded that our designs should be entertaining, socially engaging, and hands-on and target people who are expressive, experimental, and enjoy discovery. The

document also mentioned children, Maori, and academics as priority audiences. Our team used this insight in the brainstorming phase of our project to influence our designs.

Our trip to the ice core facility and discussions with Dr. Bertler impacted our team's design concepts. For example, the cold temperature in the ice core storage freezer influenced many of our ideas for the atmosphere of the exhibition. The use of light to discern ice layers inspired several 'light table' designs. Our discussions with Dr. Bertler and tour of the laboratory provided us a necessary understanding of ice core research methods and greatly informed our brainstormed ideas.

Naturalistic observation of museum visitors informed our team that visitors interact with exhibitions in a variety of ways. Some seemed interested in learning all the information from an exhibition while others more interested in touching an interactive component or looking at an interesting display. We noted the features that caused visitors to regularly interact with an exhibition in a meaningful way to understand what worked or did not; this helped us efficiently design a successful interactive. Our observations and guidelines revealed several aspects of museum engagement that guided our design development process.

Chapter 5: Objective II - Interactive Design Development

The purpose of this objective was to generate and refine design ideas for the ice core interactive based on our observations of visitors at Te Papa, our research on exhibition design, and our understanding of the museum's vision for the renewal project. We completed this objective by conducting two rounds of brainstorming and then evaluating the designs to present to the renewal team. We sought feedback from the renewal team and Dr. Bertler to further refine the designs.

Methodology for Objective II

A. Design Brainstorming

Our team held brainstorming sessions to generate design ideas. Using Crawford's Slip Writing Approach, we first conducted individual brainstorming to produce a wide range of unique designs. We kept in mind our meetings with the renewal team, information from museum documents, our knowledge of ice core research, and the general guidelines from our visitor observation. Our team separated and drew inspiration from images of existing exhibitions as well as pictures from our tour of The New Zealand Ice Core Research Facility. We used the "Do, Think, Feel" goals from the 'Ice Core Experience Outline' and 'Climate Change, Timeline and Causes Goals and Notes' documents to guide our brainstorming. At this stage, ideas did not have to be fully developed or even feasible; they could be rough and undeveloped, with a goal to produce a wide range of ideas.

After the period of individual brainstorming, our team convened to discuss our ideas. This method was consistent with Crawford's Slip Writing Approach and allowed each group member to discuss his or her individual ideas. After presenting the ideas, we conducted front-end evaluation, an established refinement method from the Worcester EcoTarium, to find common themes, strengths, and weaknesses in each design. We used the processes of ice core research, information gained from our meetings with Dr. Bertler, to categorize our initial designs. Our team separated again for more individual brainstorming, this time focusing on the information we discussed in our front-end evaluation. This cyclical process, shown in Figure 25, forms part of an overall process shown in Figure 9, and is used by the Worcester EcoTarium for developing museum exhibitions.

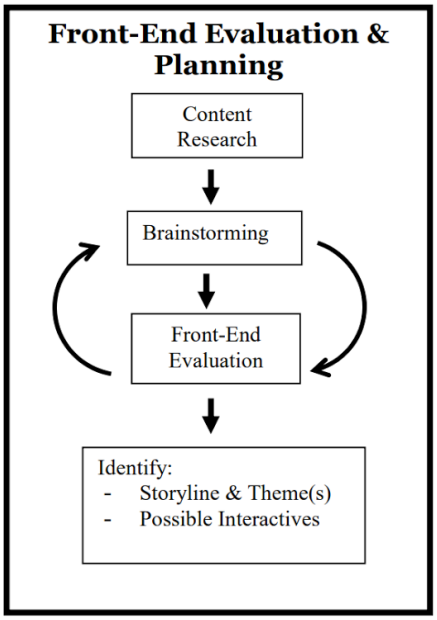


Figure 25: Front-end Evaluation and Planning from the EcoTarium in Worcester, Massachusetts

B. Design Refinement

With the results of our second brainstorming session, we organized roundtable discussions with members of the renewal team to present, assess, and review our designs. We presented each of our design ideas with "Do, Think, Feel" goals to explain the intended visitor response to each design. The first discussion was with renewal team designers to analyze the logistics and feasibility of our designs. Our team sought input on the strengths and weaknesses of each design and which designs fit best into the goals of the renewal project.

We met with our sponsor liaison, Dr. Dean Peterson, and designer Chloe Johnston, to review our designs. In this meeting, our team wanted additional feedback on our designs and to ensure that our ideas were in line with our sponsor's expectations.

We set up a roundtable discussion with content writers Jen Craddock and Ralph Upton from the renewal team. Prior to this meeting, we outlined a content hierarchy for our interactive, a document that organized the primary, secondary, and tertiary information that visitors should gain from our interactive design. Our team presented our designs, discussed how to display content through the climate change timeline, and gained their feedback.

In addition to meetings with the renewal team, our team set up an interview with Dr. Bertler to discuss her recommendations on specific ice core content in our designs. We sought her feedback on our designs as well. Our questions for Dr. Bertler were related to what an ice core researcher would want visitors to learn from our interactive and are shown in Figure 26.

- What information would be the best to include in the exhibit? What information do you want to communicate to visitors?
- Can we make an “ideal core” of the best parts of many parts of different cores?
- What time period should the ice core represent?
- What do layers tell us?
- What should visitors take away be from this exhibition? What are the most important things that ice cores prove about climate change?

Figure 26: Interview Questions for Dr. Nancy Bertler

Throughout the rest of the design refinement stage, we reviewed our feedback and used thematic content analysis to inform our future work. Our team discussed the content of our designs and their place within the entire renewal project as well as how our designs reflected Dr. Bertler’s and the renewal team’s feedback. Consolidating this information allowed our team to assemble a final design concept using the most effective aspects of our designs. As we concluded design refinement and began prototyping and testing, we remained open to new ideas if they arose and evaluated them with the same procedure as our initial designs.

Results for Objective II

A. Design Brainstorming

During brainstorming, we sketched our designs and wrote notes to present to each other. A collection of some of our rough sketches are shown in Figure 27.

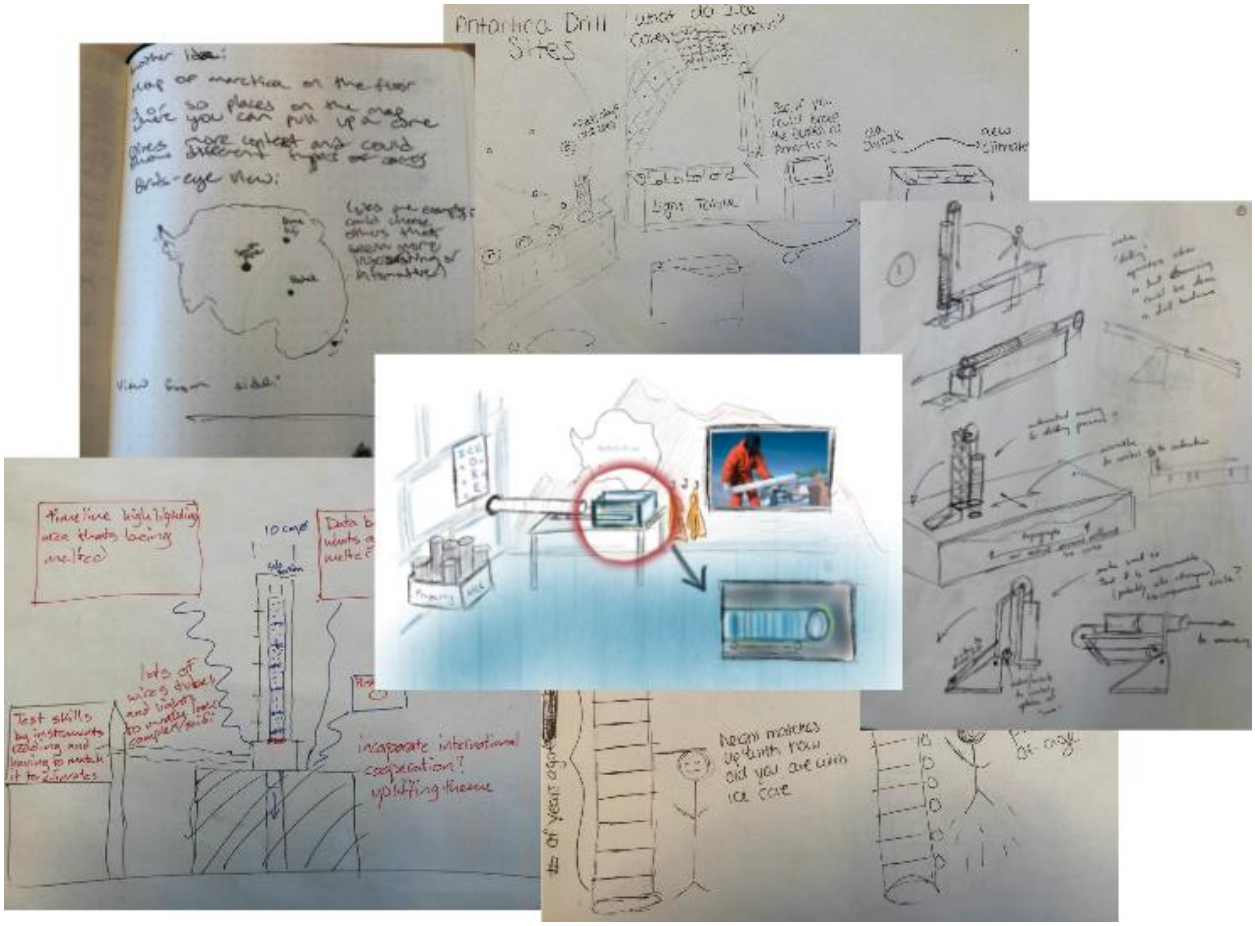


Figure 27: Collage of Individual Brainstorming Designs

The design ideas in Figure 27 are explained in Table 5:

Table 5: Individual Brainstorming Designs with Notes and Explanations

Design Idea	**Notes and Explanation**
Map with Ice Cores at Each Location	A map of Antarctica allowing a visitor to extract and examine ice cores from locations corresponding to real drill sites.
Examination of Ice Cores on a Light Table	A light table that illuminates an ice core and exposes hidden information to the visitor.
Drill Equipment	Scaled-down drill equipment that allows visitors to “drill” an ice core out of the floor and then examine it.
Ice Claw	Scaled-down, simplified drill equipment on tracks that allows visitors to remotely move the equipment to drill sites.
Laboratory Experiment	Scientific equipment that allows visitors to “melt” an ice core and study the data stored within.

Walk-in Ice Core	A large, hollow core allows visitors to walk around and through the core and explore the information at a magnified scale.
Vertical Ice Core on Wall	A vertical ice core with layers correlating to the ice's age allowing visitors to compare their height to the age of the ice core.
Timeline Connected to Ice Core	A sliding ice core with layers allows visitors to pull it up from the floor which causes a nearby timeline to progress through time, displaying important information on the way.

After discussing our individual ideas and completing front-end evaluation, we conducted a second session of individual brainstorming to develop design variations, shown in Figure 28.

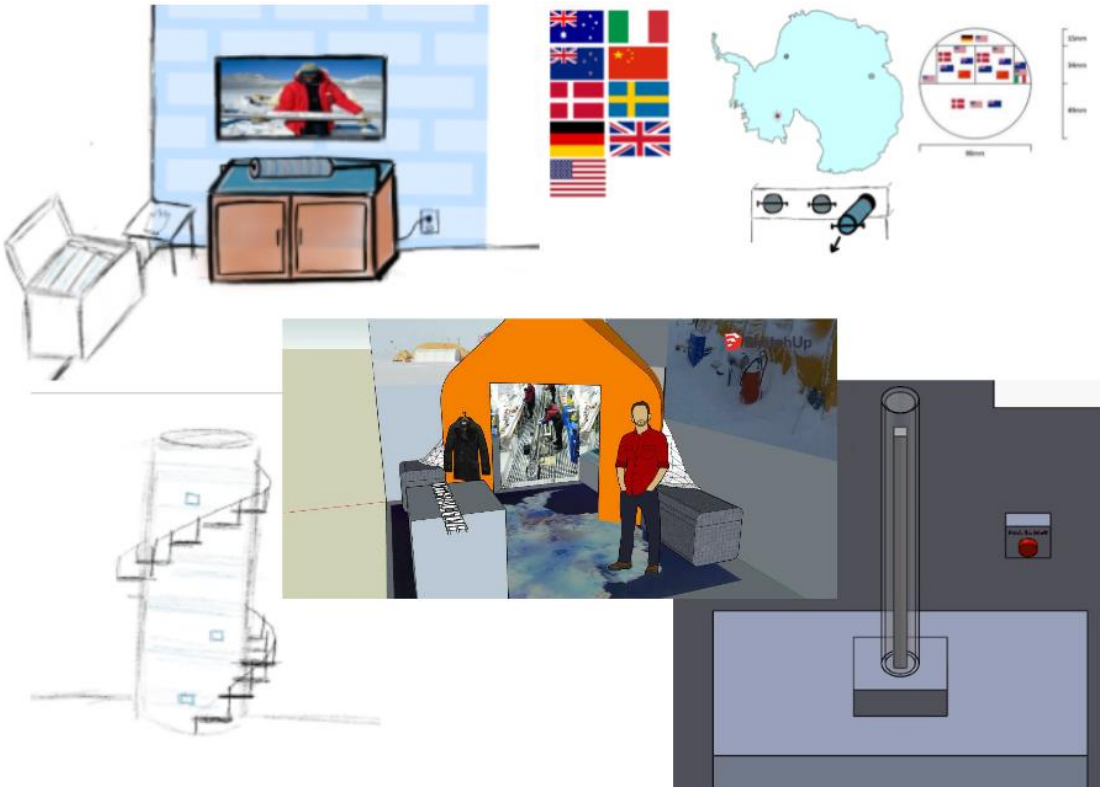
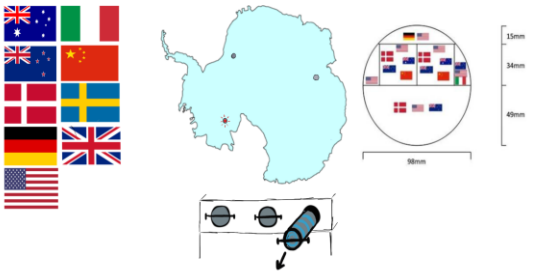
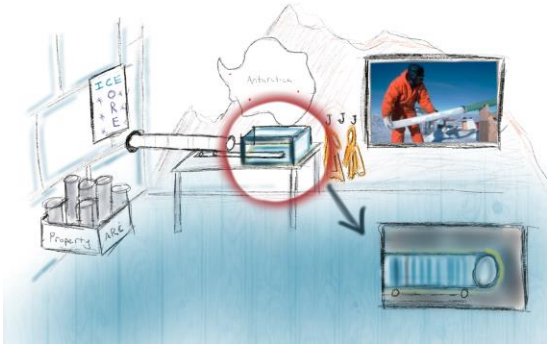


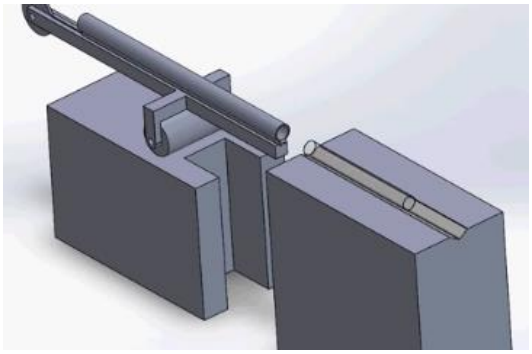
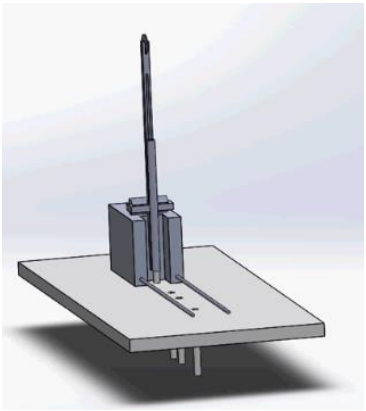
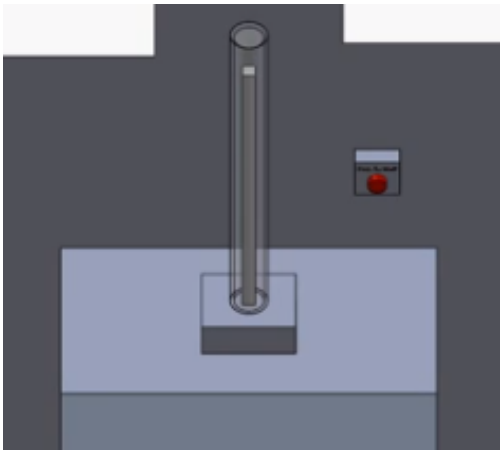
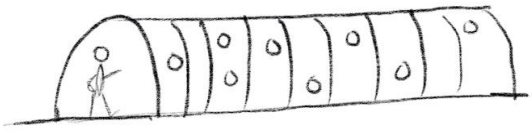
Figure 28: Collage of Detailed Designs After Second Round of Individual Brainstorming

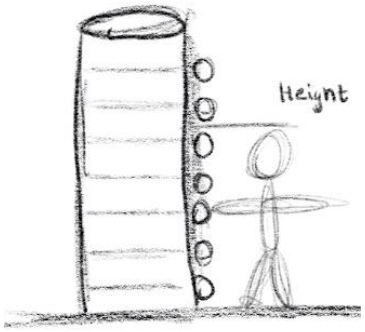
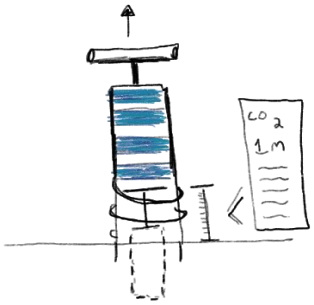
B. Design Refinement

After group brainstorming, we presented all of our designs with "Do, Think, Feel" goals to various renewal team members and Dr. Bertler. Our design ideas and the corresponding "Do, Think, Feel" goals are summarized in Table 6.

Table 6: Designs Presented to Renewal Team Members and Dr. Bertler

Name of Design Idea & "Do, Think, Feel" Goals	Representation of Design Idea
Atmosphere Do: Examine an Antarctic research base. Put on a coat/gloves (for picture taking) and enjoy the cool and intriguing atmosphere. Think: Scientists camp in the Antarctic and perform research that shows evidence for climate change. Feel: As if you were in Antarctica on a research expedition to drill and analyze ice cores. Excitement about an interesting experience. Awe that scientists live in Antarctica.	
Map with Ice Cores at Each Location Do: Extract a model ice core from the wall and a light on Antarctic map above shows location of that core. Examine the core and notice the layers. Think: Layers represent seasons in Antarctica. International cooperation is essential for ice core research. Feel: Amazed at the level of cooperation between countries and realize it must be important for the effort. Proud of NZ's work.	
Ice Cores on a Light Table Do: Examine a model ice core on a light table and notice the layers and bubbles. Think: Deeper layers contain older ice. Each layer represents a season. Ice from different layers contain bubbles that capture snapshots of the atmosphere at that time. Feel: You're a scientist looking at the different layers and examining what they contain. Discovering what climate was like in the past.	

Drill Equipment Do: Extract/control an ice core drill. Lower the drill and pull out a core. Raise the drill and pull the core out to examine it. Think: Ice cores are 'time capsules' of atmospheric conditions. Feel: Like you are involved in the drilling processing of getting an ice core. Sense of immersion and discovery.	
Ice Claw Do: Control a drill arm that can choose from an ice core site and then descend to extract an ice core. Think: Selecting the right ice core drilling site is very important. Different drill sites will yield different evidence. Ice thinning from pressure and temperature changes affect the ice core layers. Feel: Sense of purpose in deciding drill location; sense of exploration and discovery	
Laboratory Experiment Do: Press the button and watch section of ice core "melt" at an accelerated rate in realistic lab equipment. As the ice core "melts," info on a nearby screen explains how the data tells scientists about ancient climates. Think: New Zealand scientist are at the forefront of ice core research. Understand how ice cores tell us about ancient climates. Old climate conditions let us predict modern climate change. Feel: Futuristic laboratory setting. You're a scientist discovering past climates to understand future ones.	
Walk-in Ice Core Do: Walk into a giant ice core. See the bubbles and layers on the wall around you. Think: You're inside an ice core examining it from the inside. Feel: You're deep under ice immersed in the layers.	

Height Scale with Ice Core Do: Walk up to the giant ice core on the wall and compare your height to the layers and years presented. Press buttons to light up the layer and see what it contains. Think: How scientists relate layers to time and years in the ice core. Feel: Connected to the layers with your height. Amazed how old ice cores are and how deep into the ice scientists drill.	
Timeline Connected to Ice Core Do: Extract an ice core model from the floor and notice how moving the ice core triggers the timeline to highlight different points in time. Think: Scientists link layers to time. Ice cores are time capsules that contain information. Depth in ice and time are related. Feel: A sense of discovery when extracting the ice core and new information is displayed in the timeline.	

Specific design ideas from this phase will be referred to by their *italicized* title from Table 6.

Refinements Discussed with Designers

We presented our designs to the designers of the renewal team in a roundtable discussion on January 26th. The designers in this meeting were Clayton McGregor (contract exhibition designer), Chloe Johnston (experience designer), and Nick Clarkson (graphic designer). Table 7 displays the feedback from the designers on specific design ideas during this meeting. Design ideas not explicitly mentioned in this table did not receive specific feedback from the designers.

Table 7: Feedback from Designers on All Design Ideas

Strengths	● *Map with Ice Cores at Each Location* - highlights international cooperation ● *Walk-in Ice Core* - a great way to display data and what the layers mean ● *Ice Cores on a Light Table* - shows a physical reveal and it leads to educational reveal ● *Atmosphere* - shows the feel that you're a scientist in Antarctica ● Many ideas show that visitors could work together to reveal something
Weaknesses	● *Drill Equipment* and *Laboratory Experiment* - too removed from ice cores and the more important aspect of examining ice cores ● Budget and space constraints make *Walk-in Ice Core*, *Drill Equipment*, and *Laboratory Experiment*
Suggestions	● Move UV light along stationary core on table to create a reveal of layers ● Ice core examination should be the highlight of interactive ● Gradual temperature could be shown through lighting changes ● Aesthetic defined by industrial and reused materials

Refinements Discussed with Dr. Dean Peterson and Chloe Johnston

We organized a round table discussion on January 31st with our sponsor liaison Dr. Dean Peterson and designer Chloe Johnston. Their feedback from this discussion are shown in Table 8.

Table 8: Feedback from Dr. Dean Peterson and Chloe Johnston on Design Ideas

Strengths	● *Walk-in Ice Core* ○ Abstract design avoids confusion over whether it is a real ice core ○ Makes it obvious that artistic license is used ● *Height Scale with Ice Core* - good supplementary idea
Weaknesses	● *Ice Cores on a Light Table* shows a small sample core and may cause confusion over the size and scale of an actual ice core
Suggestions	● Link layers in ice core model to real depth of ice core ● *Walk-in Ice Core* - explore sight lines so visitors can see inside and outside

Refinements Discussed with Content Writers

Our team drafted a content hierarchy, shown in Table 9.

Table 9: Our Team's Version of a Content Hierarchy for Our Designs

Level 1 (Primary Messages)	● Rising CO_2 levels lead to rising temperatures, CO_2 and temperature are linked ● CO_2 concentration has spiked in recent years, causing rapid increase of global temperatures ● Humans have caused CO_2 levels to rise rapidly and have affected other environmental factors
Level 2 (Secondary Messages)	● Ice cores contain bubbles ('snapshots') of atmospheric conditions - this is how we know atmospheric changes over time ● Layers in ice cores represent time
Level 3 (Tertiary Messages)	● Oxygen isotopes are used to estimate temperatures ● Specifics details about drilling and testing, life in Antarctica ● International collaboration

At a roundtable discussion on February 1st, we met with content writers Jen Craddock and Ralph Upton. Table 10 shows their feedback on specific design ideas and our content hierarchy.

Table 10: Feedback from Content Writers on All Design Ideas and Content Hierarchy

Strengths	● Content for children is separate from content for adults in *Walk-in Ice Core*, this appeals to a broader age range ● *Timeline Connected to Ice Core* could include New Zealand specific events, could extend beyond period related to ice core model - shows more information and appeals to New Zealanders
Weaknesses	● Link between ice core model and graph/timeline of CO_2 may not be apparent in *Timeline Connected to Ice Core* ● Difficult to connect human impact on climate to ice core model ● Might be confusion around whether ice core model is to scale or an exaggeration - *Walk-in Ice Core* and *Ice Cores on a Light Table*
Suggestions	● Compare current and ancient carbon dioxide levels ● Include tactile element to inside of *Walk-in Ice Core* for children
Content Hierarchy	● **Level 1** information is more important than **Level 2** information, but **Level 2** information will come across more easily in proposed designs ● **Level 3** information might be too complicated to convey in our designs ● Importance levels are good

Content Interview with Dr. Nancy Bertler

We interviewed Dr. Bertler on February 1st to ask her specific content questions related to the ice core information in our designs. Our notes from this interview are displayed in Figure 29.

- What information would be the best to include in the exhibit? What information do you want to communicate to visitors?
    - Link ice cores to climate change
    - Ice cores provide continuous records in ice-high resolution
    - Temperature and greenhouse gases are very important data types
    - Scientists directly measure bubbles of gas from thousands of years ago—such a simple process
    - "The only way for us to anticipate the future is algorithm models"
    - "Ice cores are one of the very few records where we can actually really test those models"
    - "If you want to know what happens in the next 20 years, [ice cores are] very important"
- Can we make an "ideal core" of the best parts of many parts of different cores?
    - RICE (New Zealand's Antarctic) ice core would be a good example core
    - Artistic license is totally ok—use idealized core as long as it represents the science
- What time period should the ice core represent?
    - "The last 10,000 years, I think is a smart choice because there are a lot of events people can associate with [within this time]"
    - This amount of time would be about 600 m out of 764 m in RICE core
- What do layers tell us?
    - Approximate dates in ice
    - It's ok to say we use layers to tell time because we're idealizing [the ice core model]
    - Volcanoes are really important to cross reference time
    - Taupo - biggest eruption in last 70,000 years
    - Nuclear tests—can see all of them [in the ice] even Chernobyl
    - Huge variation in how much time is represented in a length of ice
- What should visitors take away be from this exhibition? What are the most important things that ice cores prove about climate change?
    - "The two things you would take away from an ice core are temperature and CO_2"
    - "CO_2 and temperature are tightly linked"
    - "CO_2 has never been higher in the last 800,000 years"

Figure 29: Notes from our Interview with Dr. Bertler

Analysis for Objective II

A. Design Brainstorming

During our front-end evaluation group discussion, we used thematic content analysis to categorize our individually brainstormed ideas based on the processes and aspects of ice core research. This helped us to brainstorm other possibilities for interactive designs. This categorization is shown in Table 11. The titles we chose for our brainstormed ideas are shown in *italics* and other possible interactive designs are followed by question marks (?).

Table 11: Categorization of Brainstormed Design Ideas & Other Possible Ideas by Ice Core Research Aspects/Processes

Aspect of Ice Core Research	Explanation	Interactive Design Ideas
Life in Antarctica	Cold harsh environment, tough living	● Simulation, immersion, experience - *Atmosphere* ○ Tent & equipment, coats & gloves for picture taking ● Video of outdoor environment(?)
Site Selection	Sampling, meteorological and weather data/modeling, ice movement, different drill sites, collaboration	● *Map with Ice Cores at Each Location*, *Ice Claw* ● Something showing the modeling of weather data(?)
Equipment/Setup	Drill size, drill trench and tent, tent setup	● Videos/time lapses(?)
Drilling/Extraction	Drill rig, drill depth	● *Drill Equipment*
Sectioning	Cores cut to 1 meter lengths	● Ice core saw/cutting interactive(?)
Short-term Storage	Cool the ice in homemade freezer on site	
Packaging	Keep ice core sections in bags	● Bagging ice core section(?)
Transportation	Use of planes for transportation (big for long distances, small for short distance), ships (storms, power outages)	● Documentary of ship/plane voyage(?)
Cutting/Processing	Collaboration required, cut for different kinds of tests, ice samples are sought by many nationalities	● Diagram of ice core sectioning(?) ○ Show which sections are used for specific tests
Testing/Analysis	Discrete vs. continuous flow tests, politics surrounding testing schedules, light table reveals layers, effects of pressure & layer thinning	● *Laboratory Experiment* ● *Ice Cores on a Light Table* ○ Sliding microscope(?) ● *Height Scale with Ice Core* ● *Walk-in Ice Core*
Results	Results shared internationally after publishing, evidence for climate change	● *Timeline Connected to Ice Core*
Archive	New Zealand unique for ice core research, technology and future advances	

In addition to the design categories, our team discussed themes in ice core research that could apply to all of our design ideas. These themes included:

- Cold-feeling atmosphere with white surroundings, coats and gloves, and soundscape
- International cooperation
- Link between location in ice core and climate change timeline
- Reveal factor when examining an ice core

Our team discussed these themes, our brainstormed ideas, and other possible ideas in our meetings with renewal team members and our interview with Dr. Bertler.

B. Design Refinement

Final Refinements Discussed with Our Team

We created Table 12 by coding the feedback from renewal team members and Dr. Bertler based on strengths and weaknesses of all of our brainstormed designs. We used this table to decide which design ideas and aspects to mold into a final design, shown in the Conclusions column of Table 12.

Table 12: Comparison & Conclusions of All Designs

Design	Strengths	Weaknesses	Conclusions
Map with Ice Cores at Each Location	International cooperation, highlight NZ's role in ice core research	Probably not budget friendly, and does not connect easily to timeline	Good supplemental idea, do not pursue for interactive
Ice Cores on a Light Table	Reveal factor, ice core is center of interactive	Probably not budget friendly	Use information reveal and ice core model examination
Drill Equipment	Realistic	Large and probably not budget friendly, ice core is not central to interactive	Do not pursue
Ice Claw	Potentially familiar for visitors	Probably not budget friendly, ice core is not central to interactive	Do not pursue
Laboratory Experiment	Realistic	Ice core is not central to interactive	Do not pursue

Walk-in Ice Core	Unique presentation	Large and probably not budget friendly	Scaled down version could be feasible
Height Scale with Ice Core	Cheap, shows scale of cores	Does not connect easily to climate change timeline	Good supplemental component, do not pursue for interactive
Timeline Connected to Ice Core	Incorporates timeline link to ice core	Connection between ice core and timeline might be missed	Use timeline-ice core link

We decided to combine the promising aspects of multiple designs into a single design with two version. Both of these versions would display a stationary ice core model horizontally, similar to the way the ice core model would be presented in the *Ice Cores on a Light Table* design. To keep the reveal factor of this design, we decided to include a sliding viewport to illuminate bubbles and layers in the ice core model. This sliding viewport element was adapted from a possible sliding microscope design idea in the Testing/Analysis row of Table 11. Using the timeline-ice core link from the *Timeline Connected to Ice Core* design, the position of the sliding viewport on the ice core model would correspond to points on the timeline that displays atmospheric carbon dioxide levels over time. To incorporate the concept of the *Walk-in Ice Core* idea, we formulated two versions of our final design, shown in Figure 30 and Figure 31.

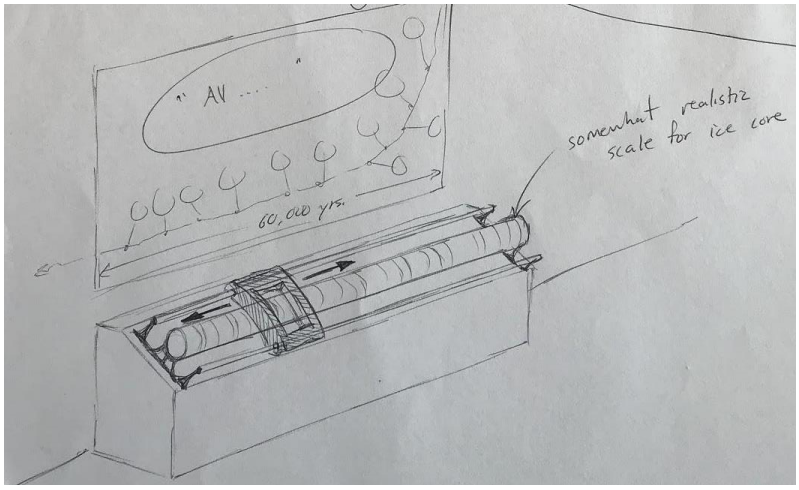


Figure 30: Sketch of *10 Centimeter Version*

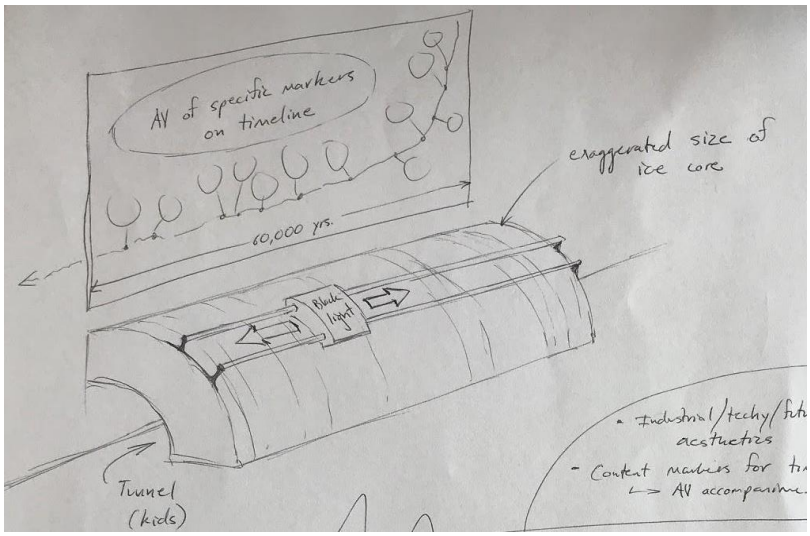


Figure 31: Sketch of *Tunnel Version*

The *10 Centimeter Version* in Figure 30 contains a more realistic representation of an actual ice core. The *Tunnel Version* in Figure 31 includes an exaggerated model of an ice core and allows younger visitors to examine the ice core from inside a tunnel-like space. Using Dr. Bertler's recommendations from our interview with her, we decided the timeline and carbon dioxide graph on both final designs would cover 10,000 years because this timescale demonstrates the stability of atmospheric carbon dioxide levels and highlights the dramatic growth in carbon dioxide levels over the past 200 years.

According to Dr. Bertler, an ice core sample of the past 10,000 years would be much larger than the space allowed for our interactive design. Therefore, it would be impossible to display a realistically scaled ice core model in our interactive. This issue was reflected in feedback from renewal team members and caused us to explore this issue in the next phase of our project.

Discussion of Results for Objective II

Our brainstorming sessions generated diverse ideas for possible designs for the ice core interactive. Individual brainstorming was beneficial because they produced unique and abstract ideas. Early designs reflected our research and meetings with the Dr. Bertler and ranged from very simple replications of the drilling process to grand displays of information. For example, the *Map with Ice Cores at Each Location* design in Figure 28 highlights the importance of international collaboration and drill site selection, aspects of ice core research highlighted by Dr. Bertler. In this design, visitors would pull out one of several ice core models from the wall and

the map would display the drill site and the nations that participated in the drilling at that site. Front-end evaluation and categorizing our design ideas helped us to pursue promising designs and draw on strengths from multiple designs. We presented our designs to the renewal team and Dr. Bertler, and their feedback helped our team narrow our focus to produce designs that had the potential to become part of a long term exhibition at Te Papa.

The design team's feedback was helpful for our team because it provided us with a framework for refining our designs. Our team used the identified strengths of our design ideas to synthesize an effective final design. We used the identified weaknesses of our design ideas to eliminate ineffective designs and used suggestions to improve design ideas. The content writers supported our plan to link the timeline to the interactive, a sentiment that many other members of the renewal team and Dr. Bertler supported. This informed our decision to integrate the timeline into our final designs. Our interview with Dr. Bertler defined many aspects of our final design, such as setting the period of the carbon dioxide timeline to 10,000 years. She also stated in her interview that she thought artistic license around the scale and actual size of the ice core model in relation to the timeline was allowable. This information, along with many renewal team members' approval of the *Walk-in Ice Core* design concept, prompted us to not prioritize the aspect of representing an accurately sized and scaled ice core model. This allowed our team to develop two versions of our final design.

We combined the most effective features from our brainstormed designs into a single design with two versions. We concluded that the *10 Centimeter Version* might be easier for visitors to understand while the large-scale ice core would target younger audiences, a priority social group based on the 'Natural Environment Exhibition Renewal 90% Concept Design Document'. We decided to test this unsupported hypothesis with visitors in our prototyping and evaluating phase. With a refined final design, our team transitioned into the next stage of our project.

The feedback from renewal team members and Dr. Bertler informed the creation of our prototype and the aspects of our design that we decided to test with visitors. For example, the feedback from Jen and Ralph on our content hierarchy helped us to solidify the intended learning outcomes of our design. This led us to create a revised content hierarchy in the prototyping phase of our project. The concern that visitors might not make the connection between the ice core model and the carbon dioxide timeline prompted us gauge this connection in our Iteration 1 prototype testing.

Chapter 6: Objective III - Iterative Prototyping

The purpose of this objective was to create a prototype of the refined design and to evaluate each versions' effectiveness through visitor testing. We created paper prototypes and invited visitors to test interactive features. The information gained during visitor testing allowed us to improve our prototypes through design iterations. The Worcester EcoTarium's Formative Evaluation and Iterative Prototyping process, Figure 32, informed our process.

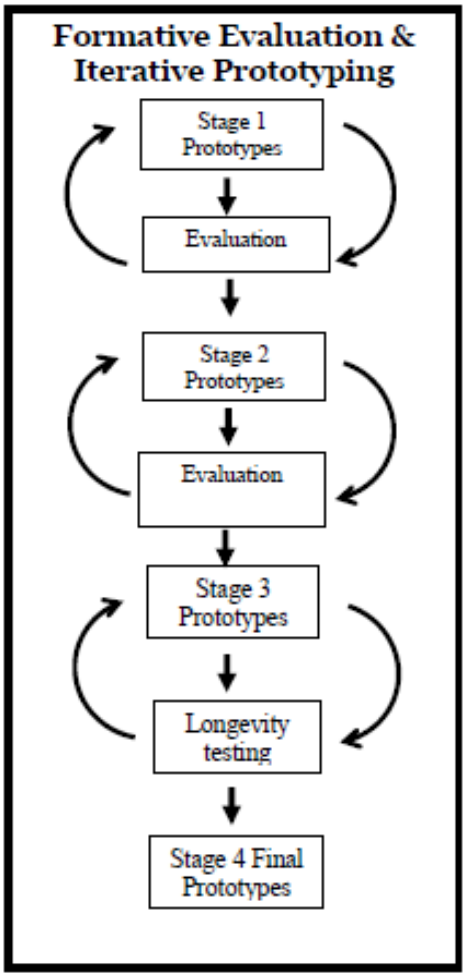


Figure 32: Formative Evaluation & Iterative Prototyping from the EcoTarium in Worcester, Massachusetts (Loring, Dec 8, 2017)

Methodology for Objective III

A. Prototype Iteration 1

The first iteration of prototyping was to test the main messages conveyed by the refined design. We performed testing in stages to find whether the design successfully conveyed the intended messages.

Prototype Creation

We used storyboarding to map out the intended visitor experience for our interactive design, including points of interaction and conveyed content. We studied storyboard examples and templates that Te Papa provided. Using the templates as a guide, we laid out the visitor experience of our designs in sequential drawings, spotlighting key aspects. We used computer generated images to more clearly display the design versions. We made the digital images of our design versions using Google SketchUp.

Our team created an information schematic to define the information and key messages of the exhibition as well as locations to display this information within the design. Along with this schematic, our team generated an updated information hierarchy to organize the information in order of importance. We presented our information schematic and information hierarchy to content writers on the renewal team in a round table discussion to gain their feedback.

We created a prototype of our *10 Centimeter Version* based on our final design from Objective II, our refined information hierarchy, and our information schematic. To create our prototype, we used paper prototyping, a time and cost effective way of prototyping that allowed us to create and test the overall messages conveyed by our design. We created a physical prototype to represent the timeline, ice core, and slider.

Prototype Testing

To test our prototype, we adapted testing procedures from museum standard practices at the Boston Museum of Science, the Worcester EcoTarium, and the Te Papa Museum. This involved three team members: a facilitator, an operator, and an observer. The facilitator interacted directly with the visitors by explaining the prototype and asking semi-structured interview questions, the operator moved prototype components to correlate with visitor actions and simulate the automated features of the interactive, and the observer took written notes of the semi-structured interview. We used our refined information hierarchy and information schematic to develop our test questions and testing process.

We conducted preliminary testing with a group of two renewal team members and one visitor. We practiced our roles of facilitator, operator, and observer and noted suggestions from the three participants to streamline the visitor testing experience. Based on these suggestions, we improved the appearance of the prototype and adjusted questions of the semi-structured interview to elicit in-depth feedback during visitor testing.

We tested our prototype on the Te Papa museum floor in Nature Space, a social learning space within the *Mountains to Sea* exhibition. We set up our prototype on a desk near the entrance of Nature Space with 3 team members, each assuming a role as facilitator, operator, or observer. We used convenience sampling to invite visitors to test a prototype for a potential new exhibition. The facilitator informed visitors that their responses would be anonymous and that their participation was voluntary. The facilitator asked visitors who agreed to participate to examine the timeline and provide their impressions on the presented data. The operator then showed the visitor the ice core prototype and the facilitator asked the visitor about their knowledge and feelings based on its appearance. Finally, the operator attached the slider to the ice core prototype and the facilitator invited the visitor to interact by moving the slider. The operator moved the timeline marker correspondingly and presented photos of events at appropriate locations along the timeline to simulate the exhibition experience.

When the visitor completed their interaction with our prototype, the facilitator asked the visitor if they had time to answer questions in accordance with a semi-structured interview. This interview was structured to elicit the learning outcomes and suggestions for design improvement from the visitor. Finally, the facilitator presented the Google SketchUp images of the *10 Centimeter* and *Tunnel Versions* and requested feedback on which design the visitor believed to be more interesting. The facilitator script is shown in Figure 33.

Facilitator Script for Test Iteration 1

Have you been to Te Papa before? Where are you from?

We appreciate that you are taking some time to help us develop this future exhibition! We want to let you know that we're testing our ideas for the exhibition – we're not testing you. Any feedback or criticism along the way is very helpful to our process and we encourage you to ask any questions or give any suggestions to make this experience better. There's no such thing as a silly question. Your participation is completely voluntary and you are welcome to leave at any time. If you don't mind, we will be taking notes on this activity.

If you are ready, we can begin.

1. Present Graph/Timeline

"There are two pieces to our design. The first is this graphic which will be presented on the wall. Have a look and see what you think."

What is your first impression from seeing this display? Why?
Any thoughts or feelings looking at this?
Did you learn anything from this? How or why did you gain this information?

2. Present Model Ice Core
[put ice core model in front of graph]
"This object will be positioned in front of the graphic on the wall."

What is your first impression when you see this object? Please keep in mind that this is a prototype.

"This object is the second component in our design. It is a model of an Antarctic ice core. Please take a moment to observe the model."

What do you notice when looking at this core?
Do you find anything about this model interesting?

3. Present Slider
[put slider over ice core model, position graph marker on graph]
"This device would be positioned over the ice core model on a rail. Please take a moment to interact with this device."

[as visitor moves slider, marker moves along the timeline]
[at points of interest, manipulator puts viewport graphic in slider, facilitator puts blurbs on timeline]

"If you see something of interest in the ice core model, please stop the slider viewport over it so that we can adjust the prototype."

What did you discover from this ice core?
Why do you think the slider and the marker on the graph move together?
With these added pieces, did you learn anything new or surprising?

4. Appeal
[present two versions of design]
"There are two versions of this exhibition, the first involves a 10 Centimeter model of an ice core similar to what you just interacted with. The other consist of a large scale of an ice core that also acts a tunnel for visitors to crawl through."

Which design is more interesting to you? Why?

5. Overall Evaluation
If you had to explain your experience with this prototype to someone at home, what would you tell them?
Do you have any suggestions for improving our design?

"Thank You again for your feedback! Your input will help us improve this design. Anything else?"

Figure 33: Facilitator Script Iteration 1

We coded the visitor responses to our testing procedure for recurring themes and messages.

B. Prototype Iteration 2

Prototype Refinement

Based on the results from Iteration 1 testing, our team refined our interactive prototype with the feedback we received from museum visitors. We used the coded visitor responses to identify the biggest weaknesses in our prototyped design and then improved these aspects in our next prototype. We also worked to create a more realistic prototype of our design to represent how it would function when implemented in the museum. We used a presentation software Prezi to more accurately reflect our idea of the interactive portion of the timeline.

Prototype Testing

Our goal for this second iteration was to test the improvements to our design and to receive additional feedback. Our team refined our testing procedure to more accurately simulate the experience the visitor would have with the interactive on the museum floor. We assumed the same three roles as facilitator, observer, and operator. We tested Iteration 2 in Nature Space using convenience sampling. The facilitator script is shown in Figure 34.

Facilitator Script for Test Iteration 2

Have you been to Te Papa before? Where are you from?

We appreciate that you are taking some time to help us develop this future exhibition! We want to let you know that we're testing our ideas for the exhibition – we're not testing you. Any feedback or criticism along the way is very helpful to our process and we encourage you to ask any questions or give any suggestions to make this experience better. Your participation is completely voluntary and you are welcome to leave at any time. If you don't mind, we will be taking notes on this activity. If you are ready, we can begin.

1. Interaction

[present the interactive]

"Please take a few moments to look at and interact with this prototype. Any questions, thoughts, or comments you can share with us will be extremely helpful to the development of this exhibition."

2. Comments

What is your first impression from seeing this display? Why?
Any thoughts or feelings looking at this?
Do you find anything about this interactive interesting?

What did you discover from the graph? The ice core and slider?
After interacting with this, do you have any thoughts about the future climate?

Did you learn anything from this?

3. Appeal

[present two versions of design]

"There are two versions of this exhibition, the first involves a 10 Centimeter model of an ice core similar to what you just interacted with. The other consist of a large scale of an ice core that also acts a tunnel for younger visitors to crawl through."

Which design is more interesting to you? Why?

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Do you have any suggestions for improving our design?

"Thank You again for your feedback! Your input will help us improve this design. Anything else?"

Figure 34: Facilitator Script Iteration 2

Results for Objective III

A. Prototype Iteration 1

In our first round of prototyping, we developed preliminary exhibition content, digital models, and physical interactive mockups for visitor testing. Once we built and tested the prototype with visitors, we gained feedback for further development of designs.

Prototype Creation

We created storyboards for the exhibition to identify steps that we should test. Figure 35 and Figure 36 show the storyboards our team created.

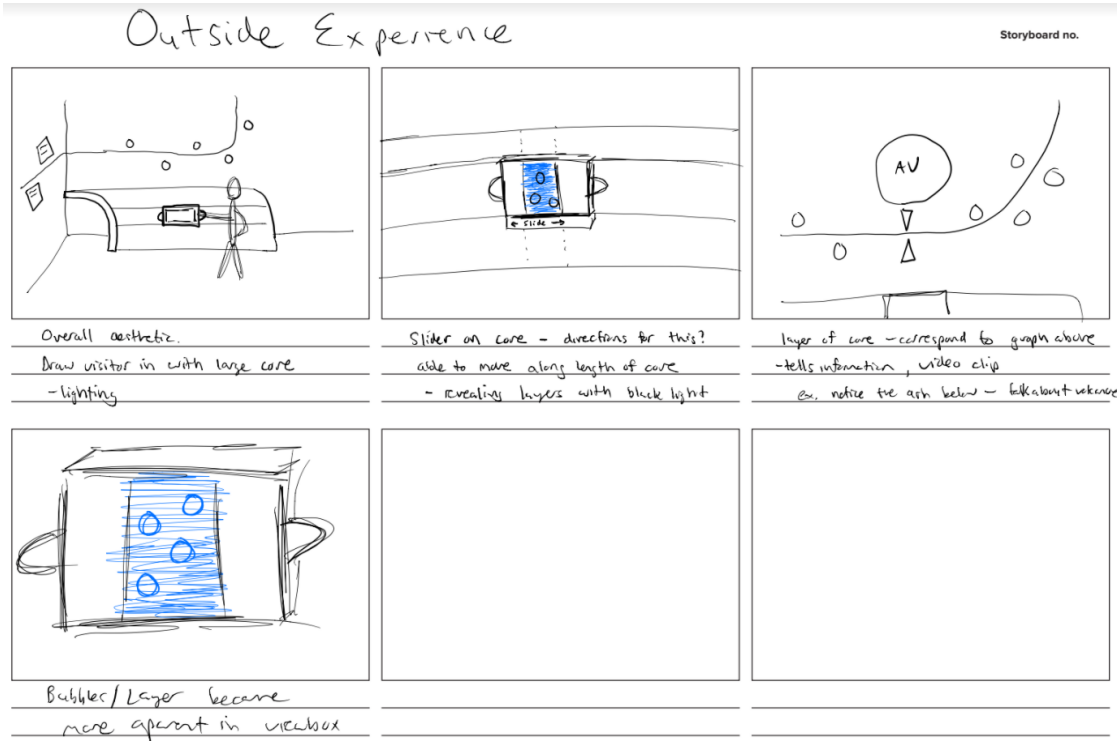


Figure 35: Outside Experience Storyboard

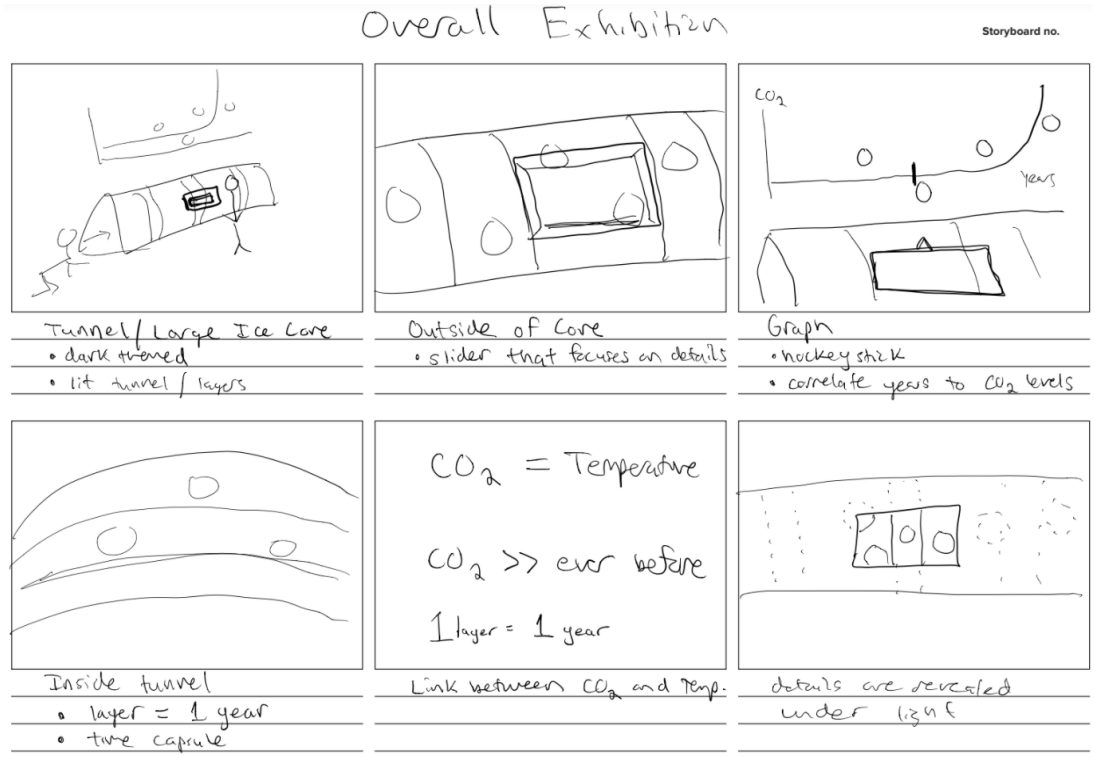


Figure 36: Overall Exhibition Storyboard

Figure 37 and Figure 38 show Google SketchUp models our team created of the exhibition versions.

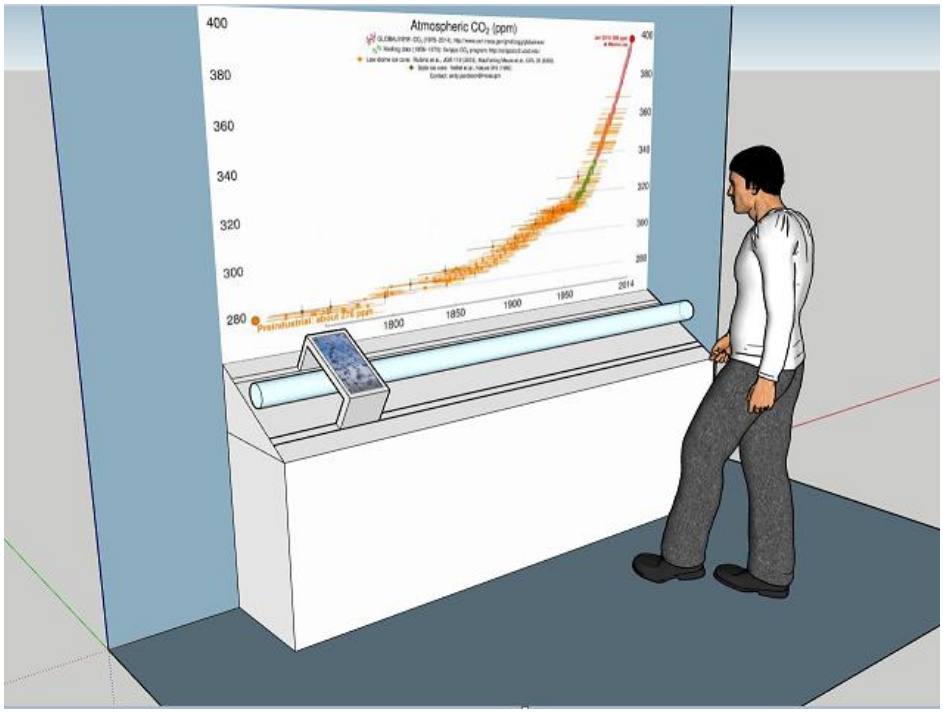


Figure 37: *10 Centimeter Version* Portrayal

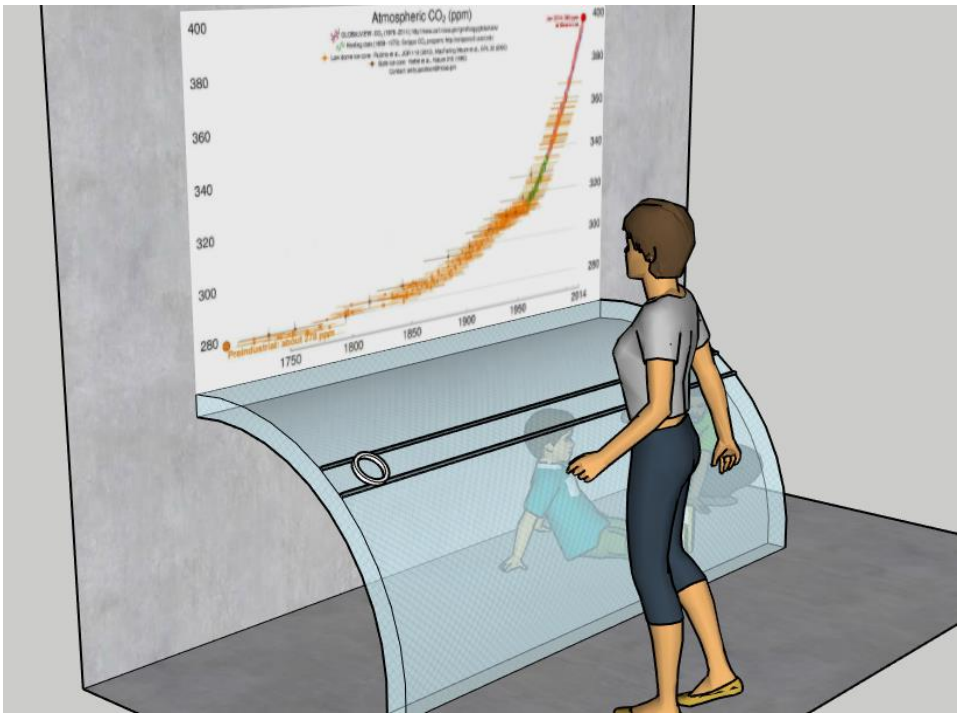


Figure 38: *Tunnel Version* Portrayal

Our team held a roundtable discussion with Ralph Upton, Jen Craddock, and Nick Clarkson to discuss exhibition content on February 13th. The information schematic and information hierarchy show content organization (Figure 39 and Figure 40).

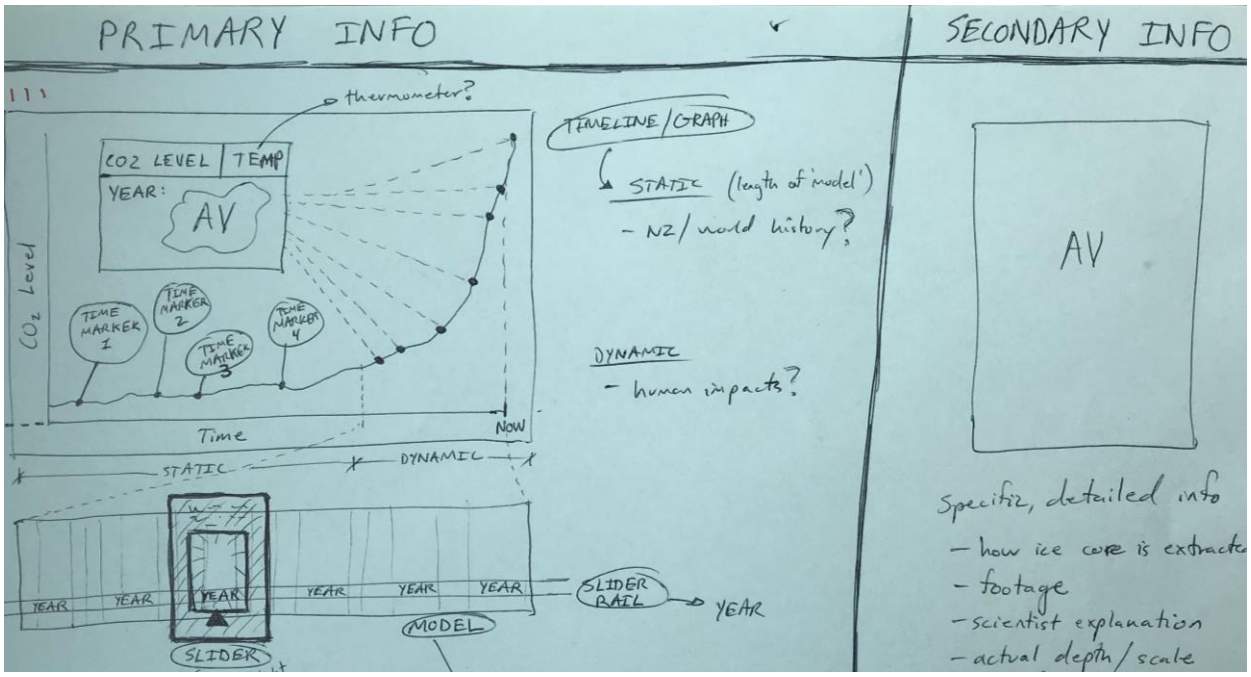


Figure 39: Information Schematic Showing the Timeline, Slider, Model, and Audio-Visual Components

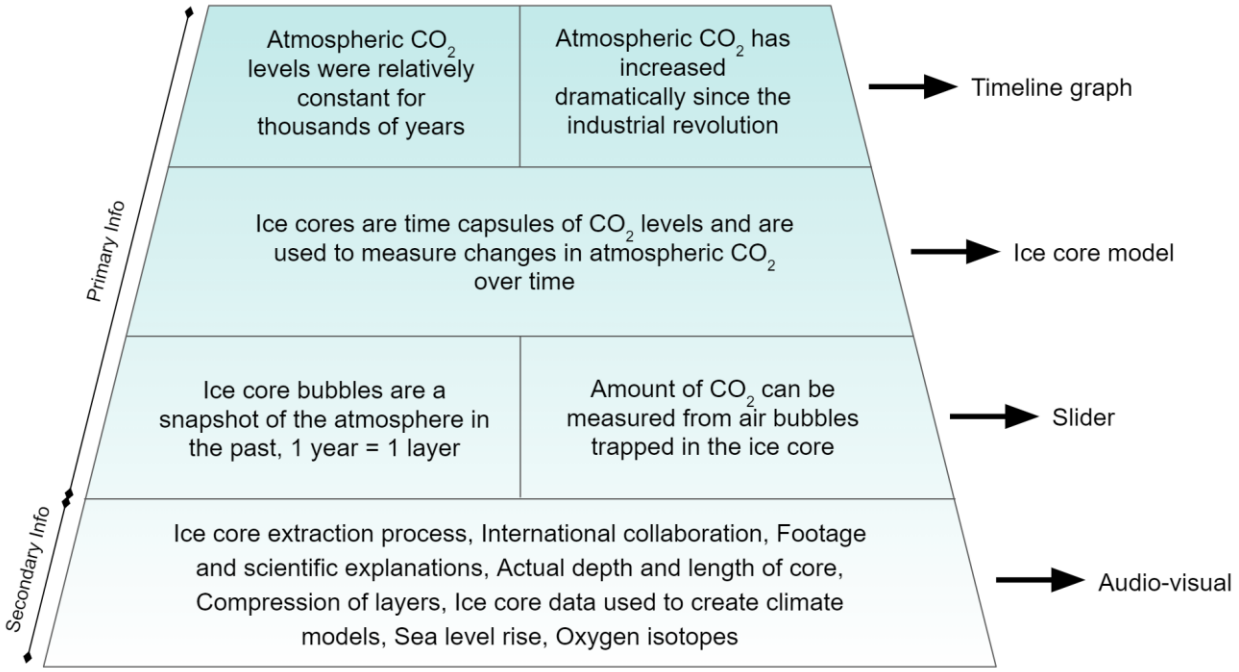


Figure 40: Information Hierarchy

The notes our team took in this meeting are as follows:

- Review content hierarchy
- New Zealand specific events on static [portion of timeline] would be good
- Dynamic region [of timeline that corresponds to the ice core model]
    - Start dynamic region at Industrial Revolution to highlight human activity
- Natural history vs human activity events:
    - [won't] say explicitly human activity [caused rise in carbon dioxide levels], but say human related events [such as the] Industrial Revolution or car ownership
    - Natural events in NZ that didn't have human action, [such as] volcanic eruptions would be good for static portion of timeline
- [Show] compression of time in ice core [layers]
    - Have 1/3rd [of timeline] show 100 years, then 1/3rd 1,000 years, and then 1/3 10,000 years
- 5-10 meters maximum for the [horizontal] space for this exhibition
- Varied [visuals] in the ice core if possible
    - [This] keeps [the ice core model] interesting
- Information about climate change and temperature [on the timeline] and explanation of visual in ice core model
    -
- [Visuals in the] ice core depends on information [scientist can extract from] an ice core
- [Use] human stories to back up the evidence [in the ice core]
- Use specific event and its date [on the timeline]
    - Taupo eruption, 27,000 years ago
    - RICE ice core extends 83,000 years
    - The ice core interactive could be 10,000 years or maybe 5,000-2,000 years
- [Ice core layers] gradually getting compressed works really well
- [Use a] cartoon timeline [and use humor to lighten the delivery of climate change info]
    - [Use] standard New Zealand history events on timeline to fit in with the [rest of the New Zealand focused] exhibition [Ex: Signing of the Treaty of Waitangi]
- [How to show the] actual depth of an ice core

The physical prototype included a timeline, ice core model, slider, and photographs for timeline events (Figure 41 and Figure 42).

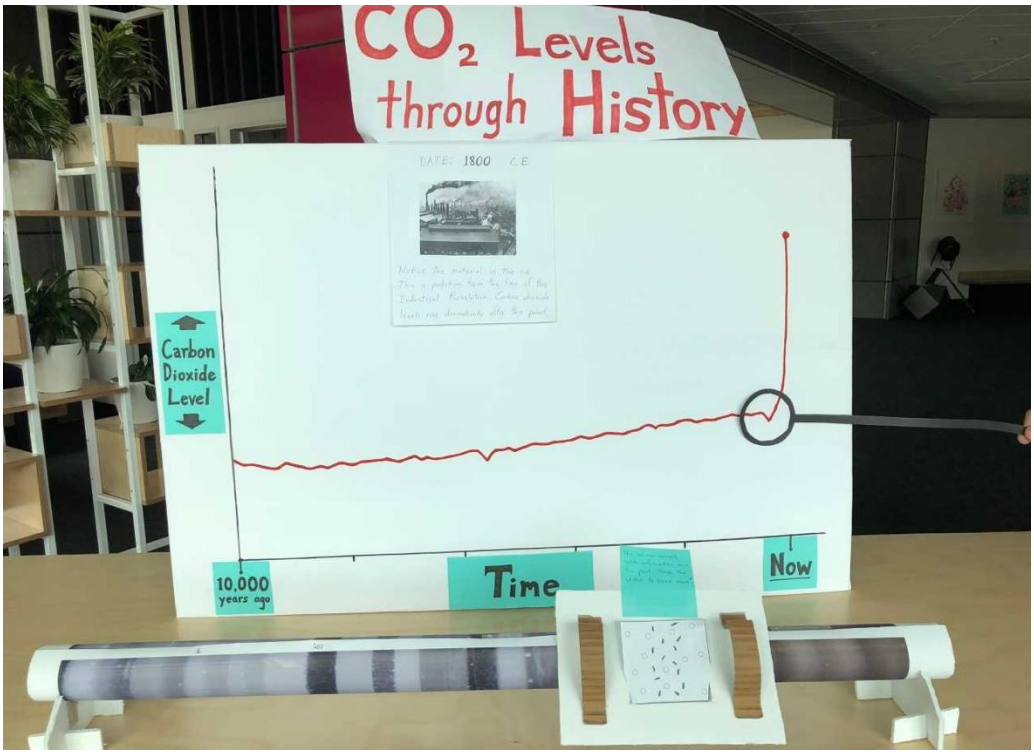


Figure 41: All Components of Iteration 1 Physical Prototype

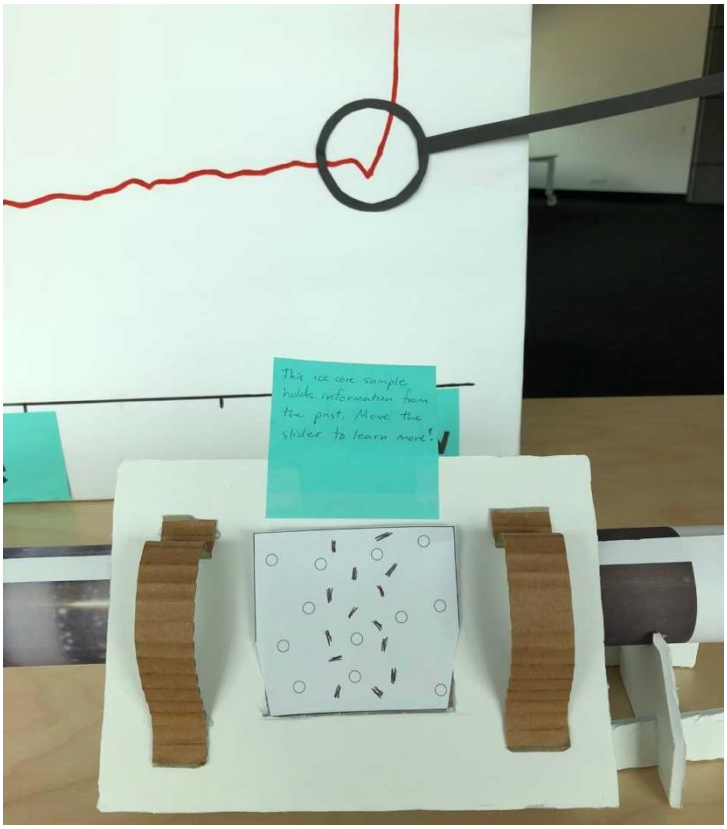


Figure 42: Slider and Timeline Detail of Iteration 1 Physical Prototype

Prototype Testing

We conducted preliminary testing with a group of two museum staff members and one visitor. Their primary feedback on this testing was as follows:

- Museum staff mentioned that three person testing group works well.
- Make the ice core print go all the way around the core to avoid confusion.
- When shown in steps, it is clear that ice cores are linked to the timeline.
- The dramatic increase in CO_2 was not apparent in our prototype. Maybe focus the timeline on a shorter amount of time to highlight this increase.

The dramatic increase in CO_2 was not apparent in our prototype. Maybe focus the timeline on a shorter amount of time to highlight this increase. We conducted six semi-structured interviews to test Iteration 1 with visitors on the museum floor. Most of these interviews involved two or more visitors. A sample interview response is shown below. For all testing results of Iteration 1, see Appendix B*. Note: responses are paraphrased because they were recorded with note taking, not audio recording.*

Iteration 1: Example Interview

Couple in their 60s, from Dunedin, New Zealand

Present Graph/Timeline
Facilitator: What is your first impression from seeing this display? Why?
Visitor: Is it something to do with carbon dioxide changing?

Facilitator: Any thoughts or feelings looking at this?
Visitor: It's a bit scary seeing it on the graph. Have you got a timeframe?
Facilitator: We have a rough timeline for now.

Facilitator: Did you learn anything from this? How or why did you gain this information?
Visitor: It shows us about climate change, definitely.

Present Model Ice Core
Facilitator: What is your first impression when you see this object? Please keep in mind that this is a prototype.
Visitor: Notes layers, darker at the end.

"This object is the second component in our design. It is a model of an Antarctic ice core. Please take a moment to observe the model."

Present Slider
Facilitator: "This device would be positioned over the ice core model on a rail. Please take a moment to interact with this device." "If you see something of interest in the ice core model, please stop the slider viewport over it so that we can adjust the prototype."

Visitor: This is a core sample from where?
Facilitator: Antarctica

Facilitator: What did you discover from this ice core?
Visitor: CO_2 levels going through the roof, killing the planet. Nuclear bomb testing on Christmas Island is really interesting and personal.
Visitor: The government does something and then runs and hides. So many disasters, planet deteriorates. We need whole world on board to make change. This puts it across well. Their [the older] generation has killed it for us. We store seeds to keep them safe, protect animals, governments need to make changes. We have seen effects of climate change, summers are getting hotter and winters are getting colder.

Appeal
Facilitator: Which design is more interesting to you? Why?
Visitor: The children would like the large version.

Overall Evaluation
Facilitator: If you had to explain your experience with this prototype to someone at home, what would you tell them?
Visitor: We're killing our planet. I'm freaked out. The more mankind has got cleverer, the more mankind has killed the planet. We've gone for more electronics and plastic, we need to go back to using less. Have we got time?. Do we all realize what we have to do? What do we do as the general public? Little ones learn about it in school, important to teach adults through this.

Facilitator: Do you have any suggestions for improving our design?
Visitor: It's a little confusing at first, but then it makes sense. Like the slider. Sitting underneath will be interesting to children.

B. Prototype Iteration 2

Prototype Refinement

Our team produced a refined prototype to test in the museum with visitors. This prototype consisted of a digital timeline that allowed for more interaction and less guidance. A strength of this change is that the interaction designed for the visitor can be tested in a way that more closely replicates a real exhibition that would stand alone.

Main aspects that we focused on included the presentation of the ice core, the time range for the carbon dioxide timeline, the detail of labels and axis, and the inclusion of an additional static display. Our team changed the appearance of the physical ice core because the results of the first iteration showed confusion with the printed layers. We updated the core to represent a realistic ice core without visible layers. Our team also changed the range of the interactive portion of the timeline to be shorter to highlight the dramatic increase in carbon dioxide levels in the past 200 years. We kept the same range of 10,000 years overall for the overall timeline but made the other non-interactive portion of the timeline static with permanent

event descriptions. The static portion ranged from 10,000 BCE to 0 CE and the interactive portion ranged from 0 CE to present day. In Figure 43, the left paper portion of the timeline represents the static portion while the digital display shows the interactive portion connected to the ice core model.

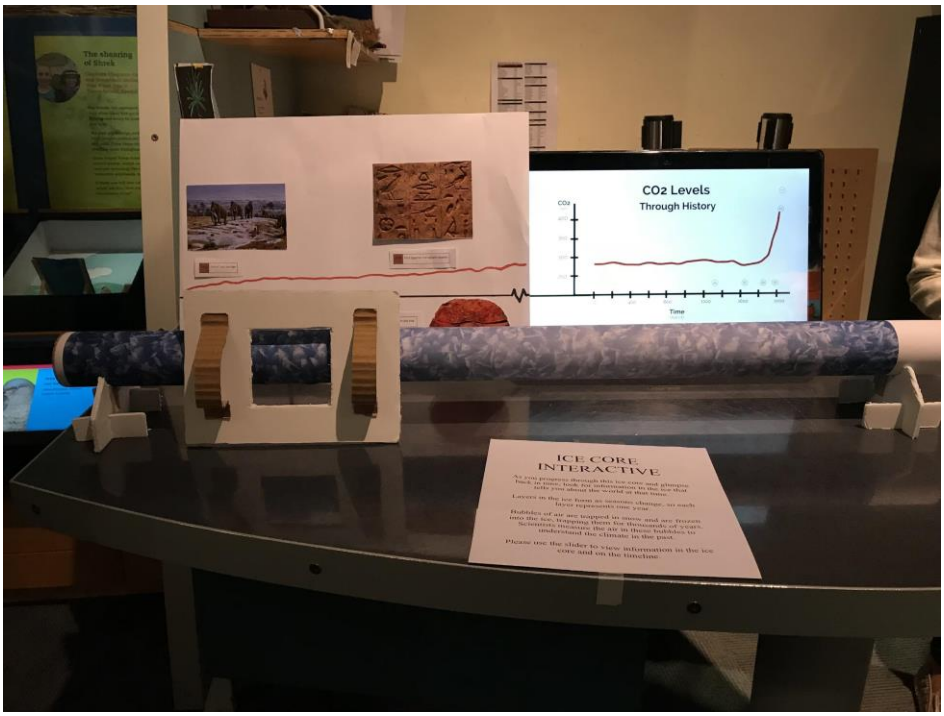


Figure 43: All Components of Iteration 2 Physical Prototype

Our team used the presentation software Prezi to represent the interactive portion of the graph. Figure 43 shows the full graph and Figure 44 shows the timeline emphasizing a data point when the slider was over a layer in the ice core model. Appendix C shows all the timeline event descriptions presented in this iteration.

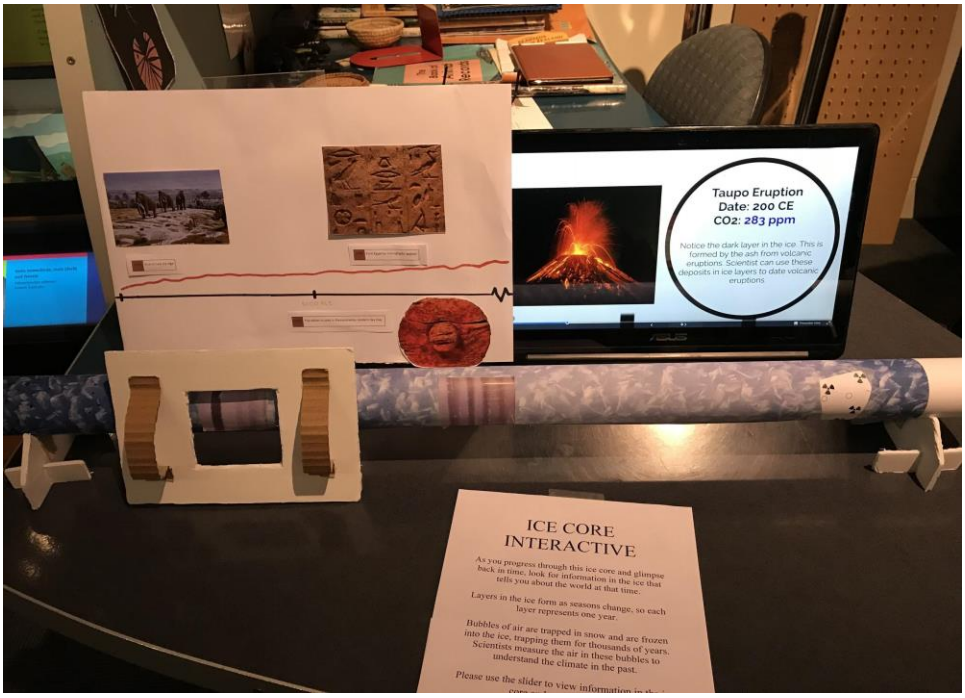


Figure 44: Slider and Timeline Detail of Iteration 2 Physical Prototype

Prototype Testing

For this round of testing we did not want the facilitator to intervene as much as in Iteration 1. We altered the script for the facilitator to reduce the amount of explanation for the visitor. This more accurately reflected the true experience the visitor would have if the interactive were on the museum floor. The operator used a computer mouse to click the Prezi screen so points on the graph were emphasized when the visitor would slide the slider over a specific layer in the ice core.

When the interaction was completed, the facilitator asked the visitor open-ended questions using a semi-structured interview and the observer took note of the duration of each test. For this testing iteration, we conducted ten semi-structured interviews, most of which consisted of multiple visitors. A sample interview response is shown below. For all testing results of Iteration 2, see Appendix C. *Note: responses are paraphrased because they were recorded with note taking, not audio recording.*

Iteration 2: Example Interview

Duration: 6.5 mins

Where they are from:
Oslo, Norway
Older woman with early 20s man and woman

Gender:
- ✓ Male
- ✓ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ✓ Young Adult: 20-45
- ✓ Adult: 45+

Interaction

[present the interactive]

Brief introduction
Looking at the prototype
Moving the slider
Looking at the screen
So if I hold it here it stands still?
Looking
Yeah well I liked it

Comments

Facilitator: What is your first impression from seeing this display? Why?
Visitor: It's interactive and its fun, you can do it at your own tempo
Didn't get pictures moving as fast
I think it's a good idea
I like it

Facilitator: Any thoughts or feelings looking at this?
Visitor: The timeline is good

Facilitator: Do you find anything about this interactive interesting?
Visitor: Yeah, I like the sliding

Facilitator: What did you discover from the graph? The ice core and slider?
Visitor: I didn't study it that hard but if I did I would. Is it ice?

Facilitator: After interacting with this, do you have any thoughts about the future climate?
Visitor: Lot of ideas about future climate
It's [climate change] a catastrophe

Facilitator: Did you learn anything from this?
Visitor: Everything has to do with everything

Appeal

[present two versions of design]
Facilitator: Which design is more interesting to you? Why?
Explanation of differences
Visitor: I would like this one (ten centimeter) because I would not be crawling behind here
A bit more explanation that both have the slider
Visitor: Well then I like this one (tunnel) because it would be more fun for kids

Overall Evaluation
Facilitator: If you had to explain your experience with this prototype to someone at home, what would you tell them?
Visitor: How [climate] has all changed

Facilitator: Do you have any suggestions for improving our design?
Visitor: I think you need to spice it up
Maybe make it more colorful

Analysis for Objective III

A. Prototype Iteration 1

We coded the impressions and feelings of visitors regarding the timeline graph into a word cloud, as seen in Figure 45. This collection of terms serves as a representation of the opinions of museum visitors about carbon dioxide levels over time.

Figure 45: Word Cloud of Impressions and Feelings of Visitors towards CO_2 Graph

We analyzed the visitor appeal of each version of our design through a graph, as seen in Figure 46, that shows the distribution of preferences for each design version. The data shows that out of the six groups, with 11 total visitors from Iteration 1, six visitors preferred the *10 Centimeter Version*, whereas the remaining five visitors preferred the *Tunnel Version*.

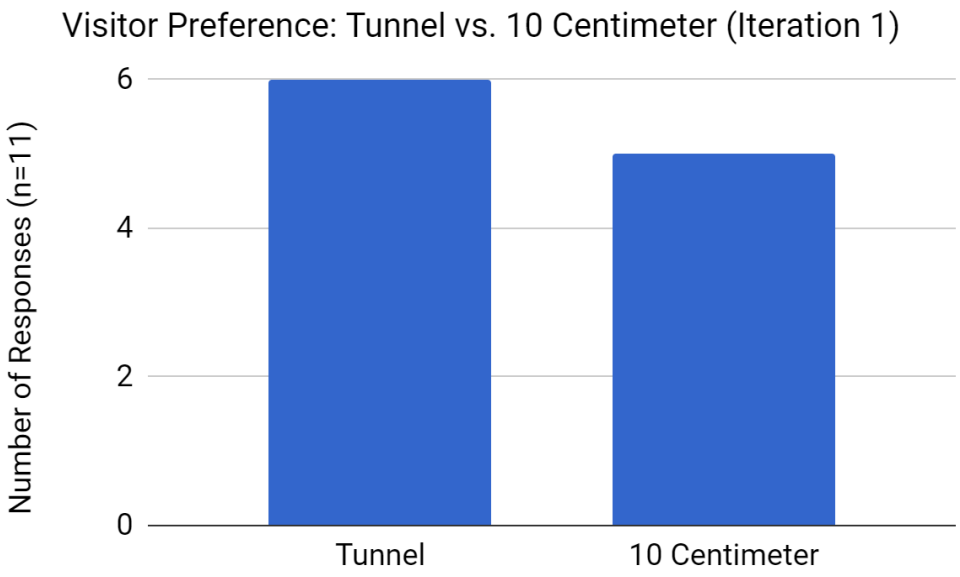


Figure 46: Iteration 1 Visitor Appeal of *10 Centimeter* and *Tunnel Versions*

The responses of all the visitors from testing Iteration 1 were compiled and organized into the chart below (Figure 47). This information serves as a representation of the feedback received from testing Iteration 1 with visitors and was used to inform Iteration 2.

Stages/Questions Asked	Response from Visitors **(n) means multiple responses
Impressions of Carbon Dioxide Timeline	It's [climate change] a disaster It's [climate change] not very good What happens next? Shows climate change Data is high, may affect our lives Alarming (2) Can't predict future, Scary, hard to say it's natural, Easy to read, can see where we're going What are the units? What happened before spike at the end?
Impressions of Ice Core Model	Identified it as an ice core sample (2) Noted there are years written on model (2) Noted the blue color Thought it represented cracked ice Darker at end, means more carbon dioxide (2) → wrong message

	Layers in the ice means pollution/dirtiness → wrong message Noted color change (2)
What are the Main Messages from this prototype?	[Climate change is a] big issue, need to think about, our problem We're killing our planet Mankind is responsible Stable for 10,000 years, but huge spike in just the last 200 years Ice can actually store information of something that happened far away... Ex: Chernobyl
Suggestions for Improvement	Show Human Population Correlation to CO_2 Level Further Information on Ice Core and their Purpose/Backstory (2) Interaction Is Important Methane as data on timeline Let people know ice traps atmosphere Adjust scale of timeline and show CO_2 level Relate to tree rings Static images for children to relate to Tangible events that people have heard of Show other ways to get CO_2 data What causes CO_2 to rise? Be more clear Differentiate causes of climate change from other timeline events

Figure 47: Coded Results of Iteration 1 Visitor Testing

B. Prototype Iteration 2

We asked visitors whether they found the *10 Centimeter Version* or *Tunnel Version* more appealing. This portion of our testing procedure was identical across Iteration 1 and 2, so we combined and coded responses from both iterations together. We conducted 16 semi-structured interviews, usually with pairs of visitors, and our sample size was 28 individuals. As shown in Figure 48, the *Tunnel Version* seemed attractive to over twice as many visitors as the *10 Centimeter Version*. There were 20 visitors who chose the *Tunnel Version* and eight who chose the *10 centimeter Version* (n=28). We coded their reasons for preferring the *Tunnel Version* into the following categories: Exciting (more memorable, attractive, appealing etc.), interactive (more points and levels of interaction), and Child-Friendly (children would be more interested in and would learn more from this design). We used a similar coding process for the *10 centimeter Version* and chose the following categories: simple (straightforward, easier to understand), Realistic (was interesting to see the real size of the ice core), and Mature (the tunnel seemed childish) (Figure 49).

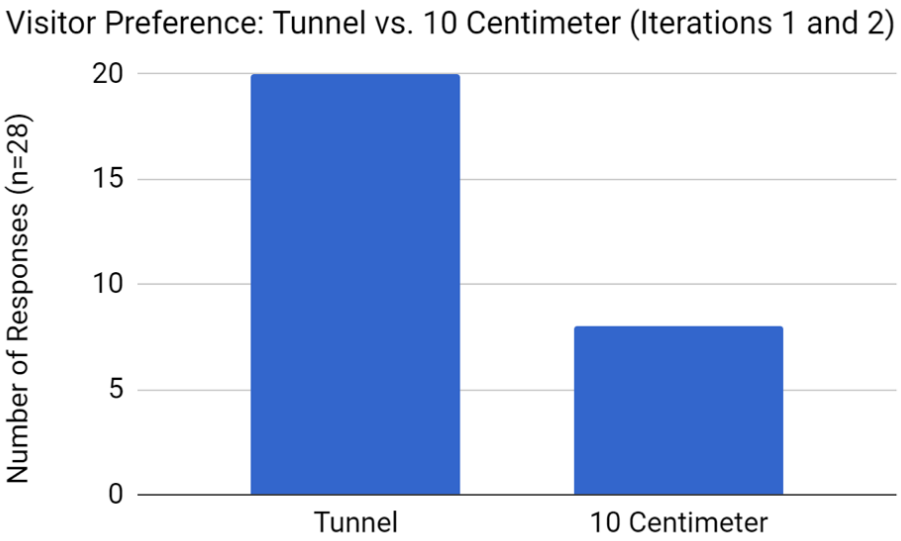


Figure 48: Iterations 1 and 2 Visitor Appeal

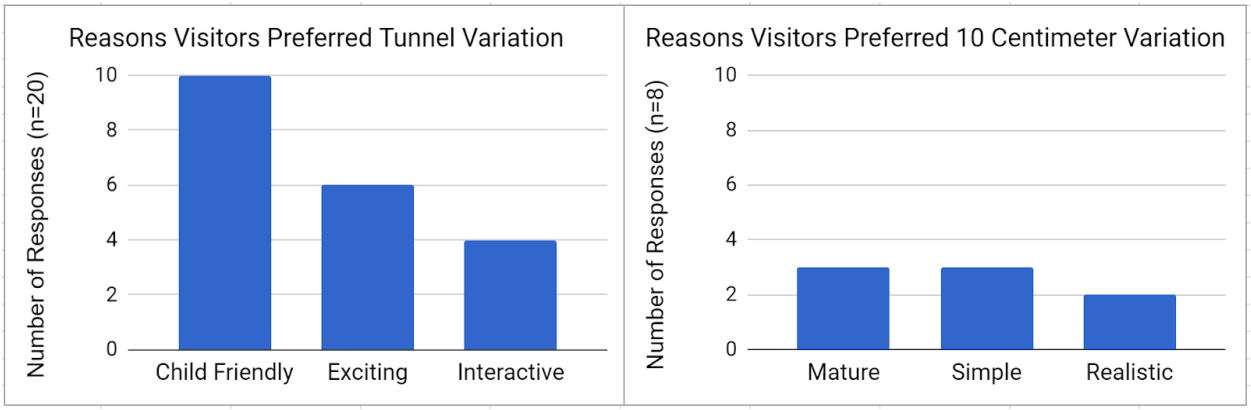


Figure 49: Graphs of Responses to Each Version Showing Reasons for Appeal

We timed Iteration 2 tests, which averaged ten minutes each, and we estimated that our Iteration 1 tests averaged to 15-20 minutes each because presenting the prototype in stages was time consuming. Since visitors mostly tested in groups, but had slightly different feedback, we analyzed preferences by number of visitors tested. We also analyzed visitor demographics by person to accurately represent the results. We used convenience sampling to test many age groups and nationalities that we believe reflects the museum's audience. Visitor demographics

are shown in the Figure 49 and Figure 50.

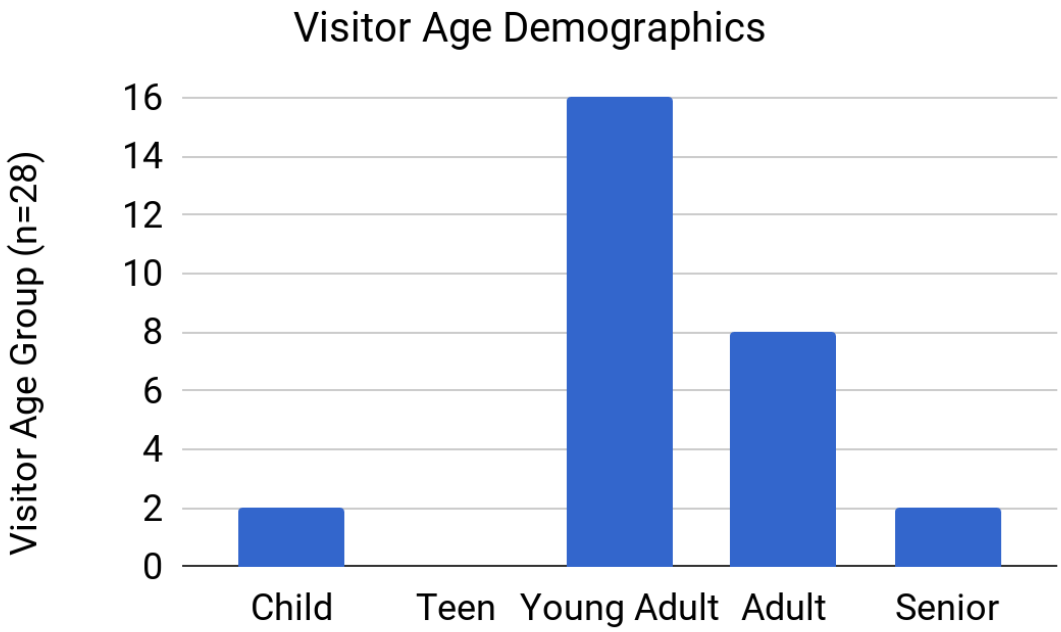


Figure 50: Age Demographics of Museum Visitors that Participated in Prototype Testing

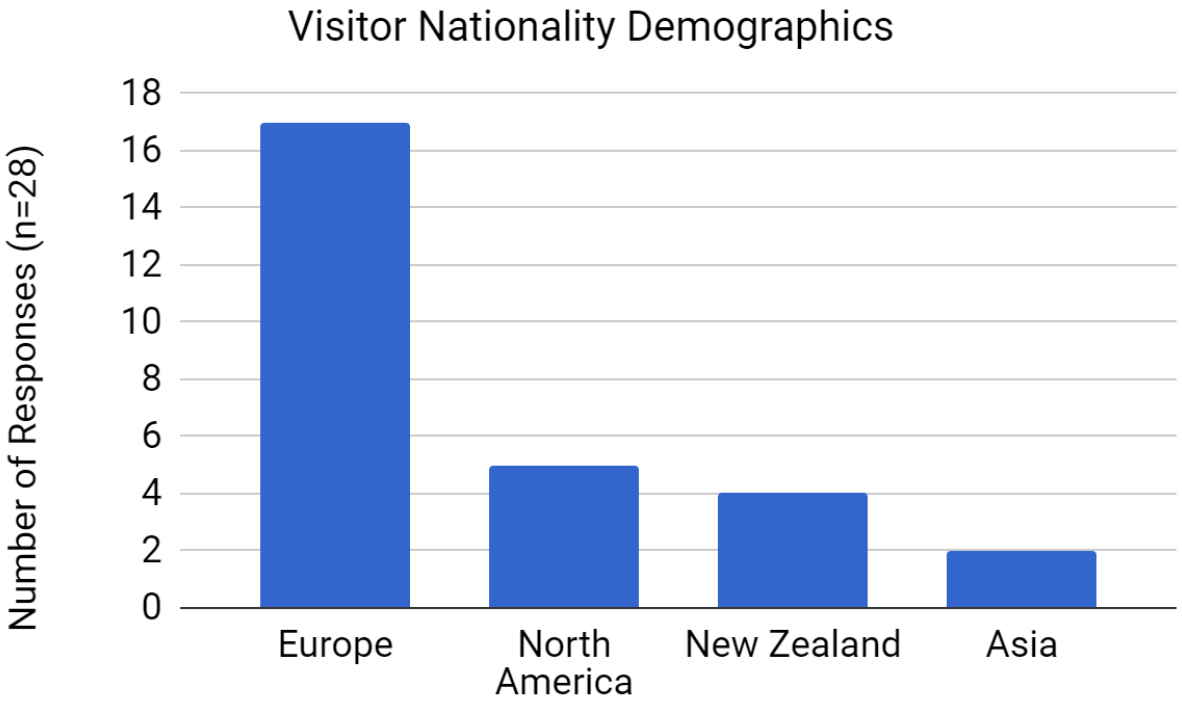


Figure 51: Nationality Demographics of Museum Visitors that Participated in Prototype Testing

Discussion of Results for Objective III

The storyboards set a foundation for our visitor testing process. By outlining each step of the visitor interaction with our design, we identified which aspects of our design would have to be controlled by our testing team. For example, we realized that in order to link the slider on the ice core model to the timeline, we would need some sort of marker on the timeline that corresponded to the position of the slider. This led us to include a hand controlled timeline marker in our Iteration 1 prototype that the operator would move in accordance with the visitor's slider movements. Our meeting with the content writers of the renewal team helped us to finalize our information hierarchy. This meeting also brought up some ideas about the manifestation of information in our design, such as the compression of the timeline scale to mimic the compression of layers in an ice core. We used some of these other ideas to suggest further visitor testing in Chapter 7.

Our revised information hierarchy and information schematic provided a framework for our Iteration 1 prototype testing with visitors. To ensure that our design conveyed the information we expected, we decided to test our prototype based on our revised information hierarchy and information schematic. We introduced components of the prototype to visitors in stages and asked them questions pertaining to each stage. In this way, we tested the information hierarchy to receive visitor feedback on specific aspects of our design. After refinement, we decided to test our full design in Iteration 2 without introducing the components in steps to simulate a more realistic experience for visitors.

We drew from the Worcester EcoTarium's testing process that consisted of two members of the design team, one acting as a facilitator and one acting as an observer, which aligned with the method used in Snyder's book, *Paper Prototyping: The Fast and Easy Way to Design and Refine User Interfaces*. Our team initially anticipated to use the process recommended by both of these sources. During the initial testing with two members of the design team, it was difficult for the facilitator to guide users through the experience, ask questions, and move pieces of the prototype accordingly. This caused our team to adjust our testing method, adding a third member to the process to act as an operator. The operator took over the facilitator's initial role to move the pieces of the prototype. This allowed for the facilitator to focus on the flow of conversation and visitor experience, while the operator focused on the movement of the interactive. Our team established that adding an extra member to the testing process allowed us to gain better feedback with visitors by streamlining the visitor experience.

The results from our preliminary testing with members of the renewal team, including Chloe Johnston and Clayton McGregor, provided feedback that our methods would provide useful results. Chloe Johnston leads all visitor testing of future exhibitions at Te Papa. As a result, her expertise was helpful to understand refinements to our testing procedure. Chloe Johnston mentioned that several in-depth interviews would be far more helpful than many quick ones. Our interactions with museum visitors of diverse ages and nationalities were thorough and gave us detailed feedback on our design.

In our preliminary testing, the renewal team members suggested reducing the length of the timeline to focus on the carbon dioxide spike in the last 200 years. However, our team decided to keep our initial timeline of the last 10,000 years for the first iteration of testing. After receiving visitor feedback in Iteration 1 that historical stability in carbon dioxide concentrations was important but not interesting, we decided to display this portion of the timeline with a static display. We showed the last 2,000 years on the interactive timeline, which highlighted the spike in carbon dioxide concentrations and provided event descriptions that were more interesting and relatable to visitors. This change eliminated visitor suggestions to reduce the length of time in our interactive timeline during Iteration 2 testing.

One of the questions in our script from both iterations was: "*Do you have any suggestions for improving our design?"* Visitors provided many answers and we compiled the most common and helpful responses here:

Suggestions from visitors for improvement:

- Focus on the carbon dioxide spike more (Iteration 1 only)
- Historical stability of carbon dioxide concentrations is important
- Relate ice cores to tree rings to make them relatable
- Parts per million (PPM) is confusing
- Vertical core would make it easier to understand
- Conclude with information on actions that reduce climate change

After seeing the carbon dioxide timeline, many visitors said they were familiar with climate change and wanted to know more information. This indicated to us that many people were interested in reducing their contribution to the problem despite having 'alarming' and 'scary' reactions to the information (see Figure 45). We noticed that this observation was consistent with the results of the 'National Visitor Study Results' document that we reviewed in Objective I. This solidifies the claims by Swim & Fraser, discussed in Chapter 2, that presenting

potentially distressing issues, such as climate change, in a positive way is effective for motivating action.

This seems to contradict the intent of our design to be a positive exhibition that is uplifting. However, these are reactions specifically towards the carbon dioxide timeline, not the entire exhibition. We decided to refrain from explicitly asserting that climate change is due to human activity to keep visitors from feeling like the idea is forced upon them. However, to encourage visitors to take ownership of the problem, we tried to create a situation where they came to that conclusion themselves. Once we added the other parts of the interactive, visitor responses tended to balance between concern of climate change, interest in ice core research, and questions about actions they could take to reduce climate change.

While these findings are important, our team established with the renewal team in Objective I that future actions against climate change would be an element of the carbon dioxide exhibition and not the ice core exhibition. The primary goal of our project was to inform museum visitors about the role of ice cores in understanding climate change. However, this information may serve as proof that our design will provide a segue for visitors into the neighboring carbon dioxide exhibition and the presentation of future actions.

Visitors' learning outcomes from testing our prototype indicated that our design was communicating the messages we intended. While responses from visitors did not exactly match the messages in our information hierarchy, many of them indicated a clear relation to these messages. As seen in the coded results in Figure 47, visitors identified that carbon dioxide levels have remained relatively constant and have risen dramatically within the past 200 years. This message is essentially the information in the top level of our information hierarchy in Figure 40. Visitors also identified that ice cores store information from the past. This message was on the middle level of our information hierarchy. Many people attributed the change in carbon dioxide levels to human activity and described other effects of human activity. This message was not outlined in our information hierarchy, as we thought making this statement might communicate the negative outlook of climate change we were trying to avoid. However, this response indicates that visitors are critical of human contribution to climate change and may be more inclined to change their own behavior after making this connection for themselves. Only one visitor out of sixteen reacted defensively to the exhibition saying, "I don't want to see that I am bad and the problem" (Iteration 2: Test 6, Appendix C). Overall, it seems that the visitor responses to our interactive were in line with our goals because we communicated the urgency of climate change to visitors while letting visitors come to their own conclusions.

We found interesting results in response to the question of which ice core representation appealed to visitors the most. This information corresponded to feedback we received from the renewal team. Many visitors thought that children would enjoy the tunnel aspect of the *Tunnel Version* and that it was more interesting and interactive than the *10 Centimeter Version*. Several of the visitors thought a more realistic representation of an ice core is easier to understand and straightforward. Overall, 75.0% groups of visitors liked the *Tunnel Version* while only 43.8% liked the *10 Centimeter Version* (n=16). However, all of the families with children strongly preferred the *Tunnel Version* and 57.1% of the visitors that liked the *10 Centimeter Version* also liked the *Tunnel Version* (n=7). We concluded that the *Tunnel Version* would appeal to the largest and most diverse audience of museum visitors.

Chapter 7: Recommendations and Conclusion

This project aimed to aid Te Papa in communicating to its visitors the importance of ice core data as evidence for climate change. Our team's goal was to develop an interactive exhibition that successfully conveyed this message. Based on the information we gained throughout this project and results of testing prototypes with museum visitors, our team created a set of recommendations for Te Papa to consider for their final exhibition. Along with our final design, these recommendations serve as a culmination of our work for the museum to consider as a basis for the next stage in their renewal project.

Recommendations

Our final design serves as a deliverable for the museum to consider in the Natural History Renewal Project. There are two versions that both consist of an ice core representation associated with an interactive carbon dioxide timeline. The two versions of this design vary in the way that the ice core is represented. The first version consists of a 10 centimeter model of an ice core, which will imitate a real ice core in appearance. The alternate version consists of an enlarged representation of an ice core that is hollow to allow children to crawl through it.

Our team recommends that the *Tunnel Version* is incorporated into the final exhibition. This design received positive feedback from museum visitors during our testing and provides interaction for adults and children. The inside of the tunnel should contain content pertinent to a younger audience with very basic messages about the ice cores. We think this information should be displayed through visual and tactile elements such as visible bubbles and raised layers based on recommendations from visitors.

Our team recommends that the carbon dioxide timeline consist of a static component and a dynamic component, the dynamic portion being the main focus of the interactive. The timeline should be simplistic and clear. Our team recommends that the two messages of this interactive should be that the CO_2 concentration level was relatively steady for thousands of years and has increased at an alarming rate in the last 200 years, and that ice cores play an important role in preserving data to understand climate change. This information should be displayed using both the visual information in the ice core and the descriptive information on the timeline. The information displayed on the timeline should be a combination of time markers, such as well-known dates in world and human history, and natural events that can be seen or

related to the physical ice core. In addition, there should be events that correspond to the CO_2 level increase and suggest a human impact on the environment.

Our team recommends a sliding mechanism that relates the ice core model to a carbon dioxide timeline. This sliding mechanism will consist of a viewport on a rail that allows the user to move the viewport along the length of the core and focus on specific points in the ice core model that correspond to events on the timeline. We think that the viewport should reveal information within the ice core model through illumination. This movement should be linked to the timeline and connect a description to the visual within the ice core model.

Our team recommends that other information on ice cores and explanation of their extraction process and purpose should be displayed as part of this entire ice core exhibition prior to the interaction. This information could be displayed in a secondary audio visual display. The purpose of this supplementary information would be to provide context for visitor interaction with our design. In addition, we recommend the supplemental display of a vertical 10 centimeter ice core model or graphic that conveys the actual depth and relation of layers in the ice to years of snowfall. This would explain how a real core is extracted and that the oldest layers are at the bottom of the core. This display has the potential to serve as a fun interactive for visitors, as they could measure their height and relate it to the length of an ice core.

Conclusion

Through assessment, design, and prototyping, our team identified a way to communicate that ice cores are important in understanding climate change. Based on the results from each of our objectives, our team presented a final design (Figure 52) for the ice core interactive to Te Papa and delivered recommendations for further progress on the renewal project.

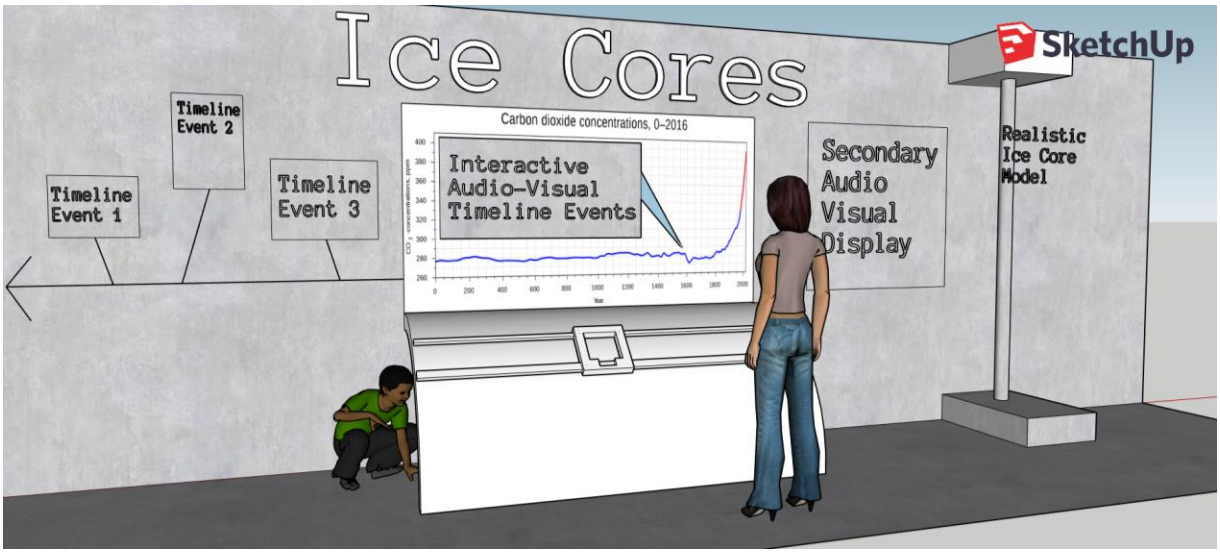


Figure 52: Representation of Ice Core Interactive Exhibition

In our final design, the interactive portion of the carbon dioxide timeline is linked to the position of the slider on the ice core model. The 'Interactive Audio-Visual Timeline Events' on the timeline would explain the event and encourage visitors to examine a corresponding visual within the ice core model. Younger audiences could examine the ice core model from inside the tunnel. External to this interactive would be a continuation of the carbon dioxide timeline with other timeline events. The 'Secondary Audio Visual Display' would convey other contextual information on ice core research and the 'Realistic Ice Core Model' would give visitors a sense of what an actual ice core looks like. It is important to note that our project focused primarily on the development of the interactive timeline and ice core tunnel portion of this exhibition. The external components in Figure 52 are a product of visitor feedback and team decisions and have not been tested with visitors.

We compiled a concise, technical summary of our final design to submit to the renewal team so they could quickly reference it when going forward with the design development. We uploaded the document to Te Papa's internal database, Pou Mataaho, so that the renewal team could easily access it, and included a copy in Appendix D.

In addition to our final design and recommendations, our team suggests the following points as potential further research for the museum to conduct to further inform their final design.

- Prototype and test appeal and educational value of inside of tunnel on *Tunnel Version* with younger audiences. We tested for the appeal of the overall *Tunnel Version* and the

overall *10 Centimeter Version* but did not have the resources or time to prototype and test a tunnel version with children.

- Prototype and test specific events on the carbon dioxide timeline. We tested with a limited number of timeline events and there may be more possibilities for this aspect of our design. Perhaps this could be done with both the permanent events on the timeline and the dynamic events that relate to the ice core model.
- Prototype and test points of interest in the ice core model. We tested with a small number of points of interest in the ice core model and other visuals in the ice might be more informative and/or appealing. This may be determined by the specific events used on the carbon dioxide timeline or vice versa.
- Prototype and test other supplemental interactive designs from our brainstorming sessions. Several renewal team members mentioned that they were intrigued by some of our other ideas. These could be incorporated into the ice core exhibition along with our recommended final design.

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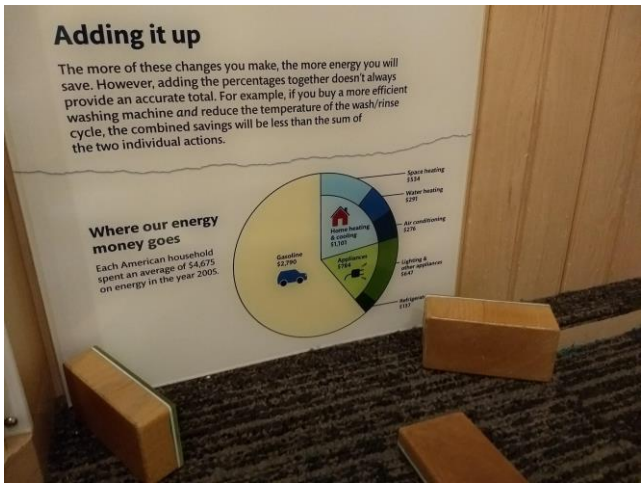
Appendix A: Photographs of Field Research

Museum of Science in Boston, Massachusetts on December 1st, 2017

How Did you Show Double?, visitor feedback

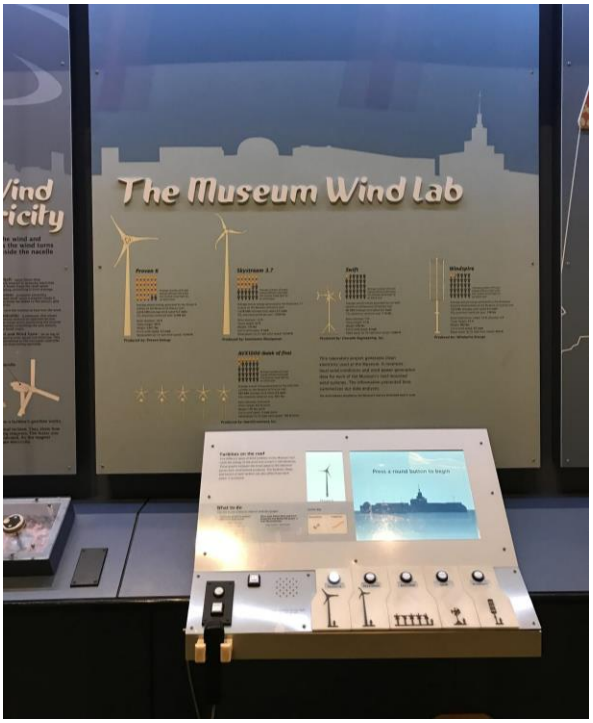
What's a Watt?, understanding energy use

Turn Your Energy into Light, light bulb



Adding it Up, a home energy distribution

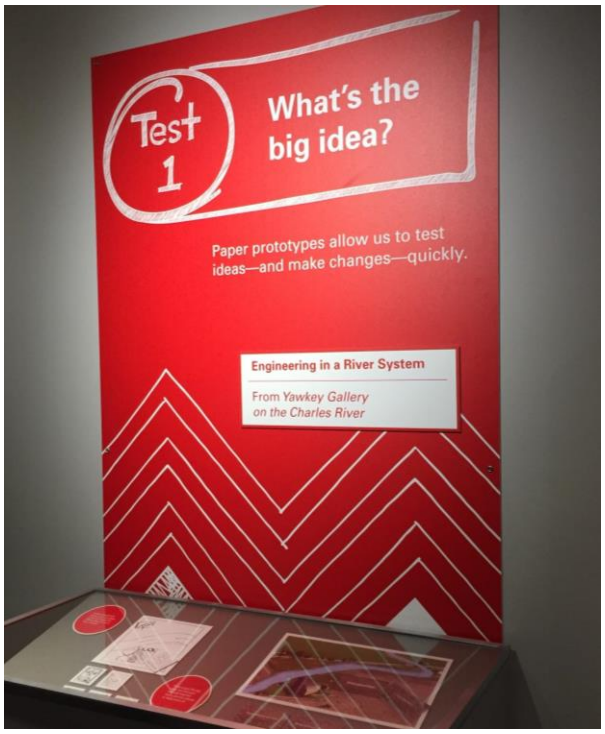
The River Table uses projections and interchangeable parts to show visitors how human decisions can impact a river



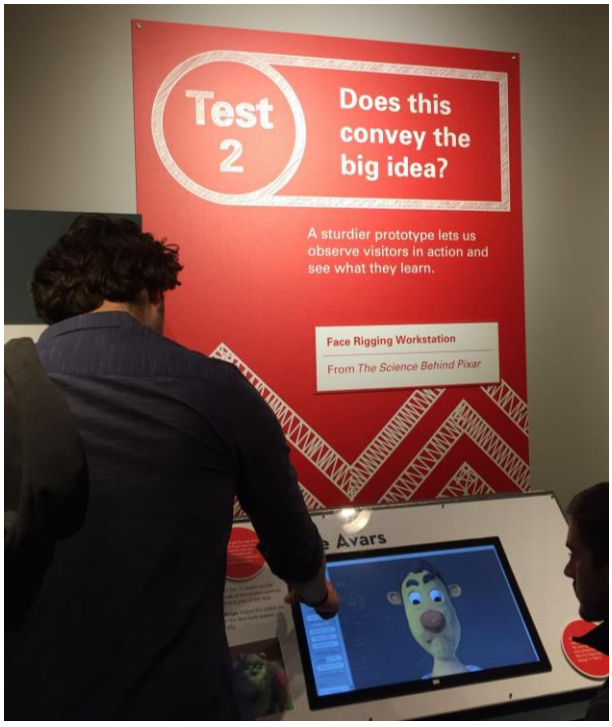
The Museum Wind Lab

The MOS workshop

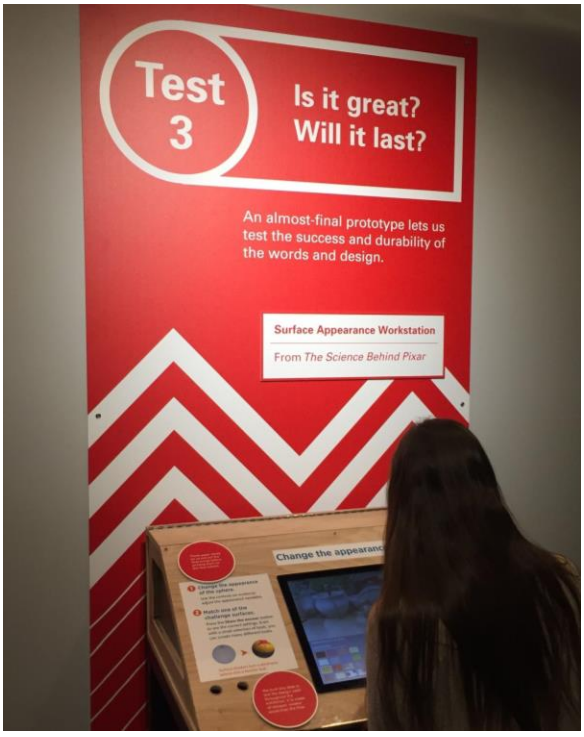
An exhibit is being renewed



Behind the Scenes Test 1



Behind the Scenes Test 2



Behind the Scenes Test 3

EcoTarium in Worcester, Massachusetts on December 8th, 2017

An interactive mechanism about forests

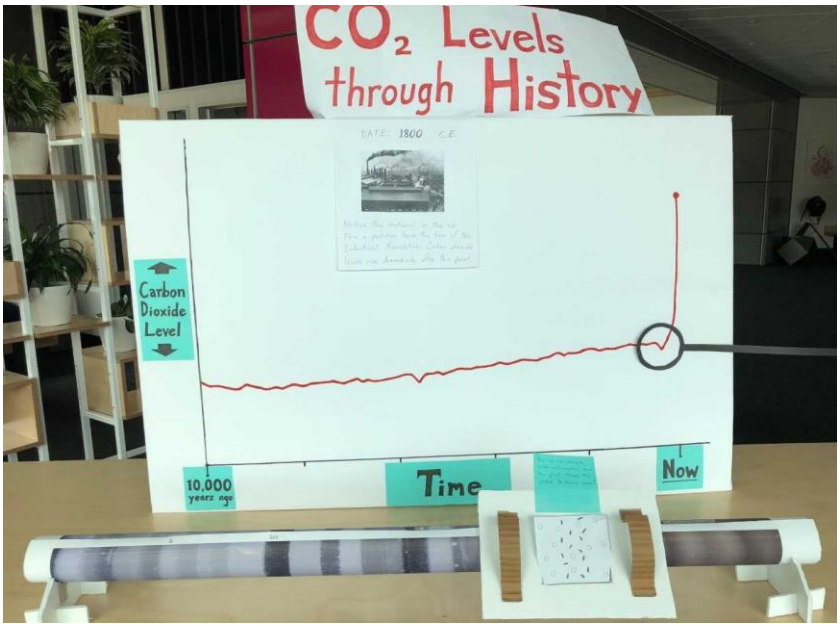
City Hot Zones heat map interactive

Exhibition instructions focus on using pictures

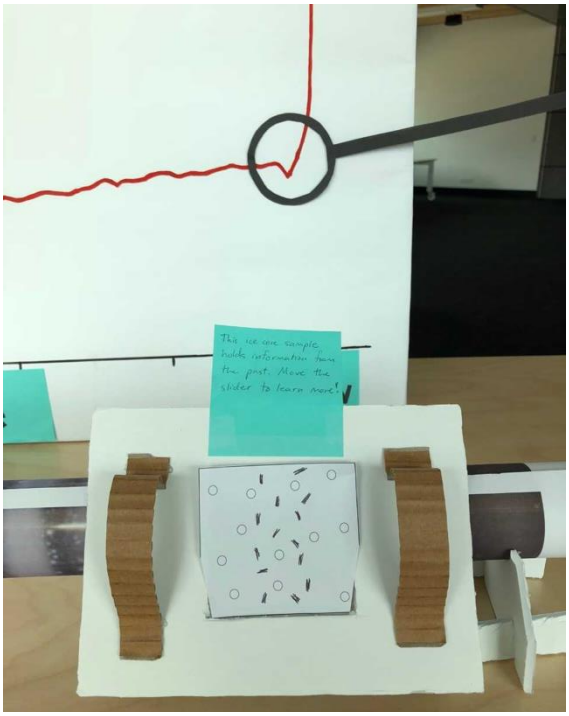
Bridges Exhibition in action

A method of gaining visitor feedback

Appendix B: Iteration 1 Testing Notes



Iteration 1 prototype ready to test



Close up picture of slider

Facilitator Script

Have you been to Te Papa before? Where are you from?

We appreciate that you are taking some time to help us develop this future exhibition! We want to let you know that we're testing our ideas for the exhibition – we're not testing you. Any feedback or criticism along the way is very helpful to our process and we encourage you to ask any questions or give any suggestions to make this experience better. There's no such thing as a silly question. Your participation is completely voluntary and you are welcome to leave at any time. If you don't mind, we will be taking notes on this activity.

If you are ready, we can begin.

1. Present Graph/Timeline

"There are two pieces to our design. The first is this graphic which will be presented on the wall. Have a look and see what you think."

What is your first impression from seeing this display? Why?
Any thoughts or feelings looking at this?
Did you learn anything from this? How or why did you gain this information?

2. Present Model Ice Core

[put ice core model in front of graph]

"This object will be positioned in front of the graphic on the wall."

What is your first impression when you see this object? Please keep in mind that this is a prototype.

"This object is the second component in our design. It is a model of an Antarctic ice core. Please take a moment to observe the model."

What do you notice when looking at this core?
Do you find anything about this model interesting?

3. Present Slider

[put slider over ice core model, position graph marker on graph]

"This device would be positioned over the ice core model on a rail. Please take a moment to interact with this device."

[as visitor moves slider, marker moves along the timeline]
[at points of interest, manipulator puts viewport graphic in slider, facilitator puts blurbs on timeline]

"If you see something of interest in the ice core model, please stop the slider viewport over it so that we can adjust the prototype."

What did you discover from this ice core?

Why do you think the slider and the marker on the graph move together?
With these added pieces, did you learn anything new or surprising?

4. Appeal

[present two versions of design]

"There are two versions of this exhibition, the first involves a life sized model of an ice core similar to what you just interacted with. The other consist of a large scale of an ice core that also acts a tunnel for visitors to crawl through."

Which design is more interesting to you? Why?

5. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?
Do you have any suggestions for improving our design?

"Thank You again for your feedback! Your input will help us improve this design. Anything else?"
Add something about if they would be interested in projections based on ice core research into the future

Observer Notes Sheet

Present Graph/Timeline

What is your first impression from seeing this display? Why?

Any thoughts or feelings looking at this?

Did you learn anything from this? How or why did you gain this information?

Present Model Ice Core

What is your first impression when you see this object? Please keep in mind that this is prototype.

"This object is the second component in our design. It is a model of an Antarctic ice core. Please take a moment to observe the model."

What do you notice when looking at this core?

Do you find anything about this model interesting?

Present Slider

"This device would be positioned over the ice core model on a rail. Please take a moment to interact with this device." "If you see something of interest in the ice core model, please stop the slider viewport over it so that we can adjust the prototype."

What did you discover from this ice core?

Why do you think the slider and the marker on the graph move together?

With these added pieces, did you learn anything new or surprising?

Appeal

Which design is more interesting to you? Why?

Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Do you have any suggestions for improving our design?

Testing Results

Test 1: Two female young adults from the U.S.

Present Graph/Timeline

What is your first impression from seeing this display? Why?

Easy to read, see where you are going.

Any thoughts or feelings looking at this?

[Climate change is] concerning, alarming - connect to what they are faced with.

Did you learn anything from this? How or why did you gain this information?

Not new, confronted with this information before.

Present Model Ice Core

What is your first impression when you see this object? Please keep in mind that this is prototype.

Don't know what it is.

"This object is the second component in our design. It is a model of an Antarctic ice core. Please take a moment to observe the model."

"Oh" moment when we said ice core.

What do you notice when looking at this core?

Ice core through time, dirtiness.

Do you find anything about this model interesting?

Would need more information.

Present Slider

"This device would be positioned over the ice core model on a rail. Please take a moment to interact with this device." "If you see something of interest in the ice core model, please stop the slider viewport over it so that we can adjust the prototype."

Correlating time and CO2 level? Understand concept - move slider slowly and see what happens.

What did you discover from this ice core?

Chernobyl - "yikes," "globalized" not "localized," things spread around the earth.

Why do you think the slider and the marker on the graph move together?

Yes, as soon as they move slider and see the graph moving match impact with ice.

With these added pieces, did you learn anything new or surprising?

Appeal

Which design is more interesting to you? Why?

Large tunnel is more exciting, see in the ice core, more effective. 10cm is more straightforward.

Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Human impact is very detrimental [to the environment].

Do you have any suggestions for improving our design?

Human population chart - force some causation, more info on ice core and what they are used for (why ice cores), important to show steady part of graph, last part of interactive hit home.

Test 2: Male and female young adults from Germany

Present Graph/Timeline

What is your first impression from seeing this display? Why?

Scary - what happened right before the spike?

Any thoughts or feelings looking at this?

Interesting [CO2] went down in 18th century - want to know why
Hard to say its a natural thing - Bam! Up
What's the impact - CO2 amount - give it some meaning

Did you learn anything from this? How or why did you gain this information?

Intrigued to know what the small dips mean
Rise is so intense

Present Model Ice Core

What is your first impression when you see this object? Please keep in mind that this is prototype.

what different colors mean?
Looked really deep into it
Dark means how much CO2?

"This object is the second component in our design. It is a model of an Antarctic ice core. Please take a moment to observe the model."

What do you notice when looking at this core?

Do you find anything about this model interesting?
Really interested in size of layers - what they mean

Present Slider

"This device would be positioned over the ice core model on a rail. Please take a moment to interact with this device." "If you see something of interest in the ice core model, please stop the slider viewport over it so that we can adjust the prototype."

"Interesting" - C.E. confusing at first

What did you discover from this ice core?
Confusing

Why do you think the slider and the marker on the graph move together?

With these added pieces, did you learn anything new or surprising?
"Oh" moment - very cool

Appeal

Which design is more interesting to you? Why?
more 10cm design
Tunnel doesn't add value - more cost
Little children get nothing out of graph
Fingerprints on tunnel

Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?
Actually measure something in the ice that happened far away

Do you have any suggestions for improving our design?
Backstory about ice - where it's from, etc
Relate to tree rings - tangible - tie info to something they've heard of
Static images for children to relate to
Other ways to get CO2 data - now we do this, etc
Why CO2 was rising - what causes differentiate causes/events

Test 3: Male and female adults from the U.S.

Present Graph/Timeline

What is your first impression from seeing this display? Why?

Al Gore's graph from movie Inconvenient Truth
Use slider, industrial revolution
What are the units?

Any thoughts or feelings looking at this?

Drop off - why?
Alarming - triggers
Can't predict the future

Did you learn anything from this? How or why did you gain this information?

Present Model Ice Core

What is your first impression when you see this object? Please keep in mind that this is prototype.

Core sample, ice or rock?

"This object is the second component in our design. It is a model of an Antarctic ice core. Please take a moment to observe the model."

Slide wasn't super clear - scientist gets it (as scientists they get it)

What do you notice when looking at this core?

Colors - curious to know what's going on
Years - don't line up - need expanded scale version

Do you find anything about this model interesting?

Present Slider

"This device would be positioned over the ice core model on a rail. Please take a moment to interact with this device." "If you see something of interest in the ice core model, please stop the slider viewport over it so that we can adjust the prototype."

What did you discover from this ice core?

Ash - darker layer - snapshot

Why do you think the slider and the marker on the graph move together?

They link CO2 over time

With these added pieces, did you learn anything new or surprising?

Will be a good exhibition - give digestible info that will stay with them

Appeal

Which design is more interesting to you? Why?

Value to 10cm design physical dimensions
Can tunnel have another level of interactivity?

Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Do you have any suggestions for improving our design?

Over 10,000 this is much…
After 200 this…..huge spike
Scale - amount of C02/timeline - linear
"Timeline" software
Let people know that ice traps atmosphere early - background
Sideways is confusing to relate to time
Image to side - explain depth a little more upfront
Present "bubbles" info right away
Atomic bomb as a data point - h-bomb testing
Core testing tells you ash, pollution
More data points
Something hopeful at the end, what can you do - limit carbon footprint, cure earth
Quantity message - add radioactivity plots

Test 4: Male adult from New Zealand

Present Graph/Timeline

What is your first impression from seeing this display? Why?

"What happens next?" pointing at the end of the graph
I understand it and I've looked at what's happening and what's after this?

Any thoughts or feelings looking at this?

[Climate change] is a disaster, it's not very good

Did you learn anything from this? How or why did you gain this information?

Present Model Ice Core

What is your first impression when you see this object? Please keep in mind that this is prototype.

It's an ice core

"This object is the second component in our design. It is a model of an Antarctic ice core. Please take a moment to observe the model."

What do you notice when looking at this core?

There's years on it (visitor has seen pictures of ice cores, seems to have some background knowledge.) Testing and following evidence

Do you find anything about this model interesting?

Present Slider

"This device would be positioned over the ice core model on a rail. Please take a moment to interact with this device." "If you see something of interest in the ice core model, please stop the slider viewport over it so that we can adjust the prototype."

What did you discover from this ice core?

Seems to really like ice core, "this is my pet subject"

This proves that something is happening

Why do you think the slider and the marker on the graph move together?

Seems to think it's cool

Important to educate people

Showing people that we found stuff in the ice

Scared for his kids and his grandkids

With these added pieces, did you learn anything new or surprising?

It's showing there's a point for all our contamination

Seems to like it

Appeal

Which design is more interesting to you? Why?

Thinks tunnel is more interesting

Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

It's a big issue, we need to think about it. Cleaning up your backyard. He's from coromandel, need to clean up at home first. Notices rubbish around beautiful nature areas

We have an addiction to hurting the environment

This is our problem, the planet will still be there but we won't

Do you have any suggestions for improving our design?

Drew him in
Interactive always gets people interested
Compared it to rock lifting exhibit in awesome forces
Gives him faith
Addiction to spending/traveling/industry is bad
Did you think about methane?

Test 5: Male and female adults from New Zealand

Present Graph/Timeline

What is your first impression from seeing this display? Why?
Is it something to do with carbon dioxide has changed?

Any thoughts or feelings looking at this?

It's a bit scary seeing it on the graph

Have you got a timeframe? → We have a rough timeline for now

Did you learn anything from this? How or why did you gain this information?

It shows us about climate change, definitely

Present Model Ice Core

What is your first impression when you see this object? Please keep in mind that this is prototype.

Noticing layers, darker at the end, pointing out years

"This object is the second component in our design. It is a model of an Antarctic ice core. Please take a moment to observe the model."

This is a core sample from where? → Antarctica

What do you notice when looking at this core?

Do you find anything about this model interesting?

Present Slider

"This device would be positioned over the ice core model on a rail. Please take a moment to interact with this device." "If you see something of interest in the ice core model, please stop the slider viewport over it so that we can adjust the prototype."

What did you discover from this ice core?

CO2 levels are going through the roof, killing the planet
That's really interest, talking about nuclear bomb on Christmas island, personal connection
Government does something and then runs and hides
So many disasters, planet deteriorates
Need whole world on board to make change
[The exhibition] puts it across well
Their generation has killed it for us [the testers]
Store seeds to keep them safe, protect animals, governments need to make changes
Asking questions about how long ice samples are kept
They have seen effects of climate change in their lifetimes, summers are getting hotter and winters are getting colder

Why do you think the slider and the marker on the graph move together?

With these added pieces, did you learn anything new or surprising?

Appeal

Which design is more interesting to you? Why?

The children would like the tunnel design

Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

We're killing our planet
I'm freaked out
The more mankind has got cleverer, the more mankind has killed the planet
We've gone for more electronics and plastic, we need to go back to using less
Have we got time?
Do we all realize what we have to do?
What do we do as the general public?
Little ones learn about it in school, important to teach adults through this

Do you have any suggestions for improving our design?

It's a little confusing for the first second but then it makes sense
Like slider
Sitting underneath will be interesting to children

Test 6: Male adult and male child from China

Present Graph/Timeline

What is your first impression from seeing this display? Why?

The chart is so strange, the data is so high. The data shows it's very high

Any thoughts or feelings looking at this?

Maybe will affect our lives

Did you learn anything from this? How or why did you gain this information?

It takes a few years...I don't know

Present Model Ice Core

What is your first impression when you see this object? Please keep in mind that this is prototype.

Don't know what it is, child also does not know

"This object is the second component in our design. It is a model of an Antarctic ice core. Please take a moment to observe the model."

What do you notice when looking at this core?

Ice core? Shows the ice is melting?

Facilitator gives a bit more explanation of what ice cores are

Do you find anything about this model interesting?

Present Slider

"This device would be positioned over the ice core model on a rail. Please take a moment to interact with this device." "If you see something of interest in the ice core model, please stop the slider viewport over it so that we can adjust the prototype."

Playing with slider, look interested

What did you discover from this ice core?

Mentioned pollution

Why do you think the slider and the marker on the graph move together?

It's highly related

With these added pieces, did you learn anything new or surprising?

The air is polluted
It's from the industrial revolution
The climate dramatically changed due to people's activity

Appeal

Which design is more interesting to you? Why?

Likes crawl through
People can be more involved
Kids can go through inside
Asked child
Child pointed to tunnel

Overall Evaluation

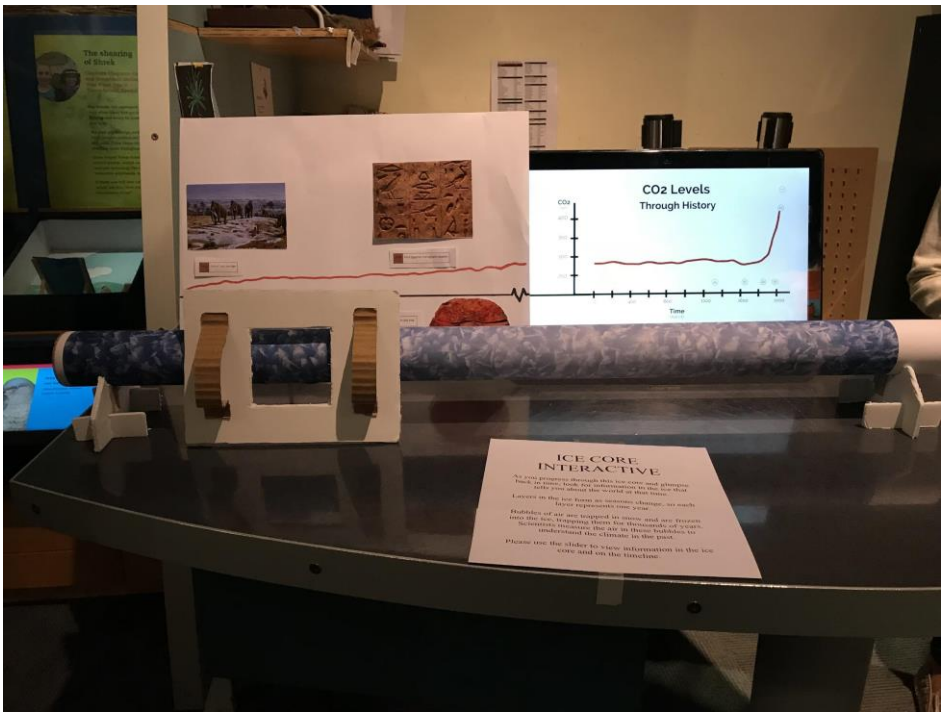
If you had to explain your experience with this prototype to someone at home, what would you tell them?

I'd invite them to visit Te Papa

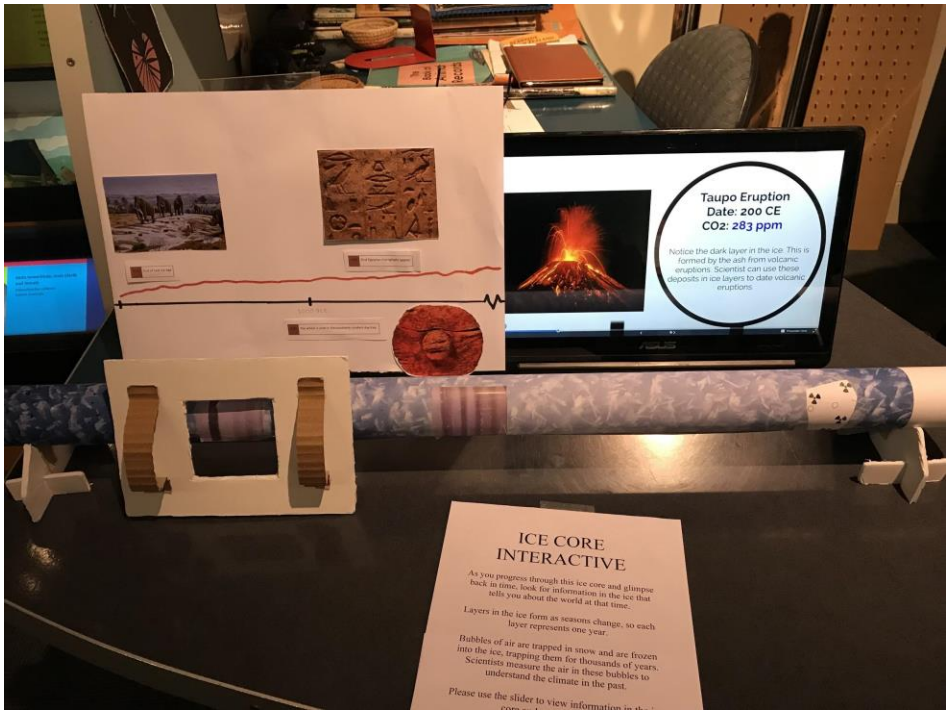
Do you have any suggestions for improving our design?

Likes tunnel design

Appendix C: Iteration 2 Testing Notes



Iteration 2 prototype ready to test



Timeline additional information display

Supplementary Explanation

ICE CORE INTERACTIVE

As you progress through this ice core and glimpse back in time, look for information in the ice that tells you about the world at that time.

Layers in the ice form as seasons change, so each layer represents one year.

Bubbles of air are trapped in snow and are frozen into the ice, trapping them for thousands of years. Scientists measure the air in these bubbles to understand the climate in the past.
Please use the slider to view information in the ice core and on the timeline.

Slide Content

Ancient Roman smelting
Date: ~ 0 CE
CO_2: ~ 278 ppm
Notice the particles in the ice. These are traces of metalworking from the Roman Empire.

Taupo Eruption
Date: ~ 200 CE
CO_2: ~ 283 ppm
Notice the dark layer in the ice. This is formed by the ash from volcanic eruptions. Scientist can use these deposits in ice layers to date volcanic eruptions.

First Polynesian travelers settle New Zealand
Date: ~ 1300 CE
CO_2: ~ 285 ppm
Around this time, Polynesians were exploring the Pacific Ocean and discovered New Zealand.

Abel Tasman finds New Zealand
Date: 1642 CE
CO_2: ~ 275 ppm
Abel Tasman arrived in New Zealand, making him the first European to find New Zealand.

Industrial Revolution
Date: ~ 1800 CE
CO_2: ~ 275 ppm
During the industrial age, manufacturing processes and other technological advances started releasing large amounts of CO_2 into the atmosphere. As seen in the timeline, CO_2 levels have rapidly increased since this time.

Chernobyl Disaster
Date: 1986 CE
CO2: 347 ppm
Notice the radioactive matter in the ice. This is from the Chernobyl disaster in Ukraine.

Present Day
Date: 2018 CE
CO_2: 409 ppm
CO_2 levels are still rising alarmingly fast. The future of our planet is dependent on reducing CO_2 emissions.

Future CO_2 Levels
Ice cores allow scientists to develop and test climate models that predict future CO_2 levels. Here are some of the predictions of future CO_2 levels in the atmosphere based on different CO_2 emissions:

Facilitator Script

Have you been to Te Papa before? Where are you from?

We appreciate that you are taking some time to help us develop this future exhibition! We want to let you know that we're testing our ideas for the exhibition – we're not testing you. Any feedback or criticism along the way is very helpful to our process and we encourage you to ask any questions or give any suggestions to make this experience better. Your participation is completely voluntary and you are welcome to leave at any time. If you don't mind, we will be taking notes on this activity. If you are ready, we can begin.

1. Interaction

[present the interactive]

"Please take a few moments to look at and interact with this prototype. Any questions, thoughts, or comments you can share with us will be extremely helpful to the development of this exhibition."

2. Comments

What is your first impression from seeing this display? Why?
Any thoughts or feelings looking at this?
Do you find anything about this interactive interesting?

What did you discover from the graph? The ice core and slider?
After interacting with this, do you have any thoughts about the future climate?
Did you learn anything from this?

3. Appeal

[present two versions of design]

"There are two versions of this exhibition, the first involves a life sized model of an ice core similar to what you just interacted with. The other consist of a large scale of an ice core that also acts a tunnel for younger visitors to crawl through."

Which design is more interesting to you? Why?

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?
Do you have any suggestions for improving our design?

"Thank You again for your feedback! Your input will help us improve this design. Anything else?"

Observer Note Sheet:

Facilitator: _____
Observer: _____
Operator: _____

Duration: _____

Where they are from:
_____

Gender:
- ❑ Male
- ❑ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ❑ Young Adult: 20-30
- ❑ Adult: 30-65
- ❑ Senior: 65+

1. Interaction

[present the interactive]

2. Comments

What is your first impression from seeing this display? Why?

Any thoughts or feelings looking at this?

Do you find anything about this interactive interesting?

What did you discover from the graph? The ice core and slider?

After interacting with this, do you have any thoughts about the future climate?

Did you learn anything from this?

3. Appeal

[present two versions of design]

Which design is more interesting to you? Why?

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Do you have any suggestions for improving our design?

Testing Results

Test 1:

Facilitator: Malachi
Observer: Holly
Operator: Tristin

Duration: 6.5 mins

Where they are from:
Oslo, Norway
Older woman and young adult man and young adult woman

Gender:
- ✓ Male
- ✓ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ✓ Young Adult: 20-30
- ❑ Adult: 30-65
- ✓ Senior: 65+

1. Interaction

[present the interactive]

Brief introduction
Looking at the prototype
Moving the slider
Looking at the screen
So if I hold it here it stands still?
Looking
Yeah well I liked it

2. Comments

What is your first impression from seeing this display? Why?

It's interactive and its fun, you can do it at your own tempo
Didn't get pictures moving as fast
I think it's a good idea
I like it

Any thoughts or feelings looking at this?

The timeline is good

Do you find anything about this interactive interesting?

Yeah I like the sliding

What did you discover from the graph? The ice core and slider?

I didn't study it that hard but if I did I would
Ice?

After interacting with this, do you have any thoughts about the future climate?

Lot of ideas about future climate
It's a catastrophe

Did you learn anything from this?

Everything has to do with everything

3. Appeal

[present two versions of design]

Which design is more interesting to you? Why?

Explanation of differences
I would like this one (10cm design) because I would not be crawling behind here
A bit more explanation that both have the slider
Well then I like this one (tunnel) because it would be more fun for kids

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

How it all changed

Do you have any suggestions for improving our design?

I think you need to spice it up
Maybe make it more colorful

Test 2:

Facilitator: Malachi
Observer: Holly
Operator: Tristin

Duration: 17 minutes

Where they are from:
Lives in New Zealand
Male around age 40

Gender:
- ✓ Male
- ❑ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ❑ Young Adult: 20-30
- ✓ Adult: 30-65
- ❑ Senior: 65+

1. Interaction

[present the interactive]

What's an ice core?

A cylinder of ice like this that scientists drill out of glacier. They find little bubbles trapped in the ice and measure the air to get info about CO2 in the air
Which is the oldest bit? This?
Alright what am I looking at? Once a year or something?
So what's the relationship between what i read there and what I'm seeing here?
When did this one get formed?
Nice representation of the Chernobyl disaster
What's ppm?
Okay so 409 molecules of CO2 per every million molecules
Okay that's pretty interesting
How do they know how old the ice cores are?
Layers are on of the easiest ways, brief explanation of layers
Oh like rings on a tree
Are you just presenting info or trying to predict the future?
Scientists create algorithms to predict change based on that past few years, explanation
So if we don't change things…
What are the actions to reduce CO2 emissions? Driving less cars?

2. Comments

What is your first impression from seeing this display? Why?

Pretty interesting
Pretty well put together
A couple points of confusion but you answered them well
Didn't know what an ice core was before but now i do

Any thoughts or feelings looking at this?

It sucks
It's not going to be good for my great grandchildren
It's a challenge for the government
It's hard to see governments change, they're in office for five years and this will impact us in a hundred years
Also is it purely humans or other things
Pointing out industrial revolution, never increased so rapidly
Till we created the internet and that fucked everything
Talking more about graph and projections
Scientists have studied increase in natural disaster
Are there animals already struggling
What kind of things do you guys do day to day to try to reduce carbon emissions? Or do you think you're a tiny piece and the government should do something to fix it
Going along with carbon emissions exhibit
We all need to do little things, every little bit helps

Do you find anything about this interactive interesting?

What did you discover from the graph? The ice core and slider?

After interacting with this, do you have any thoughts about the future climate?

Did you learn anything from this?

3. Appeal

[present two versions of design]

Tunnel looks a bit cooler
They could both work
They're both cool
Likes also the 10cm design
Would pick 10cm design if he has to pick one
Tunnel would probably cost more too

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Found it really interesting that that's how they gather data
Didn't know that before

Do you have any suggestions for improving our design?

Test 3:

Facilitator: Edj
Observer: Juliana
Operator: Tristin

Duration: 7 minutes

Where they are from:
From UK, male and female in 20s
first time at te papa

Gender:
- ✓ Male
- ✓ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ✓ Young Adult: 20-30
- ❑ Adult: 30-65
- ❑ Senior: 65+

1. Interaction

[present the interactive]

Looked confused but reading the paper on the bottom
Girl is hiding behind boy
Operator had to step in and explain the ice core and the slider mechanism
Guy started sliding the slider
He slid it fast and couldn't catch up with the timeline on the graph

2. Comments

What is your first impression from seeing this display? Why?
They don't know
Cool slider - gives a lot of info

Any thoughts or feelings looking at this?
No thoughts

Do you find anything about this interactive interesting?
I like how it tells the future of events and also the past
It is cool that you can see CO2

What did you discover from the graph? The ice core and slider?
It looks fine

After interacting with this, do you have any thoughts about the future climate?
Unclear with the question asked
It makes you think about the future - nothing in particular

Did you learn anything from this?
Not really - think about the future

3. Appeal

[present two versions of design]

Which design is more interesting to you? Why?
Both pointed to the tunnel
“I would crawl through”
People will remember and have two points of view
Very passionate about the tunnel - targets young and adults

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?
Interesting - I would go check it out
It's good to look at with info from future and past
It’s information you don't normally know

Do you have any suggestions for improving our design?

Not too difficult
Not too much info either
Don't have to be like 'ugh I have to read all of that'
Gives you enough info for each point on the graph
Gives a good flow of people too - don't have to hover and read for a half an hour

Test 4:

Facilitator: Edj
Observer: Juliana
Operator: Tristin

Duration: 6

Where they are from:
Male from Switzerland
first time at Te Papa
High 20s-low 30s

Gender:
- ✓ Male
- ❑ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ✓ Young Adult: 20-30
- ❑ Adult: 30-65
- ❑ Senior: 65+

1. Interaction

[present the interactive]

Reading the static graph
Looking at the ice core/graph and screen
Asked what does he have to do
Facilitator explains the slider mechanism and moves the slider at first
He slides it to a specific point
Looks at the info displayed while sliding
"About the history of the whole world"

2. Comments

What is your first impression from seeing this display? Why?

Nothing really
Sees the graph and points at the curve
Operator explains the static and dynamic potion

Any thoughts or feelings looking at this?

Do you show the effects for the future?
You should show how this effects would be helpful

Do you find anything about this interactive interesting?

What did you discover from the graph? The ice core and slider?

After interacting with this, do you have any thoughts about the future climate?

Did you learn anything from this?

Yea if I got into this
It would take time to go through the whole thing
Interesting with the peak and the curve that goes up
[Graph] was stagnant before and then increases suddenly

3. Appeal

[present two versions of design]

Which design is more interesting to you? Why?

The tunnel does attract more from first sight

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Display of CO2 build up with time
How future effects and how human effects

Do you have any suggestions for improving our design?

Have the future and predicting the future
Show how it will affect the future

Test 5:

Facilitator: Edj
Observer: Juliana
Operator: Tristin

Duration: 14 minutes

Where they are from:
Germany - first time at Te Papa
Mid 20s

Gender:
- ✓ Male
- ❑ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ✓ Young Adult: 20-30
- ❑ Adult: 30-65
- ❑ Senior: 65+

1. Interaction

[present the interactive]

Reading blurb on table
Asks to give feedback as he goes
Then he said he would start to move the slider
Heard about the graph and the sky rocket with CO2
Asks if there was a big gap in between points
“I don't care about the static point to be honest”
“Where it starts skyrocketing is where I am focusing on”
Al Gore movie reference

2. Comments

What is your first impression from seeing this display? Why?

I have been aware of the info
Try to stop it

Any thoughts or feelings looking at this?

No

Do you find anything about this interactive interesting?

It is an interactive which is good
When you do something active, you remember it better
Good idea to scroll along the ice core

What did you discover from the graph? The ice core and slider?

After interacting with this, do you have any thoughts about the future climate?

Did you learn anything from this?

No not really
Didn't know the eruption

3. Appeal

[present two versions of design]

Which design is more interesting to you? Why?

Tunnel would be better because multiple people have kids with them at museums

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

The CO2 levels and the atmosphere
The CO2 levels are harming the environment

Do you have any suggestions for improving our design?

Focus on the spike part [of the graph]
People will realize its skyrocketing in that part
Do you mention the temperature the temp is rising? - you should have that somewhere
More info about what CO2 means
End with an explanation of how it is harming us
More info how to prevent it from happening
How to change the industry how it is not CO2 heavy

Test 6:

Facilitator: Edj
Observer: Juliana
Operator: Tristin

Duration: 15 minutes

Where they are from:
Woman and her girl child
From Denmark
Girl around 9-10
Works around the ice core stuff in Greenland

Gender:
- ❑ Male
- ✓ Female
- ❑ Other

Age Range:
- ✓ Child: Under 13
- ❑ Teen: 13-19
- ❑ Young Adult: 20-30
- ✓ Adult: 30-65
- ❑ Senior: 65+

1. Interaction

[present the interactive]

Asked about how big it would be
Explaining to her kid in another language
Ask about that the picture are showing what's inside the ice
Explaining to kid that in the ice that there is small things
“You have to be an adult to get the connection”
“Perhaps need to another step in between the ice core and the graph to get the connection”
Ask to comment on what she sees on the screen
Asks about ppm the CO2
Doesn't get part per million
Asks if it’s the climate change - ask why it is the CO2 level and that's what we’re focusing on and not anything else like temperature rising
“How many ice ages do you go back?”
“Before the last ice age - has CO2 gone up?”
You start at 250 and it looks very flat and then it goes up quite quickly
“See what you are getting at”
Asks how long to date ice core back
70,000 years

The ones she's been looking at that's only the top and that largest is 6 km and it goes back 1 million years

2. Comments

What is your first impression from seeing this display? Why?

Any thoughts or feelings looking at this?

Do you find anything about this interactive interesting?

What did you discover from the graph? The ice core and slider?

After interacting with this, do you have any thoughts about the future climate?

Did you learn anything from this?

3. Appeal

[present two versions of design]

Which design is more interesting to you? Why?

Kid points to tunnel one
Woman said the tunnel is the best one

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Do you have any suggestions for improving our design?

"I don't wanna come here and see how bad I am"
"I wanna see how amazing this planet is and how much I can care about it"
"I don't want to see that I am bad and the problem"
Want to see the beautiful world
Kids want to touch the core so make an interactive that people can touch
Putting on the jacket and show the scientist what they do is interesting
Cool to see the guys in clothes and drilling and the process
Don't show the CO2 - show highlights on what information you can see in ice cores and what they reveal
Everything has to be touchable to interact with
In Greenland there is ice you can touch, kids want something you can touch
They will remember it
Earthquake and squid they can remember from 8 years ago

Test 7:

Facilitator: Edj
Observer: Juliana
Operator: Tristin

Duration: 6 minutes

Where they are from:
Florida
Male by himself

Gender:
- ✓ Male
- ❑ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ❑ Young Adult: 20-30
- ❑ Adult: 30-65
- ✓ Senior: 65+

1. Interaction

[present the interactive]

Reading the blurb on the table
Sliding and reading what's on the screen
“Where is the top and bottom of ice core”
Reading what's being presented and sliding
“Is this a point in time or is there other connection i should make”
“Ah, you can see the radiation in the ice” - didn't realize that
So it all the sudden jumps up at that point”
“Do you know our president doesn't believe in climate change”

2. Comments

What is your first impression from seeing this display? Why?

My brain think vertically so I would think of time as vertical

Any thoughts or feelings looking at this?

The graph grabs him the most
Anything besides the core that scientist see microscopically?
“Oh so see layers”

Do you find anything about this interactive interesting?

What did you discover from the graph? The ice core and slider?

After interacting with this, do you have any thoughts about the future climate?

Did you learn anything from this?
Not anything knew
Where, Antarctic?
How do they know that this is a representative data ice core?

3. Appeal

[present two versions of design]

Which design is more interesting to you? Why?

"What would be from their advantage point in the tunnel?"
Prefers the 10cm design because he's not a kid

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Do you have any suggestions for improving our design?

Label top and bottom of ice core

Test 8:

Facilitator: Malachi
Observer: Juliana
Operator: Tristin

Duration: 9

Where they are from:
Germany
Man and woman mid 20s

Gender:
- ✓ Male
- ✓ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ✓ Young Adult: 20-30
- ❑ Adult: 30-65
- ❑ Senior: 65+

1. Interaction

[present the interactive]

Reading the blurb on the table
Went to slide it - didn't realize that there was something popping up
"Pretty cool idea"

2. Comments

What is your first impression from seeing this display? Why?

I think it is a good idea

Any thoughts or feelings looking at this?

"I don't know how to say it in English"

Do you find anything about this interactive interesting?

What did you discover from the graph? The ice core and slider?

After interacting with this, do you have any thoughts about the future climate?

Suggestion for what you can do
"Driving a bike" - more suggestions and smaller things like plastic bags

Did you learn anything from this?

I didn't know much about the New Zealand events
I know about Europe
"Pretty interesting"

3. Appeal

[present two versions of design]

Which design is more interesting to you? Why?

10cm design is simpler to see
Tunnel is a bit too much - too far away
They both like the 10cm design

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Message - human impact on the environment

Do you have any suggestions for improving our design?

Children steps - give your toys away
Show what other countries have done that improve CO2 emissions and how they've been successful because there are tourists here
More dates and don't know where you are
Make the dates that are really bad bigger in red - more colors
Ice and maybe better picture of the layers to better see

Test 9:

Facilitator: Malachi
Observer: Juliana
Operator: Tristin

Duration: 8

Where they are from:
Mid 20s
From United Kingdom

Gender:
- ✓ Male
- ✓ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ✓ Young Adult: 20-30
- ❑ Adult: 30-65
- ❑ Senior: 65+

1. Interaction

[present the interactive]

"Each layer is its own data"
Sliding along looking at the point
"So is this placed on a specific ice core?"
Facilitator explained the RICE ice core - info taken all ice cores
"Wow" - you can see the nuclear radiation in an ice core

2. Comments

What is your first impression from seeing this display? Why?

Really liked it
See through time how you can see the info through time
It is really good

Any thoughts or feelings looking at this?

Strong relations [between ice cores and CO2 levels]
Explaining what an ice core is would be better - I was confused from afar
Dictating how fast you can go yourself it's good

Do you find anything about this interactive interesting?

What did you discover from the graph? The ice core and slider?

Didn't know the history about Abel Tasman
Expected to see the rise in CO2, but didn't realize it was that much

After interacting with this, do you have any thoughts about the future climate?

Everything can place an impact all around the world
Global change and actions need to change drastically now
If the impact of what we had is present, then it will affect the future

Did you learn anything from this?

3. Appeal

[present two versions of design]

Which design is more interesting to you? Why?

She likes the tunnel design 100%
Communication behind for the kids
10cm design looks like a standard museum - tunnel seems like something that would be in this museum

4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?

Radiation from Chernobyl got all the way over [to Antarctica] and can travel that far

Do you have any suggestions for improving our design?

Test 10:

Facilitator: Malachi
Observer: Juliana
Operator: Tristin

Duration: 12

Where they are from:
Low 20s man and woman
From London

Gender:
- ✓ Male
- ✓ Female
- ❑ Other

Age Range:
- ❑ Child: Under 13
- ❑ Teen: 13-19
- ✓ Young Adult: 20-30
- ❑ Adult: 30-65
- ❑ Senior: 65+

1. Interaction

[present the interactive]

"What do we do?"
Facilitator informs that you need to slide it
"How does it do that?" - the clicker - It would represent information popping up in the museum
"Oh that's lake taupo"
"Oh Abel Tasman" - where is he from "I imagine him Dutch"
"Big jump in CO2 isn't it"
"What was that disaster?" - *Facilitator says Chernobyl* - "oh shit wow"
Facilitator explains the fallout made it to the South Pole, scientist can track all the data and disasters through ice cores
Is it true that ice cores release the methane and CO2?

2. Comments

What is your first impression from seeing this display? Why?

CO2 in the atmosphere

I like it, you move things and little things come up
Not too much to read
Touch screen would be cool

Any thoughts or feelings looking at this?
I don't know about CO2 levels
Good idea to put the effects of the increase in CO2

Do you find anything about this interactive interesting?

What did you discover from the graph? The ice core and slider?
Ice core and see the different levels of CO2

After interacting with this, do you have any thoughts about the future climate?
"It's not gonna be good is it"
The predictions are crazy really
"Oh that's the year" - confused on the years
You should put if people continue this, then this is what [the future] would be like
Not everyone knows about the Paris Agreement so maybe say what it would be like if there was no CO2

Did you learn anything from this?

3. Appeal

[present two versions of design]

Which design is more interesting to you? Why?
Both of them like the tunnel

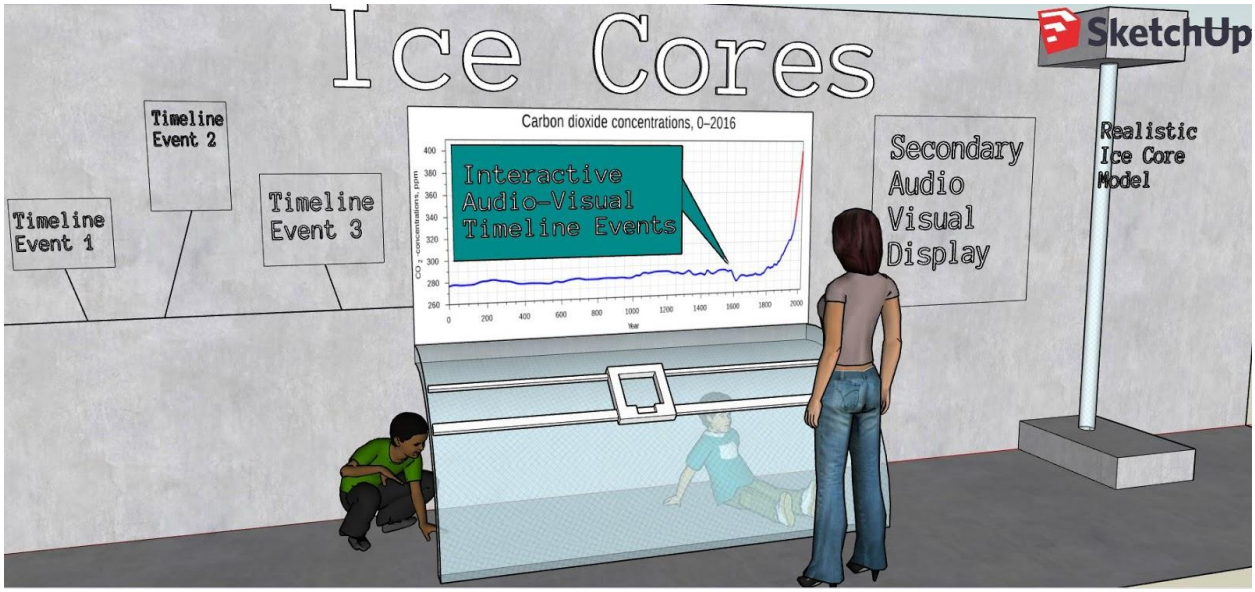
4. Overall Evaluation

If you had to explain your experience with this prototype to someone at home, what would you tell them?
A lot more CO2 now then there was years ago
"Shit is getting real"

Do you have any suggestions for improving our design?
"Interactive touch screen would make it so much more fun"
Vertical ice core would be a better representative
Pictures are always good, so you can relate to it

Appendix D: Technical Summary for Renewal Team

Final Ideas on the Ice Core Interactive Exhibition



Timeline:

- Make the interactive portion of the timeline, that corresponds to the ice core model, span 2,000 years to highlight the dramatic increase in CO_2 levels and human activities
- Make the static portion of the timeline span 8,000 years (or more? maybe to show past 80,000 years?) so that the total timeline (interactive and static portions combined) highlights the 10,000 years (at least) from present day
- Include permanent timeline events, not related to the ice core model, on the static portion of the timeline to give visitors a sense of the time scale in the display
- Include interactive timeline events, that correspond to evidence within the ice core model, on the interactive portion of the timeline to link the timeline with the ice core. Below are a list of the timeline events we used in the interactive portion of our prototype testing:
    - Ancient Roman smelting (0 CE)
    - Taupo Eruption (200 CE)
    - First Polynesian travelers settle New Zealand (1300 CE)
    - Abel Tasman finds New Zealand (1642 CE)
    - Industrial Revolution (1800 CE)
    - Chernobyl Disaster (1986 CE)
    - *Present Day (2018 CE) - this event would have to be continuously updated
    - *Future CO_2 Levels - this event would have to be continuously updated. Many visitors in our testing indicated that they wanted to know about the future of CO_2 levels and what they could do to make a difference. This would help to tie the ice core interactive into the CO_2 exhibition and inspiring visitors take action.
- Perhaps include updates to the CO_2 timeline using readings from *Baring Head* measurements

Ice Core Model (outside):

- Should be about the same length as interactive timeline
  - Ideally ~ 1.5-2m long
- Quarter section of a 1m outside radius ice core with a 10cm thickness
  - This is the scale we are thinking, however acknowledge this may change depending on safety, cost, accessibility, etc.
- Core should be somewhat transparent
  - Allow parents to keep track of their children
  - Opaque enough to make it seem like two different experiences
- Core should include slightly visible bubbles and layers similar to real core
  - Artistic license is at discretion of designers (approved by Dr. Bertler)
- Acrylic may be a good material for durability, adjustable transparency, cost, etc.
- Information that can be seen in cores should be injected inside (more realistic) or surface adhered (cheaper) with invisible ink
  - Ex. Exaggerated layers and bubbles, particles from ancient Greek and Roman smelting, volcanic eruptions, pollution, pollen, nuclear fallout
  - Gives a reveal factor that is interesting, engaging, and helps information retention

Slider:

- Slider should be an intuitive sliding frame that allows visitors to interact with timeline
  - May require explanation of what to do, such as a label/sign or arrows so that visitors know to move the slider
  - Should make visitor focus on the framed part of ice core and allow multiple visitors to see inside
- As slider is moved along the ice core, sensors trigger a marker to move along the CO_2 timeline
  - Additional timeline events would come up at intervals and may need a prompt for visitors to pause to read
- Should incorporate ultraviolet lights that bathe the framed section in black light
  - This would reveal hidden information in the ice core
  - This is a unique approach to showing additional information without a screen

Tunnel (Inside:)

- Focus content on children
  - Keep content simple
  - Focus mostly on layers and idea that ice cores are time-capsules/time-machines
- Textures such as layers and bubbles could be moulded into core to provide points of interest within the ice core model
- Timeline painted on wall or floor would give similar impression to adults but simplified
- Content “frozen” in the ice could give impression of age to replace timeline events

Other Possible Aspects:

- Life Scale (10 cm diameter) ice core model
  - Vertical orientation to show how cores are drilled/extracted
  - Realistic in appearance to a real core (with layers more defined)
  - Spanning from ground to ceiling (to show sample of depth of drilling)
  - Include facts about height and distance to relate extreme depths of drilling to familiar things visitors can relate to
  - Could serve as an additional interactive
    - Visitor could measure their height and compare it to layers in the ice

        - See how old they would be if their height was ice layers
- Digital display inside Tunnel
    - Give lighting and more exciting appeal of inside
    - Short video about ice cores - relate to children themes - animals - dinosaurs, etc
    - Touch screen or game for children to learn additional information
- Atmosphere of Exhibition Space
    - Exciting and futuristic
    - Laboratory or Antarctic feeling (see *Atmosphere* design from brainstorming)
        - Sense of immersion into real environment
- Secondary Audio-Visual Display:
    - Shows other supporting ice core information (ex: ice core extraction process, footage from Antarctica, international collaboration, compression of layers, climate models, oxygen isotopes, sea level rise, etc.)